STERKIANA

NUMBER 25 | COLUMBUS, OHIO | MARCH 1967

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PLEISTOCENE NON-MARINE MOLLUSCA OF THE RICHARDSON LAKE DEPOSIT, CLARENDON TOWNSHIP, PONTIAC COUNTY, QUEBEC, CANADA[1]

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ABSTRACT

The paleoecology and the quantitative changes in the non-marine molluscan assemblages from two marl sections in the Richardson Lake deposit are described. These changes and variations in lithology and shoreline features are used to reconstruct the environmental conditions prevailing during marl deposition and the development of modern Richardson Lake. The marl sections grade abruptly downward into Champlain Sea deposits and contain little extraneous material besides plant remains. Neither section represents a complete cycle of infilling of a lake, the truncation being related to decreasing water levels in the Ottawa and St. Lawrence River valleys. Of the 27 species of Mollusca recorded, 9 are post-depositional invaders in the sections. The quantitative changes in the aquatic species present in the sections suggest variations in depth, temperature, and pH of the waters as well as in substrate conditions. These changes are contrasted between the two sections with regard to their proximity to deeper areas of the lake and a moderating climate. Comparison of these assemblages with other Late Pleistocene and living molluscan assemblages elsewhere in glaciated regions of Eastern North America indicates that the Mollusca migrate in response to temperature changes. In this case the temperature is influenced by the advance and retreat of the continental glaciers.

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1. Investigation supported by NSF Grant GB-818, OSU RF Project No. 1642.

ILLUSTRATIONS

INTRODUCTION

Purpose of investigation

This investigation was undertaken to study the Pleistocene Mollusca recovered from the marl deposit adjacent to Richardson Lake, Clarendon Township, Pontiac County, Quebec, Canada. Critical examination of marl obtained from two systematically collected stratigraphic sections and a quantitative study of the molluscan assemblage of the marl led to reconstruction of the paleoenvironments which obtained as the marl was accumulated. Paleoecological interpretations presented are made from the observed vertical variation and abundance of the most prominent species in the collections.

An attempt is made here to relate the two closely adjacent and presumably nearly synchronous fossil records of Section G and Section GG to each other and to fossil records of other marl deposits in glaciated regions of North America. In this way it may be possible to establish the relationship between the distribution of non-marine Mollusca and the events resulting from Late Wisconsin glaciation in northern United States and southern Canada.

Location of Deposit

The Richardson Lake marl deposit lies on land owned by George Chamberlain along the boundary between Lots 18 and 19, about ¼ the length of the lots from the northern range line, in the seventh range, Clarendon Township, Pontiac County, Quebec, Canada.

Method of Investigation

This marl deposit was located with the aid of Waddington's *Marl Deposits of the Province of Quebec* (1950) and collections for this paper were made during June 1966. The areal extent of the deposit was determined by use of a 1-inch soil auger and collection sites chosen which would yield suitable marl sections. Selection of collection sites was determined by the level of ground water, accessibility, proximity to a small divide which effectively splits the deposit, and thickness of the sections. A pit was excavated at each of two locations, from the surface to the base of the marl section, and samples collected from stratigraphic columns in each pit. Each sample, 1 foot by 1 foot by 2 inches thick, was labeled and sealed in plastic bags to curtail loss of moisture and induration of the sediment.

Laboratory work consisted of washing a 2000 milliliter volume of each sample through 10, 20, 30, and 50 mesh sieves and allowing the retained material to dry. The residues from the 10 and 20 mesh sieves were hand-picked to remove all identifiable mollusk remains; the shells were identified to species and counted separately for each sieve size of each sample. The data obtained were illustrated graphically (Figs. 4 through 16) to facilitate interpretation of the results. An approximation of the number of mollusks per unit volume of sample was determined and is shown as specimens per thousand milliliters of sample.

Acknowledgements

I wish to express my appreciation for the kind support and encouragement given me by my adviser, Professor A. La Rocque, during the preparation of this report and the privilege of consulting the manuscript of *Pleistocene Mollusca of Ohio* (La Rocque, in press) which is currently being published by the Ohio Geological Survey. The kindness and co-operation which I received from the residents of Pontiac County and especially around the Richardson Lake area are very much appreciated. My friends in the Geology Department also deserve thanks for many helpful services and suggestions which aided in the completion of this project.

I gratefully acknowledge the financial aid received through National Science Foundation Grant No. GB-818, Ohio State University Research Foundation Project No. 1642, in support of the preparation of this report.

GEOLOGY OF THE AREA

Regional Geology

The Richardson Lake marl deposit is situated near the southern edge of the Canadian Shield in the southwestern portion of the Laurentian Highlands. This part of the shield, which has been designated as the Grenville physiographic province by Bostock (1964, p. 14) and Gill (1949, p. 64), has also been called the Grenville subprovince by Wilson (1939). The bedrock, here mostly covered by much younger unconsolidated sediments, is reported to consist of crystalline limestone, injection gneiss formed largely from intrusion of these limestones by granites (Sabourin, 1965, p. 8), gabbros and hornblende gneisses (Osborne, 1944, Map). The closest outcrop of pre-Pleistocene basement rock is about 2½ miles northeast of Richardson Lake. This outcrop is largely Grenville carbonates which have been intruded and metamorphosed by granites and their accompanying solutions (Sabourin, 1965, Map). Sabourin (p. 8) thinks that perhaps there are two layers of crystalline limestone as well as paragneisses beneath the area. Similar exposures of crystalline carbonate rocks are exposed some six miles west-southwest of the deposit near the junction of Quebec Route 8 and the Portage-du-Fort road. In the area east and north of Richardson Lake the bedrock outcrops thrusting through the Pleistocene-Recent cover are scattered and isolated, and reflect the structural trends of the region.

In this area the Pleistocene geology has understandably been neglected in favor of hopefully more profitable studies on the igneous-metamorphic rocks. Sabourin (1965) mapped an area immediately to the east of the deposit and designated the unconsolidated, surficial material as Pleistocene-Recent in age. For mappable units he delineates sand and gravel, till, and clays. The deposits surrounding Richardson Lake which Sabourin mapped as sand and gravel are thought to have been deposited by the Champlain Sea which encroached over the Ottawa and St. Lawrence River valleys following the waning remnants of the Wisconsin ice sheet. This area and the area to the southeast along the Ottawa River were part of a structural and topographic low which apparently influenced ice movements and permitted influx of the sea. Sabourin (1965, p. 33) reports that north of the Ottawa River Valley the ice moved nearly due south and that within the valley striae indicate a southeastward movement. Gadd (1963B, Legend) reports a single direction of glacial striae, also southeastward, in his studies of the Chalk River area, north of Pembroke, Ontario. Wilson (1924, p. 12) states that in the Arnprior-Quyon area which is south and east of Richardson Lake there is also a single southeastwwrd direction of striae. Karrow (1961, pp. 100, 101) states that after partial deglaciation, the Ottawa-St. Lawrence Lowlands were invaded by marine waters which advanced as the ice retreated and formed the Champlain Sea. Gadd (1963B, Legend) reports that marine conditions must have existed at least as far up river as the Chalk River area because of what he believes to be reworked marine deposits containing the fossil marine pelecypod *Macoma*. De Geer (1892, p. 469) and later workers in the Ottawa-St. Lawrence valley have studied wave terraces and beaches believed to be remnants of the Champlain Sea. They state that the highest elevation from present sea-level attained by the Late Pleistocene marine inundation was at least 690 feet. Evidence that these terraces are actually marine is in the form of imbedded marine fossils, such as *Macoma*. As the ice receded inlets were opened which drained the ancestral Great Lakes into the Champlain Sea, thus converting marine to brackish- and fresh-water conditions. The outlets which came into existence are designated the North Bay-Mattawa and Fossmill outlets in the literature. Carbon 14 dates on material collected by Terasmae indicate that the latter outlet opened some 9,000 to 10,000 C-14 years B.P. (Gadd, 1960, pp. 27, 28). Isostatic uplift of the Ottawa-St. Lawrence region was undoubtedly occurring at this time, displacing the marine and brackish-water environments and exposing the region to erosion. Karrow (1961, p. 101) would place the marine inundation at 11,000 to 12,000 C-14 years B. P. on dates derived from marine shells and Terasmae (1965, p. 36) indicates that the inundation was coming to a conclusion some 9,000 to 9,500 C-14 years B.P. or earlier. At this time the St. Lawrence drainage was taking shape, probably occupying its present configuration some 7,000 to 8,000 C-14 years B.P. (Terasmae, 1965, p. 38). Needless to say, a wide range of dates is cited for these events, but they fall within the same general period of time.

The age of the surficial deposits surrounding Richardson Lake and the adjacent lakes and marshes is indicated to be Late Wisconsin by the studies consulted in the preceding text, which also provides a background into which the development of the marl deposit may be placed. The glacial deposits provided the material which the waters of the Champlain Sea reworked into beaches and shallow sandy sea bottoms in this area. The uplifting land drained the area leaving topography that has so far developed only a youthful drainage pattern.

Richardson Lake Area

For several miles in all directions from Richardson Lake the bedrock is overlain by unconsolidated sand, gravel, and boulders. In most places sand predominates and is well-sorted, evenly bedded, and contains relatively few pebbles or boulders. But in other localities there are numerous boulders and cobbles in the sand. The boulders and cobbles as well as most of the smaller material are of predominantly igneous and metamorphic origin and are similar to rock seen in outcrop to the north and west. The sedimentary components have an appearance similar to Ordovician limestone outcrops to the east and observed to the south of the area, south of the Ottawa River. The sand in the area is mostly medium- to coarse-grained, sub-angular to sub-rounded, and composed of a complex suite of minerals. However, the majority of the sand grains are quartz.

The topography of the area is relatively flat or slightly rolling with a large number of depressions, many of which contain small lakes, ponds, or swamps and have internal drainage. Richardson Lake is one of a series of four lakes and accompanying marshes occupying an elongate, shallowly S-shaped depression about 1½ miles long. An unnamed creek drains into the Ottawa River from the southwest shore of Richardson Lake and is itself mostly a series of interconnected marshes. Vegetation around Spring Lake (adjacent to the southern end of Richardson Lake) is dense scrub as is a swamp at the east end of it which marks the western extremity of this depression. Around Richardson Lake grass grows along the shores and the lake itself has a sand bottom except along the northern and eastern shores where there is a small swamp and perennial vegetation growing to the water's edge. The small lake to the north of Richardson Lake has a sand bottom, marshy borders, and is being filled in by a delta of sand along the northwestern shore.

The low area is being filled in with vegetation and by the accumulation of sand which is washed into the valley in large quantities, especially during the spring thaws. This is evidenced by a large gully some 21 feet deep by 19 feet across at its widest point near the farmstead of George Chamberlain. The Chamberlains reported that the headward erosion of this gully amounted to some 45 feet during the course of one afternoon. The sand can be seen forming a delta at the head of Richardson Lake. Other less spectacular evidences of infilling are visible around the valley.

Between Richardson Lake and the small lake to the north marshy ground and swamps extend along both sides of the connecting feeder stream through which flows relatively clear water. The marshes around the lakes and especially between this small lake and Richardson Lake are very acidic. The submerged portions of vegetation and the bottom debris are coated with rust-colored precipitate. Beneath these swamps, between the lakes and at the north end of Richardson Lake, lies the marl deposit. In places the marl extends at least 20 feet below lake level and is covered by 18 inches of sand and soil, or muck with between 3 inches and 2 feet of water. Near Richardson Lake there is a small divide of sand splitting the marl deposit (Fig. 3, insert).

Along the present shores of the lakes and above the marshy areas are seen evidence of previous lake levels in the form of terraces. Four terraces are readily recognizable at 16 inches, 4½ feet, 8 feet, and 15 feet above the present level of Richardson Lake. The lowest terrace has a well-developed sod cover so that the water level must have been lowered to its present level a long time ago. The terraces are especially noticeable around the windward shores of the two lakes and the connecting marl deposit. The Richardson Lake marl deposit is split into two portions by a low divide or saddle extending east-northeast and west-southwest across the feeder stream near Section GG (Fig. 3). This divide splits the deposit into about 1/3 and 2/3, the larger portion being in the swale toward the small lake (Fig. 3). The 4½ foot terrace probably represents the last time the entire valley was covered with water and also the approaching termination of marl deposition. At this water level the divide would have been awash and the two lakes connected, with about 2½ feet of water covering the area of Section G and slightly more over Section GG. The upper four samples of Section G show a dwarfing of the individuals in the assemblage as compared with the remainder of the section. This dwarfing may have been due to stagnation of the water.

With the down-cutting of the outlet into the Ottawa River, which would coincide with the lowering of water levels in the Ottawa-St. Lawrence Valley, the divide separating the marl deposit was breached and the water level lowered, probably in stages, to the present lake level. This lowering of the water level drained the area between the two lakes, cut the erosion surface seen in Section GG, and deposited the coarse, roughly bedded sand unconformably above the marl in that section. This marked the termination of marl deposition and explains the fact that aquatic mollusks are found right up into the grass in Section G and that no Pleistocene terrestrial species are present as in other lakes which filled in normally (Clowers 1966, Table 2, p. 45). Much of the deposit, especially near the valley walls, is covered by sand eroded from the hills, in some places to depths approaching 3 feet. On the valley floor there is an abrupt vegetation change from moss and other moisture-loving plants to good upland grasses. This vegetation change marks the 2 foot thickness of the marl.

The sand overlying the marl unconformably in section GG is coarse-grained and lacks mica flakes which are common in other portions of the sand in the surrounding hills. Within the sand is a band of a darker colored sand (Section GG) which upon closer examination is finer grained, of a more uniform size, and contains some mica. This dark layer was correlated by auger holes with the 16 inch terrace. The marl sampled in Section GG extends into the lake and forms the bottom along the windward or northwestern shore and is only sparingly covered with muck. The marl itself varies in purity due to components of non-carbonate sand, clay, and vegetation and the lithologic units are designated principally on such variation. It will be seen that the faunal or ecological breaks coincide rather closely with these lithologic breaks, especially in Section G.

SYSTEMATIC PALEONTOLOGY

General Statement

A summary of data pertaining to the species recovered from the Richardson Lake marl deposit is contained in this section. The account includes an abbreviated synonymy, a short description of the important shell features, a synopsis of available ecological data, distribution, and geologic range in North America for each species. Special emphasis is centered on important associations and variations in migration patterns in other Late Pleistocene and Recent deposits.

Compilation of material for this paper was facilitated by access to information and comparative material gathered by other workers in Pleistocene non-marine Mollusca at Ohio State University. Additional important references consulted include: Baker (1928), Pilsbry (1946, 1948), Herrington (1962), La Rocque (1963, 1964), and La Rocque (in press).

Class Pelecypoda

Order Teleodesmacea

Family Sphaeriidae

Sphaerium lacustre (Müller) 1774

Tellina lacustris Müller 1774. Verm. Terr. et Fluv., vol. 2, p. 204.
Cyclas rosaceum Prime 1851, Proc. Boston Soc. Nat. Hist., 4, p. 68.
Musculium rosaceum Baker 1928, F.W. Moll. Wis., pt. 2, p. 358, pl. 99, figs. 19, 20.
Musculium jayense Baker 1928, F.W. Moll. Wis., pt. 2, p. 353, pl. 99, figs. 27, 28.
Musculium ryckholti Baker 1928, F.W. Moll. Wis., pt. 2, p. 359, pl. 99, figs. 6-9.
Sphaerium lacustre Herrington 1962, Rev. Sph. N. Am., p. 19, pl. 2, fig. 1.

TYPE LOCALITY. Europe, probably Denmark.

DIAGNOSIS. Shell small to medium in size, valves thin, posterior higher than anterior; beaks slightly toward anterior; growth lines moderately fine to fine; anterior end rounded, posterior almost straight; hinge very long; lateral teeth slim but distinct, cardinal teeth weak. (Modified from Herrington, 1962, pp. 19, 20).

ECOLOGY. *S. lacustre* is most abundant in small lakes and ponds, but is also recovered from larger lakes, rivers, and streams. It is found in greatest abundance on muddy substra-

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EXPLANATION OF FIGURES 1-6, OPPOSITE PAGE

Fig. 1. Sketch map of southeastern Canada and northeastern United States with a box indicating the approximate location of Figure 2.

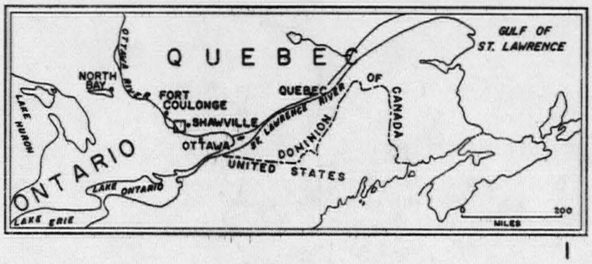
Fig. 2. Map of south-central Pontiac County, Quebec, showing the location of Richardson Lake in Clarendon Township, and its relationship to the Ottawa River drainage.

Fig. 3. Sketch map of the Richardson Lake area with insert indicating the sites from which marl samples were obtained.

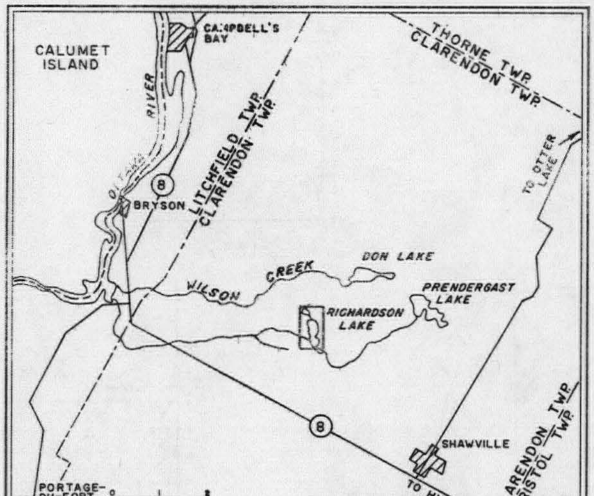
Fig. 4. Stratigraphic variation of *Gyraulus parvus* (Say) in the Richardson Lake deposit.

Fig. 5. Stratigraphic variation of *Sphaerium nitidum* Clessin in the Richardson Lake deposit.

Fig. 6. Stratigraphic variation of *Sphaerium lacustre* (Müller) in the Richardson Lake deposit.



1



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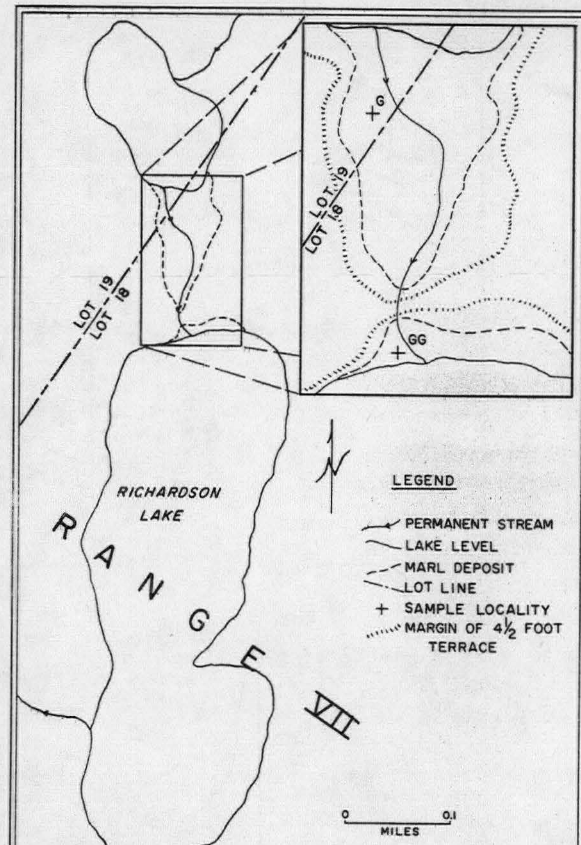

3

EXPLANATION OF SYMBOLS
FOR FIGS. 4-16

VARIATION OF SPECIES IN PIT G. IS
REPRESENTED BY +——.
VARIATION OF SPECIES IN PIT GG IS
REPRESENTED BY ×— —.

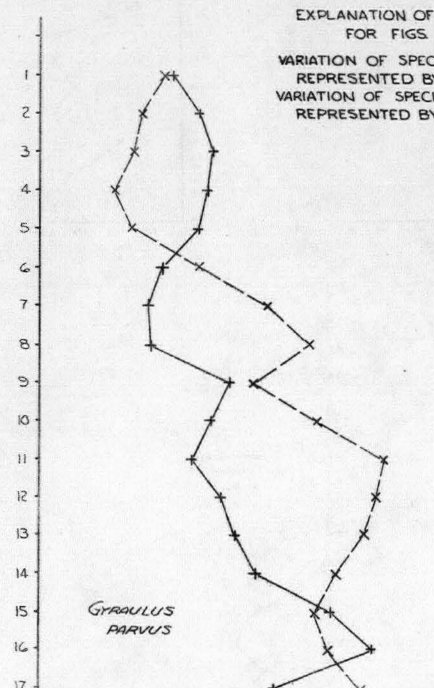

FIG. 4

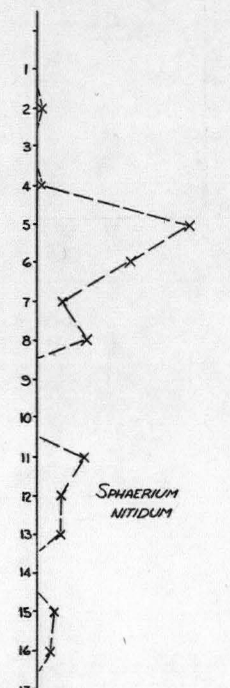

FIG. 5

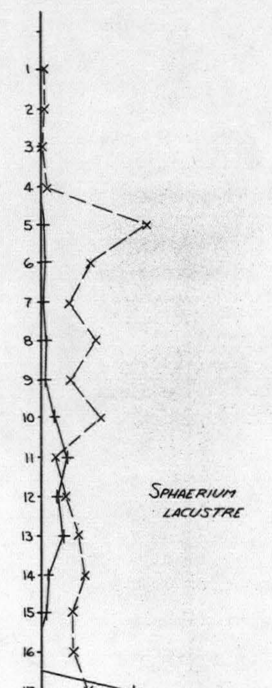

FIG. 6

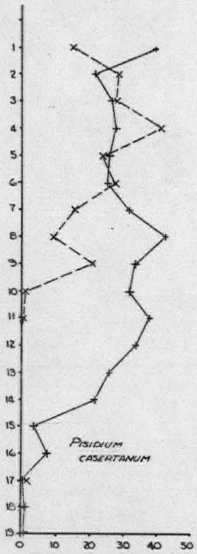

FIG. 7

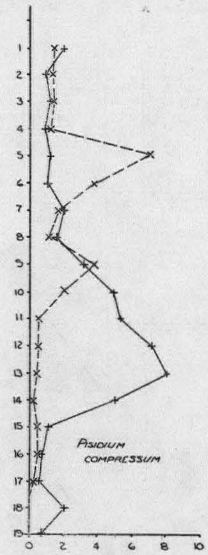

FIG. 8

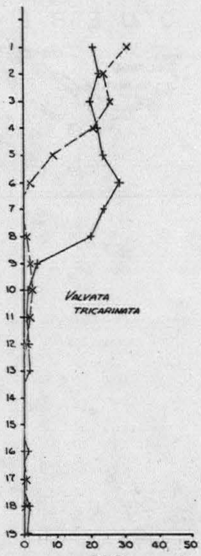

FIG. 9

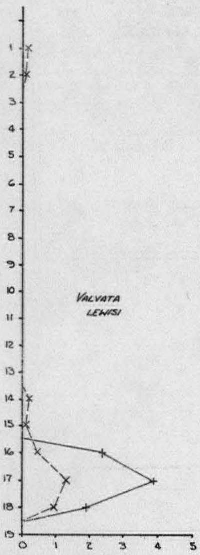

FIG. 10

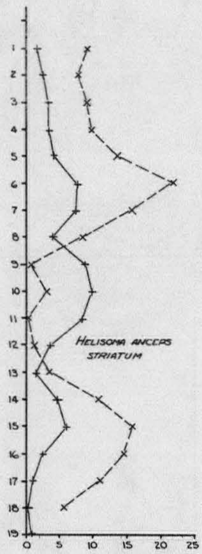

FIG. 11

FIG. 12

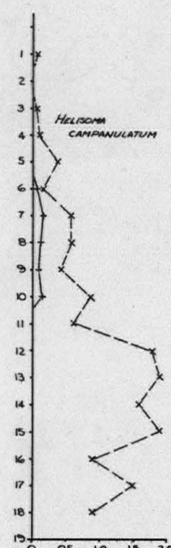

FIG. 13

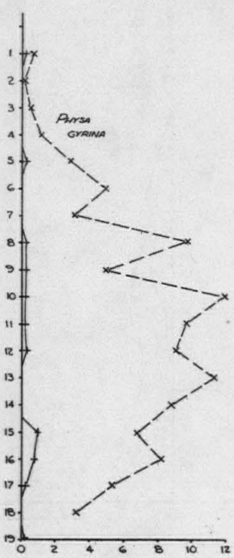

FIG. 14

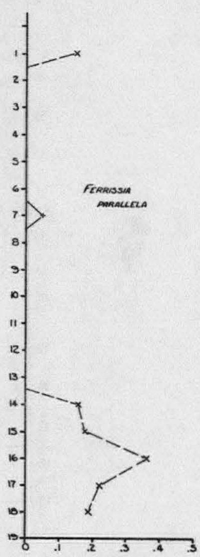

FIG. 15

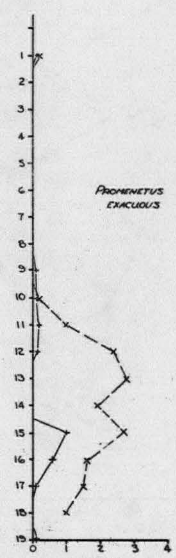

FIG. 16

tes. Mowery's summary of the habitat of *S. lacustre* (1961, p. 7) relates that it is found in swamps, ponds, lakes or streams on a firm bottom of fine deep or hardpacked mud, fine gravel, and hard clay, in water up to 0.6 m. deep. It has been collected in water with a determined pH of 6.4 to 7.46 and a fixed carbon dioxide ratio of between 9.3 and 18.87 ppm.

GEOGRAPHIC DISTRIBUTION. Nova Scotia into the Northwest Territories, south to the Gulf Coast and Atlantic Seaboard.

GEOLOGIC RANGE. This common Late Pleistocene and Recent species has been recorded by Taylor and Hibbard (1955, p. 12) from Illinoian deposits of Kansas and the form *ryckholti* has been recovered from Early and Middle Pliocene sediments of Kansas and Oklahoma.

REMARKS. A relatively abundant and an especially fragile species, S. *lacustre* shows a great deal of fluctuation in both sections. The species is most prominent near the base of Section G where there is considerable silt mixed with the coarser sand and in samples 5 and 6 of Section GG which from examination of the sediment may have been a comparatively solid mud bottom.

Sphaerium nitidum Clessin 1876

Cyclas tenuis Prime 1851, Boston Soc. Nat. Hist., p. 161; unidentifiable *fide* Herrington 1958.

Sphaerium tenue Prime 1865, Monogr. Am. Corbic., p. 47, fig. 44.

Sphaerium nitidum Clessin 1876, *in* Westerlund, Neue Binnenmoll. Sibir., p. 102.

Sphaerium walkeri Sterki 1901, Naut., 14, p. 141.

Sphaerium tenue La Rocque 1953, Cat. Rec. Moll. Canada, p. 117.

Sphaerium nitidum Herrington 1958, Naut., 72, p. 10.

Sphaerium nitidum Herrington 1962, Rev. Sphaeriidae, p. 21, pl. 1, fig. 6.

TYPE LOCALITY. Siberia.

DIAGNOSIS. Shell small, very thin valves, somewhat circular in outline; beaks subcentral, low; growth lines fine, uniformly spaced, discernible over the beaks. (Modified from Herrington, 1962, p. 21).

ECOLOGY. 'Requires cold water, hence found only in deep water, at considerable altitudes, or quite far north. (Herrington, 1962, p. 21).

EXPLANATION OF FIGURES 7-16, OPPOSITE PAGE

Fig. 7. Stratigraphic variation of *Pisidium casertanum* (Poli) in the Richardson Lake deposit.

Fig. 8. Stratigraphic variation of *Pisidium compressum* Prime in the Richardson Lake deposit.

Fig. 9. Stratigraphic variation of *Valvata tricarinata* (Say) in the Richardson Lake deposit.

Fig. 10. Stratigraphic variation of *Valvata lewisi* Currier in the Richardson Lake deposit.

Fig. 11. Stratigraphic variation of *Helisoma anceps striatum* (F. C. Baker) in the Richardson Lake deposit.

Fig. 12. Stratigraphic variation of *Fossaria obrussa decampi* (Streng) in the Richardson Lake deposit.

Fig. 13. Stratigraphic variation of *Helisoma campanulatum* (Say) in the Richardson Lake deposit.

Fig. 14. Stratigraphic variation of *Physa gyrina* Say in the Richardson Lake deposit.

Fig. 15. Stratigraphic variation of *Ferrissia parallela* (Haldeman) in the Richardson Lake deposit.

Fig. 16. Stratigraphic variation of *Promenetus exacuous* (Say) in the Richardson Lake deposit.

Herrington confirms older work in which this species was recovered from locations far north in Canada and Alaska (Dall, 1905, Baker, 1920, Baker and Cahn, 1931, and Kindle, 1925).

GEOGRAPHIC DISTRIBUTION. Alaska; Canada, in Quebec, Ontario, Newfoundland, and the Northwest Territories; south into Washington, Utah, Michigan, New York, and Maine; Eurasia.

GEOLOGIC RANGE. Before Clowers (1966, p. 35) no fossil record of this species was known in North America.

REMARKS. This species is rare in the deposit, occurring sporadically in the section of Pit GG. This section is adjacent to Richardson Lake (Fig. 3) which in the past was deeper and more extensive than at present as is indicated by the wave benches higher along the present shores. Clowers (1966, pp. 35, 36) reported *S. nitidum* from the Box Marsh marl deposit in Ontario. The presence of this species is indicative of a much cooler climate than at present or a much deeper body of water. The absence of this species in Section G argues for greater depth and consequently colder water at Section GG. The presence of *S. nitidum* supports the evidence suggested by the presence of *Promenetus exacuous* in the deposit. Although rare, this species shows preference for sand substrate (Sample GG-66-18) and rather solid mud bottoms (Samples GG-66-T, GG-66-6).

Sphaerium sulcatum (Lamarck) 1818

Cyclas sulcata Lamarck 1818, Anim. sans Vert., 5, p. 560.
Sphaerium crassum Baker 1928, F.W. Moll. Wis., pt. 2, p. 319, pl. 94, figs. 11-13.
Sphaerium lineatum Baker 1928, *Ibid.*, p. 315, pl. 96, figs. 4-7.
Sphaerium sulcatum Herrington 1962, Rev. Sphaeriidae N Am., p. 28, pl. 1, fig. 1.

TYPE LOCALITY. Lake George, New York.

DIAGNOSIS. Shell large, transversely oval, inflated, almost equipartite, solid; growth lines pronounced, unevenly spaced; hinge long; lateral teeth short to medium in length; cardinal teeth offset anteriorly. (Modified from Herrington, 1962, pp. 28, 29).

ECOLOGY. Taylor (1960, p. 46) states that *S. sulcatum* '.... has a preference for a soft bottom in fairly still waters, in eddies of a creek or river, along shore in lakes, and even in lakes filling in with marl. Herrington has found that this species is almost invariably associated with *Pisidium compressum*.' 'Small lakes, also eddies in rivers and creeks. It has a preference for soft sand with vegetation; never in swamps or ponds.' (Herrington, 1962, p. 29).

GEOGRAPHIC DISTRIBUTION. This species has been recovered from as far north as James Bay, Ontario and other glaciated portions of Canada. In the United States *S. sulcatum* seems to be limited in southward extent to glaciated areas. (Herrington, 1962, p. 29).

GEOLOGIC RANGE. *S. sulcatum* has been recovered from Pleistocene sediments of the Nebraskan as well as from Recent molluscan assemblages.

REMARKS. In the Richardson Lake marl deposit this species is rare and is found in the lower portions of both sections, rapidly decreasing in numbers upward as the non-carbonate sand and vegetation decrease in favor of nearly pure carbonate deposition. The specimens recovered are not as large as those recorded by Herrington (1962, p. 28) from Carleton County, Ontario. This is likely to be due to properties of the environment and not migration as some larger specimens or adult forms would have been recovered along with the juvenile forms.

Pisidium casertanum (Poli) 1791

Cardium casertanum Poli 1791, Test. utr. Sicil. vol. 1, p. 65, pl. 16, fig. 1.
Pisidium abditum Baker 1928, F.W. Moll. Wis., pt. 2, p. 407, pl. 103, figs. 1-5.
Pisidium neglectum Baker 1928, *Ibid.*, p. 390, pl. 105, figs. 7, 8.
Pisidium politum Baker 1928, *Ibid.*, p. 400, pl. 102, fig. 19.
Pisidium roperi Baker 1928, *Ibid.*, p. 400, pl. 102, figs. 23-25.
Pisidium casertanum Herrington 1962, Rev. Sph. N. Am., pp. 33, 34, pl. 4, fig. 1; pl. 7, fig. 7.

TYPE LOCALITY. Sicily.

DIAGNOSIS. Shell with rather long outline, of moderate weight; beaks generally subcentral, not high; growth lines distinct, rather fine; periostracum moderately dull to slightly glossy; anterior endmoderately long lateral teeth distinct, cardinals near anterior cusps. (Modified from Herrington, 1962, p. 33).

ECOLOGY. By far the most abundant of the *Pisidia, P. casertanum* has become adapted to a wide variety of habitats; bog ponds, temporary ponds, swamps, swamp-creeks, creeks with considerable current, rivers, and lakes. (Herrington, 1962, p. 34).

GEOGRAPHIC DISTRIBUTION. Almost cosmopolitan; Eurasia, Australia and New Zealand; North and South America from the Arctic Circle to Patagonia. (Herrington and Taylor, 1958, p. 14).

GEOLOGIC RANGE. This species, common in sediments of the Wisconsin, has a range of Pliocene to Recent.

REMARKS. *P. casertanum* is the most common of the pelecypods in the deposit. In both sections it becomes more abundant upward, but not invading the area of Section GG until near the middle of the section. In both sections the species demonstrates preference for rather soft muddy substrate with moderate vegetation. The invasion of this species into the area of Section GG may well correspond to a shallowing of the water, to depths preferred by *P. casertanum*. This decrease in water depth is evidenced by the several terraces seen on the slopes above the present lake level.

Pisidium compressum Prime 1851

Pisidium compressum Prime 1851, Proc. Boston Soc. Nat. Hist., 4, p. 164.
Pisidium compressum Baker 1928, F.W. Moll. Wis., pt. 2, p. 370, pl. 100, figs. 9-13.
Pisidium compressum Herrington 1962, Rev. Sphaeriidae N. Am., p. 35, pl. 5, fig. 2; pl. 7, fig. 14.

TYPE LOCALITY. Fresh Pond, near Cambridge, Massachusetts.

DIAGNOSIS. Shell medium sized, heavy, shape varies from short and high to moderwtely long; beaks prominent, far back, narrow and with ridges; growth lines coarse to moderately fine. (Modified from Herrington, 1962, p. 35). Anterior cusp of left valve parallel to dorsal margin, not twisted; shell tapers ventrally in end view; hinge about ¾ shell length; anterior end rounded; shell lacks heavy ridges except occasional nearly straight ridges on beaks; anterior and posterior ends with non-parallel slope. (Modified from La Rocque, in press).

ECOLOGY. *P. compressum* is found in many habitats but prefers rivers and small creeks (Sterki 1916, p. 447); Herrington (1962, p. 34) reports the species most common in shallow water, with sand substrate and vegetation, but that it has been collected from depths of several meters; Taylor (1960, p. 47) states that this form inhabits only perennial waters with some current and never swamps or ponds; Reynolds (1959, p. 47) states that the species is a burrowing form, feeds on detritus and plankton, and inhabits those environments with a firm substrate. It has been collected from water with a determined pH of between 7.0 and 8.73, and a fixed carbon dioxide ratio of between 9.3 and 30.56 ppm.

GEOGRAPHIC DISTRIBUTION. Cosmopolitan in North America; as far north as Great Slave Lake, Northwest Territories, south to Mexico. Baker (1928, p. 371) quotes Sterki as saying the species is more common in the East than in the West.

GEOLOGIC RANGE. This species is known from the Middle Pliocene to the Recent.

REMARKS. *P. compressum* is generally less abundant in the Richardson Lake deposit than reported by Clowers (1966), but occurs throughout both sections. The valves of specimens in Section GG are generally somewhat smaller and thicker than those recovered from Section G. This species achieves maximum abundance in portions of each section which by the present compactness and structure may have provided relatively firm mud bottoms to the lake. In Section G this species is most abundant near the middle of the section in an area of nearly pure marl and only moderate vegetation. In the upper portion a decreased, but relatively constant population seemed to have existed through time. Perhaps the depth of water was decreased considerably, as the sediments maintain fairly consistent characteristics, except for the superimposed soil zone. In Section GG *P. compressum* is most common in sediments similar to those in Section G, only here it is in the upper portion of the section. Again, water depth in connection with the downcutting of the outlet may have been the prime factor as Table 3 shows relatively constant percentages both above and below the maximum.

Class Gastropoda

Order Ctenobranchiata

Family Valvatidae

Valvata lewisi Currier 1868

Valvata striata Lewis 1856, Proc. Acad. Nat. Sci. Phila., p. 269 (non Philippi, 1836)
Valvata lewisi Currier 1868, List Moll. of Mich., Kent Sci. Inst., Misc. Publ., no. 1, p. 9.
Valvata lewisi Baker 1928, F. W. Moll. Wis., pt. 1, p. 26, pl. 1, figs. 28-30.
Valvata lewisi lewisi La Rocque 1953, Cat. Rec. Moll. Canada, p. 263.

TYPE LOCALITY. Little Lakes, New York.

DIAGNOSIS. Shell turbinate, fragile; about 3½ whorls, regularly convex, diameter rapidly increases, regularly striated; sutures deeply impressed; spire somewhat depressed, flattened apex; fine spiral lines disappear on second whorl; growth lines fine; aperture circular; lip simple; umbilicus wide, deep, exhibiting inner margins of whorls. (Modified from Baker, 1928, p. 27).

ECOLOGY. This species has been collected mainly in lakes from shallow water of less than 1 meter depth, on and in masses of vegetation with substrates of sand and mud.

GEOGRAPHIC DISTRIBUTION. Canada, the Mackenzie River area south into the northern United States, eastward to the Atlantic Seaboard.

GEOLOGIC RANGE. Leonard (1950, p. 11) has recorded *V. lewisi* from Yarmouth sediments. Later (1952, p. 8) he assigned it a range of Late Kansan and Early Yarmouth to Recent.

REMARKS. *V. lewisi* corresponds well with the descriptions given by Baker. It is rare in the Richardson Lake marl deposit, but occurs in the basal portion of each section and exhibits a negative correlation with *V. tricarinata*. In both sections this species is restricted to that portion which contains non-carbonate sand and abundant plant remains, decreasing upwards in abundance with the decrease of non-carbonate sand and benthic vegetation. This species is one of the key indicators of environment of the ancestral lake in this location.

Valvata tricarinata (Say) 1817

Cyclostoma tricarinata Say 1817 Jour. Acad. Nat. Sci. Phila., vol. 1, p. 13.
Valvata tricarinata Baker 1928, F. W. Moll. Wis., pt. 1, p. 11, pl. 1, figs. 1-3.
Valvata tricarinata tricarinata LaRocque 1953, Cat. Rec. Moll. Canada, p. 264.
Valvata tricarinata Hibbard and Taylor 1960, Mus. Paleont., Univ. Michigan, vol. 16, p. 79, pl. V, figs. 14, 15.

TYPE LOCALITY. Delaware River.

DIAGNOSIS. Shell turbinate, thin, translucent; about 4 rapidly enlarging whorls; flattened between carinae; 3 distinct, sharp carinae on large body whorl, one at shoulder, one on periphery, one on base, encircling deep, funnel-shaped umbilicus; slight ascending slope from carina to suture on upper surface of whorl; spire elevated, but apex depressed; aperture circular, somewhat angulated by carinae; lip simple, sharp, continuous. (Modified from Baker, 1928, pp. 11, 12).

ECOLOGY. In Wisconsin, Baker (1928, p. 14) found *V. tricarinata* in shallow water or to depths exceeding 9 meters. This species is found with or without vegetation in both streams and lakes with mud, sand, gravel, and bare-rock bottoms.

GEOGRAPHIC DISTRIBUTION. Mackenzie River and Great Slave Lake south and east into New England and Virginia; west into Iowa.

GEOLOGIC RANGE. *V. tricarinata* has been recorded by Taylor (1960, p. 32) from Pleistocene sediments of the Nebraskan and Wisconsin. It is a common fossil in the Wisconsin. Living representatives are widespread and abundant in contemporary assemblages.

REMARKS. In the samples studied the (111) form of *Valvata* is the only carinate form recovered. Whittaker (1921, pp. 73, 74) noted that *V. tricarinata* is one of the most abundant species found in marl deposits of the Ottawa River Valley. In this deposit the species is present in nearly all samples, but is very prominent in the upper half of each section, the abundance in Section G seemingly anticipating that of Section GG. The portions of the sections in which this form is abundant are those in which the vegetation was sparse to moderate and with a substrate composed entirely of carbonate muds. It is lacking in the basal samples of each section where non-carbonate sand is prominent. This species shows a negative correlation with *V. lewisi*. The anticipation in abundance in Section G over Section GG may be related to a warming trend in water temperature, Section GG being adjacent to deep, cold water warming more slowly than the water over Section G.

Family Amnicolidae

Amnicola limosa (Say) 1817

Paludina limosa Say 1817, Jour. Acad. Nat. Sci. Phila., vol. 1, p. 125.
Amnicola limosa Baker 1928, F. W. Moll. Wis., pt. 1, p. 93, pl. 6, figs. 1-6.
Amnicola limosa limosa La Rocque 1953, Cat. Rec. Moll. Canada, p. 267.

TYPE LOCALITY. Delaware and Schuylkill rivers, Pennsylvania.

DIAGNOSIS. Broadly conic in shape, inflated; about 4½ whorls, regularly increasing, apex blunt, part of second whorl encircles nuclear whorl then descends, later whorls rounded, slightly shouldered; body whorl globose; aperture mostly basal, subround-ovate, somewhat angled at top; base of shell rounded, (Modified from Baker, 1928, pp. 93, 94, and Berry, 1943, p. 23).

ECOLOGY. This species has a wide range of habitats, occurring in creeks, rivers, and fresh- and brackish-water lakes. It is generally found in dense beds of *Chara, Potamogeton, Vallisneria,* and *Elodea*. These plants are not consumed as food, but harbor rich colonies of diatoms on which the mollusk feeds. (Berry, 1943, p. 26).

GEOGRAPHIC DISTRIBUTION. *A. limosa* is found in Manitoba, south to Texas; in New England and New Jersey, west into Utah.

GEOLOGIC RANGE. This species has been recovered from Late Pleistocene sediments and living representatives are commonly found in creeks, rivers, and lakes.

REMARKS. *A. limosa* is rare in the Richardson Lake marl deposit, yet Clowers (1966, p. 41) found it to be very abundant in the Box Marsh deposit and Whittaker (1921, p. 73) noted the common occurrence of this species in marl deposits in the Ottawa River Valley. This species occurs sporadically in the upper and middle portions of Section GG in the interval that lacks significant non-carbonate sand content. If indeed this species is associated with the above mentioned algae, this may be evidence to speculate that the area of the deposit was at the time of marl accumulation an open body of water with some current and lacking dense beds of algae. The scarcity of this species may also be the result of migration patterns.

Order Pulmonata

Family Lymnaeidae

Lymnaea stagnalis (Linnaeus) 1758

Helix stagnalis Linnaeus 1758, Syst. Nat., ed. 10 p. 774.
Lymnaea stagnalis Baker 1911, Lymn. N. and M. Am., p. 136: synonymy.

TYPE LOCALITY. Europe.

DIAGNOSIS. Shell elongate to oval, ventricose anterior end, thin; apex smooth; 6 to 7 whorls, rapidly increasing, last whorl large, 2/3 length of entire shell; spire long, pointed, acute; sutures distinct, not greatly impressed; umbilicus closed or nearly so; aperture broadly ovate, large.

ECOLOGY. *L. stagnalis* is generally found in permanent, relatively shallow, quiet water approaching stagnation, as ponds, lakes, and backwaters of rivers. It is always associated with thick vegetation either floating or attached, preferably on mud substrate, soft. Baker (1928, p. 203) records this species from mud bottoms in 1.5 meters of water.

GEOGRAPHIC DISTRIBUTION. This species and its varieties as recorded by Baker (1928) can be described as circumboreal; in North America north of the 40th parallel of latitude.

GEOLOGIC RANGE. Records indicate that this species ranges from at least the Late Pleistocene to the Recent.

REMARKS. *L. stagnalis* is very rare in the Richardson Lake marl deposit and the specimens are small broken forms. No living representatives of the species were observed along the lake shores or in the marsh which does not mean that there are not some living in the lake. Clowers (1966) and Roy (1964) reported a scarcity of Pleistocene forms, but that it was abundant in present, closely adjacent lake, stream, and marsh areas. Although there was considerable vegetation in the lake during marl deposition there may not have been the quantities that would support a population of this species at the collecting localities. The broken specimens indicate that they were probably washed into the area from adjacent, more hospitable localities. Perhaps this species, along with *Amnicola limosa*, which also prefers abundant vegetation, lived elsewhere in the lake and this area was at the edge of their local range due to the lack of vegetation.

Stagnicola sp.

Stagnicola Leach 1819, proof sheets, pp. 141, 145.
Stagnicola Baker 1928, F.W. Moll. Wis., pt. 1, p. 210.

TYPE LOCALITY. Europe.

DIAGNOSIS. Shell elongated, narrow, whorls gradually increasing; numerous crowded growth lines crossed by elevated spiral lines; whorls to about 7, flattened or rounded, body whorl comprising about ½ length of shell; sutures somewhat indented; aperture varies from long-ovate to round-ovate; umbilicus narrow to closed.

ECOLOGY. The *Stagnicolae* generally inhabit larger bodies of water, such as lakes, ponds, streams, or pools; a few species thrive in ill-aerated waters. Preference to types and quantities of vegetation, type of substrate, depth of water and current varies from species to species.

GEOGRAPHIC DISTRIBUTION. This genus is circumboreal, occurring in the Old World as well as in North America.

GEOLOGIC RANGE. Records of this genus extend from at least the Kansan to the Recent.

REMARKS. *Stagnicola* (probably *S. palustris*) is rare in the Richardson Lake deposit, occurring singly, as small, broken spires in a few of the basal samples of both sections. This occurrence is in the sandy portions of each section which also contains remains of what may have been benthic vegetation. The condition of the shell remains indicates that they were probably washed into the collecting area.

Fossaria obrussa decampi (Streng) 1906

Limnaea desidiosa var. *decampi* Streng 1906, Naut., vol. 9, p. 123.
Galba obrussa decampi Baker 1911, Lymn. N. and M. Am., p. 289, pl. 32, figs. 15-22.
Fossaria obrussa decampi Baker 1928, F. W. Moll. Wis., pt. 1, p. 229, pl. 18, figs. 30-33; pl. 16, fig. 12.
Fossaria obrussa decampi La Rocque 1953, Cat. Rec. Moll. Canada, p. 285.

TYPE LOCALITY. Brook's Lake, Newaygo County, Michigan.

DIAGNOSIS. Shell small to medium sized, oblong, somewhat inflated, subconic, rather solid; about 5 whorls, spire whorls convex, all whorls markedly shouldered near suture, body whorl greatly flattened in middle; spire short, about ¼ length of shell, broadly conic, turreted, sutures deeply impressed; aperture long and narrow, somewhat elliptical, rounded below and forming prominent shoulder above, more than ½ length of shell. (Modified from Baker, 1928, p. 300).

ECOLOGY. Probably lives along margins of small bodies of water and on mudflats and in debris.

GEOGRAPHIC DISTRIBUTION. Great Lakes drainage; Maine west into Wisconsin; northern Michigan south to northern Illinois.

GEOLOGIC RANGE. Living representatives of this species have been collected from locations in Manitoba, Wisconsin, and Michigan. It is also common in Pleistocene deposits of the Wisconsin and post-glacial marl deposits in Ontario. (Whittaker, 1921, p. 62).

REMARKS. The form *decampi* has the characteristically prominent shoulder and flattened aperture described by Baker (1928, p. 300). No typical *F. obrussa*, as described by Baker (1928, pp. 293, 294) were found in the Richardson Lake deposit. Clowers (1966, p. 51, Fig. 10) reports *F. obrussa* as appearing in the middle of the Box Marsh section and becoming more abundant toward the top of that section. He attributes this to migration, so perhaps the species had not been able to reach the area of Richardson Lake that was sampled. The form *decampi* is prominent in both sections, becoming generally more plentiful upward. It is most abundant in that portion of the section which contains a slight admixture of non-carbonate sand and silt and moderate vegetation and least abundant in the nearly pure carbonate mud portion of the sections.

Baker (1928, p. 294) suggests that the form *decampi* probably occupies the same habitat as the species *obrussa*, but the evidence of Clowers' sections implies that they are most likely separate species or perhaps extremes in variation of the same species which are influenced by some variation in environment. In this deposit only the one form was recovered and there was little variation in the shell characteristics which would suggest that it belongs to a separate species and is not an end member of a widely varying species.

Family Planorbidae

Armiger crista (Linnaeus) 1758

Nautilus crista Linnaeus 1758, Syst. Nat., ed. 10, p. 709.

Gyraulus (Armiger) crista Baker 1928, F. W. Moll. Wis., pt. 1, p 385, text fig. 164.

Armiger imbricatus Baker 1945, Moll. Fam. Planorbidae, pp. 47, 50.

Gyraulus crista La Rocque 1953, Cat. Rec. Moll. Canada, p. 293.

TYPE LOCALITY. Europe.

DIAGNOSIS. Shell very small, depressed, ultra-dextral, fragile; sculpture of coarse growth lines ending in conspicuously costate periphery; fine, crowded spiral lines; about 2½ whorls, rapidly increasing in diameter, flatly rounded below. costae as low ridges on both upper and lower surfaces; flattened spire; umbilicus wide, open to apex; aperture ovate. (Modified from Baker, 1928, p. 358).

ECOLOGY. In shallow, quiet waters of small lakes with silty or muddy bottoms and containing abundant vegetation.

GEOGRAPHIC DISTRIBUTION. Holarctic; North America, from Maine west into Alberta, south to California, central Utah, and states north of the Ohio River. Recorded from Pleistocene deposits as far south as Texas.

GEOLOGIC RANGE. Its general range is from Middle Pleistocene to Recent with specimens being recovered from Kansan, Sangamon, and Wisconsin deposits in North America.

REMARKS. *A. crista* is represented by a single specimen in the lower portion of Section GG. Roy (1964) reported this species from localities in Wisconsin which were in front of the moraines marking the farthest extent of the last Wisconsin ice advance in that region. The occurrences in Wisconsin are rare and sporadic and indicate a rather small population and a much cooler climate than at present. The possibility exists that in the Richardson Lake deposit the water was too deep at the collecting points for this species to survive and when the depth decreased the temperatures were too warm.

Gyraulus parvus (Say) 1817

Planorbis parvus Say 1817. Nicholson's Encycl., ed. 1, vol. 2, pl. 1, fig. 5.

Gyraulus parvus Baker 1928, F. W. Moll. Wis., pt. 1, p. 374, pl. 23, figs. 27-31, 39.

Gyraulus parvus Baker 1945, Moll, Fam. Planorbidae, pp. 74, 270, 330, 336.

Gyraulus parvus La Rocque 1953, Cat. Rec. Moll. Canada, p. 294.
Gyraulus parvus Hibbard and Taylor 1960, Mus. Paleont., Univ. Michigan, vol. 16, p. 100, pl. VI, figs. 2, 3, 5, 6, 11, 12, 15.
Gyraulus parvus Taylor 1960, U.S.G.S. Prof. Paper 337, p. 58.

TYPE LOCALITY. Delaware River, near Philadelphia, Pennsylvania.

DIAGNOSIS. Shell discoidal, ultra-dextral, depressed, rounded periphery; growth lines oblique, crowded, fine; about 3½ whorls, rapidly enlarging, rounded below periphery, somewhat flattened above on body and spire whorls; flat spire, nuclear and second whorl depressed below body whorl; sutures deeply impressed; basally concave, umbilical region wide, shallow; aperture long-ovate, oblique or nearly in same plane as body whorl. (Modified from Leonard, 1959, pp. 60, 61).

ECOLOGY. *G. parvus* is most commonly found in small, quiet water bodies on mud, sandy mud, sand, gravel, or boulder substrates; on logs and vegetation, at depths of one foot to four feet. Abundant vegetation in protected places appears to be the most desirable habitat although this species is widely distributed and occurs in many varied habitats throughout its range and areal extent.

GEOGRAPHIC DISTRIBUTION. North America east of the Rocky Mountains from Florida to northern Canada and Alaska.

GEOLOGIC RANGE. Hibbard and Taylor (1960, p. 100) give this species a range of Middle Pliocene to Recent. This species is common in aquatic sediments of the Nebraskan, Aftonian, Sangamon, and Wisconsin.

REMARKS. A small percentage of the total mature shells identified to the genus *Gyraulus* possess a well angulated body whorl corresponding to forms illustrated and described by Baker (1928, p. 382) as *G. altissimus*. A complete series of forms was found demonstrating the gradation from markedly angulated to well rounded body whorls. Few immature specimens had any angulations and by breaking the body whorl of mature angulated specimens at regular intervals, the angulation is seen to give way to a rounded body whorl. This is probably a genetic variation which manifests itself during late growth stages and may be evidenced by the small number of angulated forms as compared to the total number of individuals in the samples. Roy (1964, p. 28) and Clowers (1966, p. 45) noted similar angulations of the body whorl of mature *Gyraulus*. All specimens were identified as *G. parvus*. This species makes up the majority of the molluscan assemblage in most samples and shows a gradual decrease in numbers upward in both sections.

Helisoma anceps striatum (Baker) 1902

Planorbis bicarinatus striatus Baker, 1902, Naut., vol. 15, p. 120.
Planorbis antrosus striatus Walker 1918, Synopsis and Cat., p. 96.
Helisoma antrosa striata Baker 1928, F.W. Moll. Wis., pt. 1, p. 328 pl. 19, figs. 28-31.
Helisoma anceps striatum La Rocque 1953, Cat. Rec. Moll. Canada, p. 288.

TYPE LOCALITY. Coldspring Park, Milwaukee, Wisconsin; Pleistocene.

DIAGNOSIS. Shell nearly planispiral, about 3½ whorls, dorsal and ventral carinae distinct, cord-like, elevated; dorsal carina approximately centered on upper surface of body whorl; body whorl well-rounded; small, deep umbilicus, smoothly concave, width less than one-half of shell diameter; surface sculpture of heavy spiral lines, becoming distinct ridges in several specimens and thickenings of shell at points of growth quiescence; aperture higher than wide, nearly in plane of body whorl, lunate, bell-shaped in immature specimens.

ECOLOGY. Baker (1928, p. 328) states that *H. anceps striatum* is a lake species, capable of living in cold waters of ice front lakes formed immediately after the ice retreated. This variety or form is found in marl, silt, and peaty marl; studies indicate that it lived in shallow fresh-water lakes containing abundant vegetation.

GEOGRAPHIC DISTRIBUTION. Known from deposits of Pleistocene age in Wisconsin and Michigan, east into Quebec, south into Illinois, Indiana, and Ohio; Recent forms have been recorded within the area north of the Great Lakes.

GEOLOGIC RANGE. Described from Late Wisconsin deposits and perhaps from older sediments as well. Living forms have been collected from northern Wisconsin and Minnesota.

REMARKS. *H. anceps striatum* is common in the Richardson Lake deposit. It seems to have a more constant population through time in Section G than in Section GG which may be due to changes in the water temperature adjacent to the deeper portion of the lake. Perhaps overturn in the deep lake affected the Section GG and not Section G. This species shows its greatest abundances in parts of the sections which are slightly silty (non-carbonate) or where the mud bottom was fairly solid. This species demonstrates very well by the size of individuals the changes in the environment through time.

Helisoma campanulatum (Say) 1821

Planorbis campanulatus Say 1821, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 166.
Helisoma campanulatum Baker 1928, F.W. Moll.. Wis., pt. 1, p. 345, pl. 21, figs. 1, 2, 4, 5, 8, 9, 13, 14.
Helisoma campanulatum La Rocque 1953, Cat. Rec. Moll. Canada, p. 292.

TYPE LOCALITY. Cayuga Lake, New York.

DIAGNOSIS. Shell ultra-sinistral, discoidal, rounded; 4-5 whorls, subcarinate above, rounded below; sutures deeply impressed; spire very flat, first whorls depressed slightly below later whorls; umbilicus relatively small, deep, exhibiting about 2½ volutions; aperture lunate, expanded.

ECOLOGY. *H. campanulatum* is generally found in water less than 1 meter deep in lakes, marshes, and the quiet water along stream shores. (Baker, 1928, p. 346) The substrate is rock, sand, or mud, the latter two with large quantities of vegetation.

GEOGRAPHIC DISTRIBUTION. Vermont west to North Dakota, south into Ohio and Illinois, north into the Mackenzie River drainage.

REMARKS. *H. campanulatum* comprises a minor part of the molluscan sample taken from the Richardson Lake deposit and occurs in quantities similar to those recorded by Clowers (1966, p. 49), Shallom (1965, p. 42) and Roy (1964, p. 39, 40, 46, 47 except Mountain deposit). Where there are only one or two specimens per sample these are invariably large, mature specimens. Only where several specimens occur together are juvenile forms present. In Section GG this species is most plentiful in the lower half of the section where there is non-carbonate silt and sand mixed with the marl or the non-carbonate fraction is predominant. In Section G this species is only present in the middle of the section which is composed of marl with some silt content. Here the only forms recovered were mature specimens so perhaps there is some correlation of migration with water temperature as well as depth and vegetation which may be illustrated by the decline in abundance seen in Section GG above sample 12.

Promenetus exacuous (Say) 1821

Planorbis exacuous Say 1821, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 168.
Menetus exacuous Baker 1928, F. W. Moll. Wis., pt. 1, p. 361, pl. 23, figs. 1-5.
Promenetus exacuous exacuous La Rocque 1953, Cat. Rec. Moll. Canada, p. 292.

TYPE LOCALITY. Lake Champlain, New York, Vermont, and Quebec.

DIAGNOSIS. Shell ultra-dextral, greatly depressed, with an acute periphery; about 4 whorls, rapidly increasing in diameter; flattened spire; sutures impressed; umbilicus deep, rather narrow; aperture ovate, oblique to body whorl. (Modified from Baker, 1928, p. 361).

ECOLOGY. Baker (1928, pp. 362, 363) found this species on mud flats in quiet water from a few cm. deep to 0.6 m. deep. In quiet, marshy places, on logs and at the edges of clear cold water streams. Leonard (1959, p. 67) relates that *P. exacuous* was found living on vegetation in the cool waters of a pond.

GEOGRAPHIC DISTRIBUTION. North America, east of the Rocky Mountains, from Mexico to the Mackenzie River area and Alaska.

GEOLOGIC RANGE. A common, though not abundant, fossil in Wisconsin sediments, *P. exacu-*

ous is given a range of Sangamon to Recent by Hibbard and Taylor (1960, p. 107).

REMARKS. This species is found mainly in the bottom half of both sections but occurs sporadically throughout the stratigraphic interval. It seems to be the most abundant in those samples containing considerable vegetable remains and clay-sized particles which fill in the areas between predominantly non-carbonate sand-sized grains. The greater percentages of this species occurring in Section GG as compared with Section G are interesting in that the samples of Section G contain lesss vegetation and have higher non-carbonate sand contents than those from similar positions in Section GG. Also the location of Section GG faces the windward shore of present day Richardson Lake.

The continuity of specimens of *P. exacuous* in succeeding samples is much better than that recorded by either Roy (1964) or Clowers (1966) and the Richardson Lake deposit seems also to contain a higher percentage of species than either of those mentioned above. Roy (1964, Fig. 1, p. 6) indicates that his specimens were collected from lake deposits closely adjacent to the Mountain Moraine and on the side from which ice advanced. Roy's samples may indicate cool environments along the moraine. Based on this single species, cool or cold early stages in the development of Richardson Lake area were followed by a warming trend to the present or at least until the termination of marl deposition.

Family Ancylidae

Ferrissia parallela (Haldeman) 1841

Ancylus parallelus Haldeman 1841, Monogr., pt. 2, p. 3.
Ferrissia parallela Baker 1928, F. W. Moll. Wis., pt. 1, p. 395, pl. 29, figs. 1-5.

TYPE LOCALITY. New England.

DIAGNOSIS. Shell cap-like, narrow, elongate longitudinally, lateral margins nearly straight, widening slightly anteriorly, ends well rounded; anterior slope longer than posterior slope, slightly convex; posterior slope straight to concave; apex anterior and to the right of center of the shell, sub-acute.

ECOLOGY. According to Baker (1928, p. 397) *F. parallela* is most common in quiet waters ranging from 0.3 to 2 meters in depth. The species is commonly recovered from ponds and lakes where it lives in the vegetation, generally near the surface.

GEOGRAPHIC DISTRIBUTION. Nova Scotia and New England west to Minnesota; Manitoba south to Rhode Island, central New York, northern Ohio, and Indiana.

GEOLOGIC RANGE. This limpet has a range of Pliocene (Taylor, 1960, p. 61) to Recent, and is common in Wisconsin deposits.

REMARKS. This species is rare in the Richardson Lake deposit; it was recovered from the bottom five samples of Section GG, but not in a similar interval of Section G. *F. parallela* becomes less abundant upward as the carbonate content of the fine fractions of succeeding samples increases from less than 20 percent to nearly 100 percent of the fines. Plant remains are prominent in all fractions in this interval and decrease upward.

Family Physidae

Physa gyrina Say 1821

Physa gyrina Say 1821, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 171.
Physella gyrina Baker 1928, F. W. Moll. Wis., pt. 1, p. 449, pl. 27, figs. 30-35, 37-40; pl. 28, figs. 1, 5, 6.
Physa gyrina gyrina La Rocque 1953, Cat. Rec. Moll. Canada, p. 298.

TYPE LOCALITY. Bowyer Creek, near Council Bluffs, Iowa.

DIAGNOSIS. Shell sinistral, large, ovoid-subcylindrical, rather thick, sculpture of coarse growth lines; 5 to 6 whorls, the body whorl comprises ¾ total shell length, slightly inflated or compressed; spire acute, rather long, pointed; whorls rounded, somewhat shouldered sutures impressed; aperture generally more than half length of shell, comma shaped.

ECOLOGY. A species characteristic of quiet, shallow, slow-moving bodies of wwter, especially on mud substrate.

GEOGRAPHIC DISTRIBUTION. United States east of the Mississippi River with inroads into Texas; Ontario and Quebec northward to the Arctic regions.

GEOLOGIC RANGE. Taylor (1960, pp. 32, 39) reports this species from deposits of Nebraskan age. It is commonly found in Late Pleistocene and Recent assemblages.

REMARKS. *P. gyrina* is much more common in section GG than in Section G (Fig. 14). In both pits this species is less prominent near the base, where there is abundant vegetation and sand substrate, and becomes more numerous upward. Samples 7 through 16 in Section GG are relatively pure calcareous mud with low to moderate vegetation content, whereas a similar interval in Section G contains more dark-colored sediments and slightly more vegetation. The description of this interval in these sections is similar to that described by Clowers (1966, Fig. 11, p. 51) who reported this species as the most abundant in an apparently similar interval from the Box Marsh deposit. Size range and average sizes are also similar to the specimens recovered by Clowers.

Terrestrial Gastropoda

Order Pulmonata

Family Succineidae

Succinea grosvenori Lea 1864

Succinea lineata Binney 1857 Proc. Acad. Nat. Sci. Phila., p. 19; not *S. ovalis* var. A. *lineata* DeKay, 1844.
Succinea grosvenori Lea 1864 Proc. Acad. Nat. Sci. Phila., p. 109.
Succinea greerii Tryon 1866, Am. Jour. Conch., vol. 2, p. 232, pl. 2(17), fig. 8.
Succinea grosvenori Pilsbry 1948, Land Moll. N. Am., vol. 2, pt. 2, p. 819, figs. 444, 452 i, j.
Succinea grosvenori La Rocque 1953, Cat. Rec. Moll. Canada, p. 329.

TYPE LOCALITY. 'Santa Rita Valley, Kansas?' (Pilsbry, 1948, p. 821).

DIAGNOSIS. Shell rather short, fragile, inflated, strongly convex whorls, well impressed sutures and occasional coarse sculpture; rare interrupted and irregular spiral impressions on periphery. (Modified from Pilsbry, 1948, p. 821).

ECOLOGY. '... as now understood, tolerates an astonishingly wide range of practically all external conditions. It occurs from the warm, humid Gulf Coast to semi-arid areas in the Great Plains and mountain states, and in British America it extends north within the border of the Northwest Territories.' (Pilsbry, 1948, p. 821).

GEOGRAPHIC DISTRIBUTION. Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario; south into Florida and Arizona.

GEOLOGIC RANGE. A widespread though rare form, Leonard (1952 p. 24) gives it a range of Blancan to Recent.

REMARKS. This species is represented by a single specimen in samples 4, 15, and 17 in Section GG, which would indicate that there was an environment close by into which this terrestrial gastropod had migrated and prospered. The lack of this species in the upper samples of both sections suggests that the environment had changed or shifted from what it was at that time.

Succinea ovalis Say 1817

Succinea ovalis Say 1817, Jour. Acad. Nat. Sci. Phila., vol. 1, p. 15.
Succinea ovalis Pislbry 1948, Land Moll. N. Am., vol. 2, pt. 2, p. 801, figs. 430-433.

TYPE LOCALITY. Philadelphia, Pennsylvania.

DIAGNOSIS. Shell oval, inflated, thin; fine growth lines; about 2½ whorls, the last greatly inflated; aperture ovate, ¾ length of shell. (Modified from Pilsbry, 1948 pp. 802, 803).

ECOLOGY. Generally recovered from low ground near streams, often on annual vegetation a short distance above the ground, or beneath logs, stones, and forest litter.

GEOGRAPHIC DISTRIBUTION. Newfoundland and James Bay west into North Dakota and Nebraska; south into Alabama and North Carolina.

GEOLOGIC RANGE. Leonard (1950, p. 24) designates the range of *S. ovalis* as Yarmouth to Recent.

REMARKS. This species is represented by single occurrences in the top three samples of Section G and is associated with other Recent or living terrestrial species. The absence of *S. ovalis* in other portions of both sections would indicate that either the environment was inhospitable, that the species had not migrated this far, or that it had not been transported into the aquatic environment.

Family Pupillidae

Gastrocopta contracta (Say) 1822

Pupa contracta Say 1822, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 374.
Leucochila contracta Call 1900, Descr. Cat. Moll. Indiana, p. 398, pl. 6, fig. 10, text fig. 12.
Bifidaria contracta Billups 1902, Nautilus, vol. 16, p. 51.
Gastrocopta contracta Pilsbry 1948, Land Moll. N. Am., vol. 2, pt. 2, p. 880, fig. 474: 9-12.

TYPE LOCALITY. Occoquan, Virginia.

DIAGNOSIS. Shell ovate-conic in outline, rimate, bluish-milky in color, translucent; about 5½ whorls, marked by fine growth striae, last half of body whorl straightened, pinched at base, low rounded ridge exists behind peristome; aperture rounded-triangular, expanded; anguloparietal lamella S-shaped; columellar lamella large, deeply placed; callus in front near margin; two palatal folds, upper small, lower large, also deeply placed. (Modified from Pilsbry, 1948, p. 881).

ECOLOGY. *G. contracta* inhabits a variety of environments including stream floodplains and slopes, in logs and debris on floors of hardwood forests, and limestone bluffs wherever there is sufficient moisture.

GEOGRAPHIC DISTRIBUTION. Eastern Canada and United States: Maine, Ontario and Manitoba, south to Florida and Mexico; Jamaica (introduced).

Vertigo ovata Say 1822

Vertigo ovata Say 1822, Jour. Acad. Sci. Phila., vol. 2, p. 375.
Vertigo ovata Pilsbry 1948, Land Moll. N. Am., vol. 2, pt. 2, p. 952, text fig. 513: 1-3, 4 7.
Vertigo ovata Oughton, 1948, Zoogeogr. Study Ontario, p. 62.
Vertigo ovata La Rocque 1953, Cat. Rec. Moll. Canada, p. 335.
Vertigo ovata Hibbard and Taylor 1960, Mus. Paleont., Univ. Michigan, vol. 16, p. 135, pl. 11, fig. 8.

TYPE LOCALITY. Philadelphia, Pennsylvania.

DIAGNOSIS. Shell ovate in outline, about 5 whorls, amber colored, spire convexly conic, apex obtuse; whorls increase rapidly in size, body whorl much the largest with strong crest behind apertural lip; sutures impressed; parietal lamella long and strong, columellar lamella strong; angular lamella small; basal fold well-developed; upper and lower palatal folds strong.

ECOLOGY. *V. ovata* has high moisture requirements and is commonly found in moist environments as provided by shaded slopes near streams and shores of ponds. It is found in and under plant debris, leaves, grasses, logs, sticks, moss, and in swampy meadows.

GEOGRAPHIC DISTRIBUTION. Labrador west into British Columbia and north to Alaska; south to Florida, Mexico, and the West Indies.

GEOLOGIC RANGE. Two Tertiary occurrences, Early Pliocene Laverne local fauna, and Middle Pliocene Buis Ranch local fauna both from Beaver County, Oklahoma, provide the earliest known records of this living species.

REMARKS. Representatives of this species recovered from the top sample of Section G still retain their color and have undoubtedly been buried no more than a couple of years. This occurrence would suggest that these terrestrial snails either had not migrated into the area until recently or that their habitat was far enough from the deposit to preclude their being carried into the area of collection.

Euconulus fulvus (Müller) 1774

Helix fulva Müller 1774 (part). Hist. Verm. Terr. et Fluv., vol. 2, p. 56.
Euconulus fulvus Pilsbry 1946 Land Moll. N. Am., vol. 2, pt. 1, p. 235.

TYPE LOCALITY. Fridrichsdal, Denmark.

DIAGNOSIS. Shell small, flatly conic, slightly convex outlines, cinnamon colored, about 5 whorls; whorls slightly convex, sutures indented; apex obtuse, rounded; base of body whorl convex, periphery is slightly angulated; aperture elliptical, umbilicus small.

ECOLOGY. Most abundant in floodplain areas bordering streams, living under loose bark and decaying debris in hardwood forests. Among damp leaves in well-shaded places. (Pilsbry, 1946, p. 236).

GEOGRAPHIC DISTRIBUTION. A Holarctic form, but wanting in the South Atlantic and Gulf Coast States from Texas to South Carolina.

GEOLOGIC RANGE. A common fossil in Wisconsin deposits, *E. fulvus* ranges from Middle Pliocene to Recent.

REMARKS. Four specimens of *E. fulvus* were recovered from the top three samples of Section G which is an open area covered with annual grass and moss vegetation typical of low, continuously damp, alkaline soils. The specimens still retained their color and may be regarded as being dead for no more than a couple of years. At present there are a few small stands of hardwood and scrub vegetation in the depressions and low places around the area. Perhaps this type of vegetation became established in the area in geologically recent times and this species did not migrate until after the flora was established, thus accounting for only Recent specimens being recovered.

Retinella indentata (Say) 1822

Helix indentata Say 1822, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 372.
Vitrea indentata Dall 1905, Harriman-Alaska Exped., vol. 13, p. 39.
Retinella indentata Pilsbry 1946, Land Moll. N. Am., vol. 2, pt. 1, p. 288, fig. 146a.
Retinella indentata La Rocque 1953, Cat. Rec. Moll. Canada, p. 313.

TYPE LOCALITY. 'Harrigate and New Jersey'

DIAGNOSIS. Shell depressed, highly polished, 4 whorls with regular, sub-equidistant impressed axial striae continuous to umbilicus; aperture rather large, lip simple; umbilicus very small. (Modified from Say, quoted by Pilsbry, 1946, p. 289).

ECOLOGY. Inhabits many localities, chiefly damp woodlands; also in quarries, sandy outwash plains, along railroad tracks, pine forests, and cliffs and bluffs along creeks, in the ground debris.

GEOGRAPHIC DISTRIBUTION. North America, from Canada (49° north latitude) south to northern Alabama; from Maine west to Kansas.

GEOLOGIC RANGE. Baker (1920, p. 389) has described this species from deposits of Yarmouth, Sangamon, Peorian, and Wabash age; it is widespread today.

REMARKS. *R. indentata* is represented by single specimens in samples 2 and 14 in Section G. From the synopsis of the ecology of this species it is evident that it prefers relatively hilly conditions and large rock fragments as a habitat. These conditions are for the most part absent in the Richardson Lake area.

Retinella rhoadsi (Pilsbry) 1899

Vitrea rhoadsi Pilsbry 1899, Nautilus, vol. 12, p. 101.
Retinella (Glyphyalops) rhoadsi rhoadsi Baker 1930, Proc. Acad. Nat. Sci. Phila., vol. 82, p. 207.
Retinella rhoadsi Pilsbry 1946, Land Moll. N. Am., vol. 2, pt. 1, p. 286, fig. 145.
Retinella rhoadsi La Rocque 1953, Cat. Rec. Moll. Canada, p. 313.
Retinella rhoadsi Taylor, 1960, U.S.G.S. Prof. Paper 337, p 81.

TYPE LOCALITY. White Pond, Warren County, New Jersey.

DIAGNOSIS. Shell similar to that of *R. indentata* but differing in having a wider umbilicus, showing the penultimate whorl within;

axial grooves more numerous, therefore closer. (Modified from Pilsbry, 1946 p. 286).

ECOLOGY. This species has been recovered from damp hardwood forests, swampy areas around springs, and stream floodplains.

GEOGRAPHIC DISTRIBUTION. Maine, Vermont, New York, Ontario, and Michigan; south to West Virginia, North Carolina, Maryland, and Delaware.

GEOLOGIC RANGE. Taylor (1960, p. 81) records this species for the Rexroad local fauna of Pliocene age; Taylor and Hibbard (1955, p. 12) record it from the Sangamon of Kansas. It has a relatively wide present day distribution.

REMARKS. Several representatives of this species were recovered from the upper four samples of Section G along with other Recent terrestrial forms. Its presence in four contiguous samples would indicate a favorable environment near the collecting locality for some time previous to the draining of the area and that the species moved into the immediate area rather quickly after the draining. This species should be compared with *R. indentata*, which is supposedly closely related but inhabits more rugged topography and therefore is not as abundant in the deposit.

Zonitoides nitidus (Müller) 1774

Helix nitida Müller 1774, Hist. Verm. Terr. et Fluv., vol. 2, p. 32.
Zonitoides nitidus Dall 1905, Harriman-Alaska Exped., vol. 13, p. 42.
Zonitoides nitidus Pilsbry 1946, Land Moll. N. Am., vol. 2, pt. 1, p. 476, fig. 259.
Zonitoides nitidus La Rocque 1953, Cat. Rec. Moll. Canada, p. 316.

TYPE LOCALITY. Fridrichsberg, Denmark.

DIAGNOSIS. Shell umbilicate, umbilicus 1/5 diameter of shell; about 4½ whorls gradually expanding, convex; sutures indented; growth lines fine, weak, lacking on embryonic whorls; base smooth, translucent; aperture lunate. (Modified from Pilsbry, 1946, p. 447).

ECOLOGY. Generally found near water as on stream floodplains, and margins of ponds, streams, and marshes, mainly on alkalic terrains. (Oughton, 1948, pp. 89, 94).

GEOGRAPHIC DISTRIBUTION. Holarctic; from Alaska south into California, Utah, South Dakota, Arkansas, Tennessee, and Maryland.

GEOLOGIC RANGE. Pilsbry (1946, p. 447) quotes F. C. Baker in establishing a range of Sangamon to Recent, based on a few specimens.

REMARKS. *Z. nitidus* is represented by only one specimen in the Richardson Lake marl deposit, which was recovered from sample 1 in Section G. This specimen retains its color as do the other living terrestrial gastropods recovered in the same sample and is not representative of the environments which prevailed at this locality during marl deposition. From the evidence of the terraces a suitable environment was not available until after the waters receded and the marl deposit was uncovered.

Family Limacidae

Deroceras sp.

Deroceras Rafinesque 1820 Annals of Nature, vol. 1, p. 10.
Deroceras Pilsbry 1948, Land Moll. N. Am., vol. 2, pt. 2, p. 535.

TYPE. *Limax gracilis* Rafinesque (=*Limax laevis* Müller.

DIAGNOSIS. Shell oval, very shallow caplike, concentrically striate; nucleus off center, to left of middle of posterior margin.

ECOLOGY. Living representatives of this genus inhabit many environments from deciduous forests to house basements, nearly everywhere there is moisture.

GEOGRAPHIC DISTRIBUTION. Cosmopolitan; Palearctic regions and both Americas.

GEOLOGIC RANGE. Hibbard and Taylor (1960, p. 20) report some representatives of this living genus from Upper Pliocene or Lower Pleistocene deposits of Kansas.

REMARKS. Representatives of the genus are very rare in the Richardson Lake deposit, being found only in the upper portions of Section G with other Recent terrestrial gastropods. The very nature of the shell makes it an easily overlooked and misidentified fossil and careful study could extend its known range farther back in geologic time.

COMPOSITION OF FAUNA

General Statement

The non-marine Mollusca collected from the Richardson Lake marl deposit, Quebec Canada consist of 27 species. The majority of these species are typical lake forms and have been recovered in similar associations from marl deposits elsewhere. There are five sphaeriid clams, 13 ctenobranchiate, and nineteen pulmonate gastropods in the samples recovered from the two sections.

A quantitative analysis of the mollusks from the samples collected was made to determine the relative abundance of each species in each sample and its vertical and chronological distribution in the two sample areas. The abundance of each species is related to the lithologies in the separate sections and to the evidence of decreasing water depth as supplied by shoreline features.

The assumption is made that the most abun-

TABLE 1. Number of Mollusks per Thousand Milliliters of Sediment

Sample	Lithologic Units Section G	Lithologic Units Section GG*	Number of Specimens Section G	Number of Species Section G	Number of Specimens Section GG	Number of Species Section GG
1			630	14	1050	12
2			780	12	1380	9
3	Unit 1		950	12	1720	10
4	*********		960	8	1770	13
5	Unit 2		1140	9	970	12
6	*********		1200	8	2060	11
7	Unit 3	Unit 5	1870	9	1090	11
8	*********		960	9	2660	11
9			550	9	1290	9
10			650	9	2320	9
11			790	9	3130	11
12	Unit 4		530	8	1580	13
13			430	7	1220	11
14			260	8	1300	12
15		********	400	8	1130	14
16	*********	Unit 6 ********	900	11	1930	15
17	Unit 5	Unit 7	1000	12	920	15
18	*********	********	530	11	540	13
19	Unit 6	Unit 8	2110	12	--	--

* Top four units of Section GG were unfossiliferous sand and are not included in this table.

dant species are autochthonous and that the minor elements are allochthonous forms. This assumption must be modified somewhat as many species are more prolific or naturally more abundant than other species. Therefore, continuity through several samples of both mature and juvenile forms of minor molluscan elements is also considered indicative of autochthonous forms, albeit with great care. It is also noted that the minor elements of the assemblage indicate considerably more concerning the environment than most of the major components. The possibility that the small numbers of the minor elements may be due to environmental factors approaching their tolerance limits must not be disregarded.

Table 1 lists the approximate numerical abundance of mollusks per thousand milliliters of sediment as taken from each sample.

Samples were collected from the top to the bottom of each pit section and the samples are numbered correspondingly from the top to the base in all figures, tables, and measured sections. Figures 4 through 16 are graphic plots of percentages from Tables 2 and 3 of the most significant species. These plots are presented to provide a means of visually evaluating the relative abundance of each species in each sample, of demonstrating the vertical distribution of the important species in the section, and of providing a means of comparing mollusk assemblages, through time, from various deposits. The latter is of little use at the present as insufficient data are available as to the ecology and adaptability of individual species, paleoenvironments in which they existed, the sections from which they were collected, and correlation in the strictest sense between deposits.

Richardson Lake Marl Deposit

Of the twenty-seven species represented in the deposit, nine are terrestrial forms which for the most part are confined to the top portion of Section G; seven are prominent lake dwelling species occurring throughout both sections; seven are minor autochthonous species, but important in ecological determinations; and the remaining four species are interlopers into the area from adjacent environments. The most plentiful species in this deposit are *Gyraulus parvus*, *Pisidium casertanum*, *Valvata tricarinata*, *Fossaria obrussa decampi*, and *Helisoma anceps striatum* (Tables 2 and 3). The remainder, though less abundant, generally offer more detailed information concerning the changing environments of the lake through time than do the more abundant, nearly cosmopolitan species.

This assemblage represents some of the organisms which existed at or near the points of collection during the time interval represented by the accumulation of sediment in the sections sampled. It can be said that the greatest variety of mollusks is found in the lower third of Section GG, above which several species either disappear or are decreased drastically in number to the top of that section (Tables 1 and 3). In section G the greatest variety of mollusks is found in the topmost samples, but this number is swelled by the presence of several present day terrestrial forms. The lower third to one half of Section G then has the widest variety of Pleistocene forms in this section (Tables 1 and 2).

Section GG may be divided into two broad units on the basis of fossil mollusks; the top few samples perhaps representing a transition to a third unit. Section G may also be split into two units, much more clearly than Section GG, with the terrestrial gastropods superimposed on the section after marl deposition ceased. The break between what is here termed faunal or ecological units is very distinct and is due to substrate, vegetation, and other unknown ecological parameters. This faunal or ecological zonation not only conforms with lithologic changes in the sections, but can be recognized in the total number of specimens per thousand milliliters of sediment (Table 1) and the change in relative sizes of the individuals of a given species throughout a section.

Section G may also be divided as follows: samples 16 through 19 as one unit (see also stratigraphic Section G) with the overall smallest specimen size; samples 8 through 15 of larger sized specimens and fairly uniform numbers; samples 5 through 7 with a distinct lithological difference, much larger sized individuals, greater numbers, but no increase in variety of species; samples 1 through 4 represent an environment similar to that indicated by samples 8 through 15, with similar sized specimens.

Section GG may be divided faunally or ecologically as follows: a unit containing samples 12 through 18 showing greatest speciation which decreases as the lithology changes and also has the smallest overall size of individuals in the section; a unit composed of samples 1 through 11 shows a general decrease in number of specimens upward with slightly more variation in species near the top, size remaining relatively constant and somewhat larger than those of the bottom unit. Prominent breaks in the trend of specimen numbers (Table 1) are seen at samples G-5, G-11, and G-16, which are probably due to ecological factors not readily observable in the sediments.

The important species, ecologically, in these two sections are not necessarily the most numerous forms. The most abundant and most continuous forms apparently have wide ranges of tolerance to environmental changes and are thus well suited to belong to pioneer as well as successional communities.

Gyraulus parvus is the most plentiful species in the lower portions of both sections and demonstrates a steady decrease in numbers upward in the respective sections. At the intervals mentioned above in Section G there are slight fluctuations in numbers (Fig. 4). *G. parvus* comprises as much as 75 percent of some samples, but as little as 15 percent of others and is overall more abundant in Section GG than in Section G. The similarity of percentages at the top of both sections may indicate that the environment of the entire lake was becoming more nearly the same.

Pisidium casertanum is nearly as abundant as *G. parvus* in Section G where it increases upward to approximately the middle of the section then exhibits a slight decline, with some fluctuation toward the top of the section. In Section GG this species appears continuously from the middle of the section and increases upward to become one of the prominent species in the upper part of that section. This may be an indication of the warming of the entire lake.

Fossaria obrussa decampi and *Helisoma anceps striatum* appear continuously throughout both sections and demonstrate roughly negative correlation. In the lower half of both sections the form *decampi* shows considerable fluctuation in numbers, but in the upper half of the sections there is surprising uniformity (Fig. 12). In Section GG the form *striatum* shows two sharp increases (Fig. 11) which may be due to colder water conditions in the deeper lake as compared to the relatively stable temperature conditions which probably existed in the shallower area about Section G. These two forms or subspecies comprise 30 to 40 percent of the composite assemblage through time.

Valvata tricarinata is rare in the lower third of Section G and the lower two thirds of Section GG, but then is continuously represented in both sections with a striking increase in number of specimens upward. *V. lewisi*, although a minor species, shows negative correlation with *V. tricarinata* and appears in the lower third of both sections then decreases rapidly upward in the sections with the change in lithology from predominantly non-carbonate sand to predominantly carbonate mud (Figs. 9 and 10).

Sphaerium nitidum occurs sporadically throughout Section GG, marking the abrupt changes in the general trend of numbers of species (Fig. 5; Table 1). *Ferrissia parallela* and *Promenetus exacuous*, also minor elements of the assemblage, appear continuously through several samples in the lower portions of each section (Figs. 15 and 16). These three species comprise a maximum of three percent of any particular sample and are important ecological indicators.

Physa gyrina is a prominent component of Section GG but nearly lacking in Section G (Fig. 14). It shows a fluctuating increase in the lower third of Section GG, then decreases to less than two percent in the middle third of the section. The lack of this species in Section G may indicate that there was insufficient current in this protected area of the deposit.

The remaining species, some comprising relatively large and some relatively minor percentages of individual samples serve mainly to emphasize the previously mentioned lithologic, faunal or ecological, and numerical changes in the sections, or the superimposed terrestrial conditions after marl deposition had ceased.

(FOR TABLES 2 AND 3, SEE PAGES 27 AND 28; ABBREVIATIONS FOR BOTH TABLES ARE EXPLAINED ON PAGE 26).

PALEOECOLOGY

Richardson Lake Marl Deposit

The Pit Sections and samples from auger holes randomly drilled throughout the deposit show that whitish gray to tan marl predominates in the stratigraphic interval in which it occurs. In some places the marl is covered by peat, muck, and water and in other places by sand in disconformable contact. The marl grades sharply and quickly into dark gray mud and sand at the base of each section but only near the top of Section G and in Unit 5 of Section GG is the marl interrupted by distinct non-carbonate layers. However, some non-carbonate sand was noted in the marl, but not as distinct beds. The marl contains lacustrine molluscan remains which, with the exception of Recent terrestrial forms in the superimposed soil zone in Section G, prevail throughout both sections. In both sections the number of specimens per unit volume fluctuates from sample to sample, but remains fairly constant overall or with only a slight numerical increase upward in the respective sections. This fluctuation is probably related to the rates of sedimentation and the changing environmental conditions connected with the variations in water depth recorded by the exposed terraces on the slopes of the depression. The measured sections described are as follows:

Stratigraphic Section G of the Richardson Lake Deposit (Figure 3)

Measured Units		Thickness (inches)
1	Topsoil, gray to black, predominantly sphagnum moss as surface vegetation; minor coarse non-carbonate sand of varied mineral content; clayey; sharp irregular contact with white marl in soil; aquatic mollusks abundant. Samples G-1 - G-4 (part).	7.5
2	Marl, white, very blocky in structure plant roots and organic debris prominent; irregular medium-gray layers of fine silt less than 25 percent of total; less than 10 percent non-carbonate sand; mollusks abundant. Samples G-4 (part) - G-6.	4.5
3	Marl, light tan with pink cast; very clayey, not blocky like unit 2; rootlets and organic debris common, especially in lower part; minor non-carbonate sand apparent in lower part; mollusks abundant. Samples G-7, G-8.	4.0
4	Marl, tan, darker and more clayey than unit 3, massive; upper contact gradational; top 6 inches contains considerable plant debris and is more silty and clayey; lower 9 inches more sandy (non-carbonate); mollusks less prominent in lower part of this unit. Samples G-9 - G-16 (part).	15.0
5	Clay and mud, medium to dark gray, slightly sandy at top, grades sharply downward into battleship gray non-carbonate sand; plant debris especially common near top; yellowish pelecypod shells prominent. Samples G-16 (part), G-17, G-18.	5.0

EXPLANATION OF ABBREVIATIONS FOR TABLES 2 AND 3

AC - *Armiger crista*, AL - *Amnicola limosa*, DO - *Deroceras sp.*, EF - *Euconulus fulvus*, FO - *Fossaria obrussa decampi*, FP - *Ferrissia parallela*, GC - *Gastrocopta contracta*, GP - *Gyraulus parvus*, HC - *Helisoma anceps striatum*, LS - *Lymnaea stagnalis*, PA - *Pisidium casertanum*, PC - *Pisidium compressum*, PE - *Promenetus exacuous*, PG - *Physa gyrina*, RI - *Retinella indentata*, RR - *Retinella rhoadsi*, SG - *Succinea grosvenori*, SL - *Sphaerium lacustre*, SN - *Sphaerium nitidum*, SO - *Succinea ovalis*, SP - *Stagnicola* sp., SS - *Sphaerium sulcatum*, VL - *Valvata lewisi*, VO - *Vertigo ovata*, VT - *Valvata tricarinata*, ZN - *Zonitoides nitidus*.

TABLE 2. VERTICAL DISTRIBUTION OF SPECIES IN SECTION G, RICHARDSON LAKE MARL DEPOSIT*

Sam-	Ctenobranchiata					Pulmonata								
ple	**VT**	**VL**	**AL**	**LS**	**SP**	**FO**	**GP**	**HS**	**HC**	**AC**	**PE**	**PG**	**FP**	**SG**
1	17.0	...	...	..	..	9.6	26.5	1.5	..	..	9.1	0.2	..	..
2	23.0	..	..	..	..	7.5	33.0	2.7	..	..	..	..	..	..
3	20.5	..	..	..	0.1	8.7	37.2	3.5	..	..	..	..	..	..
4	21.8	..	..	..	..	10.8	34.7	3.6	..	..	..	..	..	..
5	23.5	..	..	..	..	11.1	33.6	4.3	..	..	..	0.1	..	..
6	28.5	..	..	..	..	11.8	25.3	7.9	0.1	..	..	..	..	..
7	24.5	..	..	..	..	6.1	23.7	7.5	0.2	..	..	..	0.1	..
8	20.1	..	..	..	..	3.8	24.9	4.1	0.1	..	..	0.1	..	..
9	4.5	..	..	..	..	8.4	40.2	8.9	0.1	..	..	0.1	..	..
10	0.6	..	..	..	..	17.2	35.6	9.9	0.1	..	..	0.1	..	..
11	0.1	..	..	0.1	..	11.5	32.6	8.6	..	..	..	0.2	..	..
12	0.6	..	..	..	..	14.6	37.3	4.0	..	..	..	0.1	..	..
13	1.6	..	..	..	..	19.7	40.2	1.6	..	..	..	..	..	..
14	..	..	..	..	..	20.2	45.5	4.9	..	..	0.8	..	..	..
15	..	..	..	..	..	12.3	60.4	6.3	..	..	8.5	1.0	..	..
16	0.1	2.2	..	..	0.1	7.9	68.3	2.8	..	..	8.1	0.7	..	..
17	..	3.9	..	0.1	0.3	8.6	48.9	1.1	..	..	4.3	0.1	..	..
18	1.5	1.9	..	..	..	9.9	29.3	0.4	..	..	5.7	..	1.5	..
19	0.2	5.1	..	..	0.1	4.9	44.3	0.9	..	..	3.0	0.1	..	..

	Pulmonata								Sphaeriidae				
	SO	**GG**	**DO**	**EF**	**VO**	**RR**	**RI**	**ZN**	**SL**	**SN**	**SS**	**PC**	**PA**
1	0.2	1.5	0.2	0.2	0.9	0.2	..	..	..	..	...	2.7	39.2
2	0.2	0.7	..	0.1	..	0.4	0.1	0.1	..	..	..	10.0	22.2
3	0.1	0.1	0.2	0.1	..	0.2	..	..	..	..	..	1.6	27.7
4	..	0.1	..	..	..	0.1	..	..	..	..	..	0.9	28.0
5	..	0.1	..	..	..	..	..	..	0.3	..	..	1.6	25.6
6	..	..	..	..	..	..	..	..	0.3	..	..	1.1	25.0
7	..	..	..	..	..	..	..	..	0.1	..	..	2.1	35.7
8	..	..	..	..	..	..	..	..	0.5	..	..	1.6	44.8
9	..	..	..	..	..	..	..	..	0.3	..	..	3.2	34.3
10	..	..	..	..	..	..	..	..	1.3	..	..	4.7	30.6
11	..	..	..	..	..	..	..	..	2.5	..	..	5.0	39.4
12	..	..	..	..	..	..	..	..	1.5	..	..	7.4	34.5
13	..	..	..	..	..	..	..	..	1.8	..	..	8.3	26.9
14	..	..	..	..	..	..	0.4	..	0.4	..	..	5.7	22.1
15	..	..	..	..	..	..	..	..	0.5	..	..	1.3	4.3
16	..	..	..	..	..	..	..	..	..	..	0.7	0.6	8.3
17	..	..	..	..	..	..	..	..	9.6	..	22.2	0.4	0.8
18	..	0.1	...	..	..	..	..	..	23.2	..	27.8	2.1	2.4
19	..	..	..	..	..	..	..	..	16.1	..	25.4	0.3	0.4

* Figures are the percentages for a given species of the total number of specimens in a given sample.

TABLE 3. VERTICAL DISTRIBUTION OF SPECIES IN SECTION GG, RICHARDSON LAKE MARL DEPOSIT*

SAMPLE	Ctenobranchiata VT	VL	AL	LS	SP	Pulmonata FO	GP	HS	HC	AC	PE	PG	FP	SG
1	30.8	..	0.2	..	..	12.2	27.7	9.2	0/1	..	0.2	0.6	0.6	..
2	23.7	..	..	..	..	14.3	22.8	7.9	..	..	..	0.1	..	..
3	28.7	..	0.2	..	..	10.4	21.0	9.0	0.1	..	..	0.3	..	..
4	20.6	..	0.1	..	..	8.4	15.6	9.7	0.1	..	0.1	1.5	..	0.1
5	9.5	0.1	0.7	..	..	9.5	19.4	13.6	0.4	..	..	2.5	..	..
6	1.0	0.1	..	..	..	7.8	34.4	21.9	0.2	..	..	4.5	..	..
7	..	..	..	..	0.1	9.0	49.7	15.9	0.6	..	..	3.6	..	..
8	0.5	..	..	..	..	5.7	57.2	9.0	0.6	..	..	9.9	..	..
9	1.6	..	..	..	..	13.7	44.6	1.0	0.5	..	..	4.3	..	..
10	0.5	..	..	..	..	15.4	58.1	3.3	0.9	..	..	12.1	..	..
11	0.2	..	..	..	..	14.4	71.7	0.5	0.6	..	0.2	9.3	..	..
12	0.1	..	0.1	..	0.1	12.1	70.9	1.4	1.9	..	1.0	9.3	..	..
13	..	..	0.1	..	..	9.1	66.7	3.8	2.0	..	2.5	11.4	..	..
14	..	0.2	..	..	0.2	9.0	62.1	10.9	1.6	..	2.7	8.9	0.2	..
15	..	0.1	..	..	0.2	11.9	57.6	15.7	1.9	..	1.9	6.8	0.2	0.1
16	..	0.5	..	0.2	0.2	8.0	60.4	14.8	0.9	0.1	2.7	8.4	0.4	..
17	0.1	1.3	..	..	0.1	7.2	66.2	11.1	1.3	..	1.6	5.1	0.2	0.1
18	0.2	1.0	..	..	..	4.6	74.8	6.0	0.9	..	1.5	2.6	0.2	..

	Pulmonata SO	GG	DO	EF	VO	RR	RI	ZN	Sphaeriidae SL	SN	SS	PC	PA
1	..	..	..	..	..	..	..	..	0.4	..	..	1.5	16.5
2	..	..	..	..	..	..	..	..	0.4	0.1	..	1.5	29.2
3	..	..	..	..	..	..	..	..	0.2	..	..	1.8	28.8
4	..	..	..	..	..	..	..	..	0.5	0.4	..	1.3	41.6
5	..	..	..	..	..	..	..	..	11.3	1.7	..	7.2	23.7
6	..	..	..	..	..	..	..	..	4.7	1.0	..	3.9	28.6
7	..	..	..	..	..	..	..	..	2.6	0.3	0.2	1.7	16.9
8	..	..	..	..	..	..	..	..	5.6	0.5	0.2	1.1	9.7
9	..	..	..	..	..	..	..	..	2.3	..	..	4.2	20.4
10	..	..	..	..	..	..	..	..	6.4	..	..	2.1	1.2
11	..	..	..	..	..	..	..	..	1.6	0.5	..	0.6	0.1
12	..	..	..	..	..	..	..	..	2.1	0.3	0.1	0.6	..
13	..	..	..	..	..	..	..	..	3.5	0.3	0.1	0.5	..
14	..	..	..	..	..	..	..	..	3.9	..	0.1	0.2	..
15	..	..	..	..	..	..	..	..	2.8	0.2	0.2	0.4	..
16	..	..	..	..	..	..	..	..	2.6	0.2	0.2	0.4	..
17	..	..	..	..	..	..	..	..	4.4	..	0.6	0.1	0.6
18	..	..	..	..	..	..	..	..	6.2	0.2	1.3	..	0.5

* Figures are the percentages for a given species of the total number of specimens in a given sample.

6	Sand, medium to dark gray, medium- to coarse-grained, pebbles and cobbles relatively common; complex suite of minerals; about 60 percent quartz grains; sand extends a minimum of 72 inches below clay. Sample G-19	2.0
	Total	38.0

Stratigraphic Section GG of the Richardson Lake Deposit (Figure 3)

Measured Units		Thickness (inches)
1	Topsoil, dark grayish brown to black near surface; very sandy, medium- to fine-grained; few pea-sized pebbles; lower contact irregular, sharp; no mollusks.	8.5
2	Sand, medium gray to brown; fine-grained; lower contact sharp; irregular; no mollusks.	1.0
3	Sand, light grayish brown; fine- to medium-grained; no mollusks.	3.5
4	Sand, dark grayish brown with considerable clay and silt content; medium- to fine-grained; lower contact highly irregular, sharp; no mollusks.	4.0
5	Marl, white to light tan; roots prominent, especially at 12 and 19 inches below upper contact; at 20 and 25 inches are 1/8 inch bands of dark rusty-brown muddy silt; upper portion contains abundant plant debris, decreasing downward, extraneous limestone pebbles; mollusk abundance varies through interval. Samples GG-1 through ~~GG~~-15.	16.0
6	Clay, black, very slightly silty; pelecypods most noticeable. Sample GG-16 (part).	1.0
7	Clay, medium to light gray, much plant material; bottom two inches grades downward into gray sand similar to that in Section G; mollusks common. Samples GG-16 (part), GG-17, GG-18.	6.0
8	Sand, medium gray, coarse- to medium-grained; pebbles and cobbles common; complex mineral suite; extends more than 60 inches downward; no mollusks in portion sampled.	
	Total	53.0

The fact that many of the species recovered are represented in nearly every sample in one or both sections indicates that either the lacustrine environment was relatively stable throughout the duration of marl deposition or that these same species had wide ranges of tolerance and were adaptable to many environments. Conversely, other forms are present in only certain portions of a section or sections, which points to their being more specialized or approaching the limits of their environment. The composite picture suggests decreasing water depth, climatic warming, relatively small changes in the amount of vegetation except near the base of the sections, and decreasing mollusk diversity with time. Since neither of the two sections sampled represents a complete infilling sequence of a marl lake, limited diversity or limited speciation may be expected as the environmental changes preserved are limited by the duration of sedimentation.

Species occurring throughout the two sections in some abundance are *Fossaria obrussa decampi*, *Gyraulus parvus*, *Helisoma anceps striatum*, and *Pisidium casertanum*. The continuous presence of these species in the sections of this deposit and in deposits studied by Clowers (1966) and Roy (1964) suggests an adaptability to variations in the environment. These species are apparently part of the pioneer community and are present in the uppermost samples in Colton Lake which Clowers (1966) states probably had a considerably different environment from that represented in the bottom of his section. Changes in their percentages mark points of disappearance of other species, as in the lower third of each section, or anomalies in the environment which are not readily observable in the sediments as in the upper portion of Section G (Tables 1 and 2).

In a discussion of Section G, the stratigraphic interval may be divided into two units on the basis of both faunal and lithologic characters, again disregarding the Recent terrestrial gastropods recovered near the top of the section. Unit 1 contains samples G-1 through G-15 and Unit 2 contains samples G-16 through G-19. This division based on lithology and diversity of species is easily recognizable, although slight changes in the environment throughout Unit 1 may be noted by fluctuation of the percentages of the species (Table 2). In Unit 2, with the exception of *Gyraulus parvus*, the long ranging species *Fossaria obrussa decampi*, *Helisoma anceps striatum*, *Pisidium casertanum*, and *Pisidium compressum* are not as abundant as compared to their occurrences in Unit 1 (Figs. 7, 8, 11, 12). *Gyraulus parvus* may be less dependent on substrate conditions than are the other species because it has been found living on submerged aquatic vegetation. Four other species, *Valvata lewisi*, *Stagnicola* sp., *Promenetus exacuous*, and *Sphaerium sulcatum* are generally present only in Unit 2 and occur in small percentages. *Valvata lewisi* is commonly recovered from sandy substrates as is *Sphaerium sulcatum*, whereas *Promenetus exacuous* is an indicator of cold or deep waters. From this, one can surmise that the water level stood at perhaps the 15-foot terrace, giving a depth of about 12 feet over Section G, that the substrate was firm, and that the water was much cooler than at present, and quiet. The sudden change in percentages and the disappearance of species at the unit boundary (Samples G-16, G-15) indicates sudden alteration of conditions such as an abrupt lowering of the water level. Since this area was somewhat protected by the divide from the wind and waves acting on the deeper lake, the environments near Section G were influenced more by solar radiation and water depth than were the environments at section GG. Unit 1 represents a time of relatively stable environmental conditions, with some minor fluctuations as suggested by the abrupt numerical and size increase of *Valvata tricarinata* at the horizon of Samples G-8 and G-9 and the decline of *Fossaria obrussa decampi* and *Pisidium compressum*. If, as Whittaker (1922, p. 150) suggests, marl being deposited today shows 50 percent shrinkage on drying, the substrate may not have been firm enough to support benthonic forms such as *Pisidium compressum* and *Fossaria obrussa decampi*. On the other hand, *V. tricarinata* was either capable of living on soft bottoms or inhabited the aquatic vegetation above the bottom. Above the level of Sample 9, *V. tricarinata* becomes one of the dominant species of the assemblage from Unit 1. *Helisoma campanulatum*, from the division based on the fauna and the lithology, was one of the interlopers into the area of collection, appearing in the middle of Unit 1 as a few adult specimens. This species has been recovered mainly from firm substrate and from vegetation growing on soft bottoms. In this case the species probably lived on vegetation growing on the soft marl substrate which suggests some slight increase in the quantity of vegetstion during the interval represented by samples G-6 through G-10. With only adult specimens present it may be assumed that they migrated from some nearby area. Samples G-1, G-2, and G-3 represent the last deposition of marl while the lake level stood between the 8-foot and the 4.5-foot terraces, most probably nearer the latter. During the deposition of the above mentioned samples there was an overall decrease in the size and number of individuals. *Valvata tricarinata*, *Fossaria obrussa decampi*, *Gyraulus parvus*, and *Helisoma anceps striatum* decreased in relative abundance whereas the pelecypods increased slightly in numbers. Throughout the section the respective species appear to develop only to a certain maximum size, but the proportion of small or perhaps dwarfed forms to large individuals varies through the section. In Unit 2 most specimens are small with only a few large forms, whereas in Unit 1 the vast majority of specimens are large. In samples G-4, G-5, and G-6 the sizes are somewhat greater than those from the remainder of the section, lacking dwarfed forms entirely. Some additional data on the pH and fixed carbon dioxide ratio of the water may help to explain some of the variations in the assemblage. Morrison (1932, p. 371) states that *Fossaria obrussa decampi* can exist only within the pH limits of 7.42 and 7.7. In the discussion of Systematic Paleontology it was noted that *Sphaerium lacustre* has been recovered from water with a pH of between 6.4 and 7.46 and a fixed carbon dioxide ratio of between 9.3 and 18.87 ppm.; *Pisidium compressum* from water with a pH of between 7.0 and 8.73 and a fixed carbon dioxide ratio of between 9.3 and 30.56 ppm. Applying these data to figures 4-16 one can see that the environments of the lake bottom changed from acidic near the base of the section to alkaline, then back to acidic near the top of the section. The question arises as to the effect of temperature, fixed carbon dioxide limits of the various organisms.

Section GG may be divided on the basis of lithology and fauna into 3 units, but not as definitively as Section G. Unit 1 is made up of samples GG-1 through GG-12, Unit 2 is made up of samples GG-13 through GG-16, and Unit 3 includes samples GG-17 and GG-18. This section was measured and collected on the northwest or windward shore (Fig. 3) of Richardson Lake where the wide expanse of water and the wind had greater influence than in the area of Section G. Here the long-ranging forms include *Fossaria obrussa decampi, Gyraulus parvus, Helisoma anceps striatum, Physa gyrina, Sphaerium lacustre, Pisidium compressum,* and *Pisidium casertanum,* which for the most part show little variation in numbers of individuals with lithologic changes. Starting with Unit 3, which is separated mainly on lithologic variation, no faunal change is noted between it and Unit 2. *Gyraulus parvus* comprises 65 to 75 percent of the assemblage of Unit 3, the remainder being made up of 15 other species. Apparently this is the preferred habitat of *G. parvus,* amongst the vegetation, in at least cool waters, and on firm sandy substrates, or the environment may have been approaching the tolerance limits of the other species, and consequently they are not abundant. The next unit (Unit 2) is delineated on the basis of the fossil and vegetation content of the section as well as lithology. It is to be noted that several species occur in Units 2 and 3, but not in Unit 1; *Valvata lewisi, Stagnicola* sp., *Promenetus exacuous, Ferrissia parallela,* and *Sphaerium sulcatum.* This portion of the section contains much more silt, non-carbonate clay, and carbonaceous matter than does a similar interval in Section G and grades more gradually upward into marl. This fact became apparent during laboratory work. As in Section G, these species suggest water much cooler than at present, perhaps with considerable depth, firm sandy bottoms, and abundant vegetation. Unit 1 is similar to Unit 1 in Section G in that *Gyraulus parvus* decreases upward and *Valvata tricarinata* becomes a dominant form in the upper portions of the interval. *Pisidium casertanum* also becomes less plentiful upward which is consistent with the lowering of the water level and the increase in temperature. Being adjacent to deeper water subject to wind and wave action tended to counteract variations in response to shallower water by bringing up colder water from the depths. *Promenetus exacuous* appears in both sections, but even though it is more abundant in Section G, it extends higher in Section GG. As this species is indicative of cold, quiet wwters (Baker, 1928, pp. 362, 363), its prominence in section G may be due to quieter waters, whereas the longer vertical extent in Section GG may be in response to upwelling of colder waters from the depths of the lake. From Tables 2 and 3 one may surmise that the form *Helisoma anceps striatum* is able to withstand slightly warmer environments than *P. exacuous,* but not as warm as present, as no living representatives were recovered from the lake. *Sphaerium nitidum,* another cold or deep water species, occurs only in Section GG, perhaps indicating a more restricted upper temperature limit than the form *striatum,* but not as pronounced as *P. exacuous* or *Valvata lewisi* which have similar occurrences. *V. tricarinata* apparently is ill-equipped to live well in water as deep or as cold as that required by *Helisoma anceps striatum,* but neither is found in the lake at present. It is apparent that the environmental limits of various organisms overlap, but these organisms are not necessarily in direct competition. They inhabit different ecological niches, living on different areas of the bottom and feeding from different sources.

The Richardson Lake marl deposit thus followed a course of accumulation not unlike the development of other deposits. In this case the changes in the fossil assemblage with time can be correlated with terraces around the slopes above the present lake level and these same terraces may be employed to clarify the truncated sections. The lake water was cold and deep over the areas of collection during the early part of the development of the marl. This is shown by cold or deep water mollusks appearing in the basal units of the sections; Unit 2 of Section G and Units 2 and 3 in Section GG. These dominantly benthonic forms and burrowers requiring firm but not solid substrate include *Promenetus exacuous, Sphaerium sulcatum, Sphaerium nitidum* (only in Section GG), and *Valvata lewisi. Ferrissia parallela,* although occurring with this group in Section GG, is not known to be a deep or cold water species. It generally lives on submerged vegetation near the surface and was probably rafted into this area on floating vegetation and lodged against the headlands and divide. During this interval the water level probably stood at the 15-foot terrace which is the highest recognizable shoreline feature noted. Sample

15 of Section G and Samples 11 and 12 of Section GG mark an abrupt change in the lake environment at the collecting localities. This change is more readily noted in Section G than in Section GG. Section GG, being closer to the deeper portions of the lake, shows less drastic faunal changes due to the neutralizing effect of cold bottom water on surface warming and decreasing water depth. Above samples G-15, GG-11, and GG-12 the interval is designated as Unit 1 in both sections. This interval represents the time of marl deposition during which the water level dropped from the 15-foot terrace to the 4.5-foot terrace and finally the area was drained. During the time represented in this interval the water temperature increased as the depth decreased and an optimum level or temperature was reached where there was a proliferation of individuals of large size. This is represented by Samples G-4, G-5, and G-6 of Section G and Samples GG-1, GG-2, and GG-3 of Section GG. The author believes that the water level stood at the 8-foot terrace during this time. This terrace is not as distinct as the others so it may have been a temporary strand as compared to the duration of the water level marked by the other terraces. Nevertheless the species present in this interval are long ranging types of larger than usual relative sizes. Samples G-1, G-2, and G-3 of Section G represent the time of lowest lake level during the deposition of marl in the deposit. During this interval the water level receded to the 4.5-foot terrace whose elevation indicates that the divide would have been either above water or slightly awash and the area around Section G relegated to a semi-isolated lagoon (Fig. 3, insert). The water in the isolated area probably became somewhat stagnant at this level, causing a decrease in abundance of large individuals belonging predominantly to lake types. At the same time *Pisidium compressum* and *Pisidium casertanum* showed good numerical increases, which is consistent as these forms are common in just such situations today.

Further lowering of the water level in the Ottawa-St. Lawrence Valley resulted in downcutting on the outlet of Richardson Lake and draining of the lake from the 4.5-foot terrace level to its present level. The divide was breached at this time and the area round Section G was drained, bringing marl deposition to a halt. A portion of the marl to the east of the divide (Fig. 3) was eroded at this stage by the drainage from the small lake, probably combined with wave action. The results are a sharp highly irregular contact between whitish gray marl and coarse roughly-bedded sand. A dark band of sand within the coarser material can be traced by auger holes to the 16-inch terrace. After the drainage of the area around Section G, terrestrial vegetation invaded the new surface. Mosses and other moisture-loving plants were followed by grasses and soil horizons were developed. Some time after drainage of the area terrestrial gastropods migrated into the newly accessible habitat and their remains occur only in the topmost samples in the soil zone. The condition of the shells shows that these terrestrial species are not more than a few years old.

Correlation of similar environments between these two pits is probably correlation in its strictest sense, as time. Units 2 and 3 in Section GG are equivalent to Unit 2 in Section G. Unit 1 in Section GG is not complete when compared with Unit 1 of Section G, as the equivalent to the top three samples of Section G has been eroded away in Section GG.

AGE AND CORRELATION

At present there is no practical method of pin-pointing the age of marl deposits such as this. Radiocarbon dates give the best results, but are too expensive to be included in this study. None of the mollusks is considered a good guide fossil for subdividing Late Pleistocene time, and pollen studies were not undertaken. Thus the age of the deposit can only be determined in relation to events within the history of the region.

The marl in the Richardson Lake deposit is separated from the underlying sand by a few inches of dark gray mud which is completely gradational between the gray sand below and the whitish-tan marl above. Below the marl and mud, the sand grades from gray into brown and tan downward. These are the same colors observed below the soil in the surrounding hills. There apparently was no break in sedimentation between the time the waters of the Champlain Sea retreated and the beginning of the early stages of Richardson Lake, as the vertical gradation from brown, tan, and gray sand to mud and marl shows no significant interruption. The last remnants of the Champlain

Sea were of relatively fresh water, probably due to the newly opened North Bay-Mattawa and Fossmill outlets draining the ancestral Great Lakes. This also provided a migration route by which the fresh-water mollusks invaded the region so quickly after a marine inundation. With the continued lowering of the water in the Ottawa-St. Lawrence Lowland, the area around Richardson Lake became dry land with only the low places holding water and developing their own small drainage systems. That this deposit is not Recent is seen in the well developed soil zone in Section G and the considerable thickness of sand with a soil zone comparable to that in Section G lying unconformably over the marl in Section GG. Whittaker (1922, p. 150) sampled present day marl and found that it exhibited about 50 percent shrinkage when dried. The marl in this deposit demonstrated very little shrinkage when dried.

The unconsolidated sand and gravel surrounding the deposit for a distance of several miles was mapped by Sabourin (1965) and designated as Pleistocene-Recent undifferentiated. De Geer (1892) and many later workers have considered this area to be part of a more or less continuous series of abandoned beaches and shallow sea bottom deposits attributed to the Champlain Sea. The sea invaded the Ottawa-St. Lawrence Valley following the retreating Wisconsin ice sheet and extended at least as far upriver as the Chalk River Area (Gadd, 1963B, Legend). Since the region had just been glaciated the bedrock was covered with a substantial thickness of glacial deposits (Chapman and Putnam, 1949). This glacial debris provided the material reworked into the now elevated marine, shore, and near-shore features by the Champlain Sea.

Karrow (1961, p. 101) places the marine inundation of the Ottawa Valley region at 11,000 to 12,000 C-14 years B. P. This inundation is in part contemporaneous with the Two Creeks interstadial of the Wisconsin glaciation (Terasmae, 1959, p. 334). Terasmae (1965, p. 38) also indicates that the conclusion of the inundation was some 9,000 to 9,500 C-14 years B. P. and that the St. Lawrence drainage probably occupied its present configuration some 7,000 to 8,000 C-14 years B.P.

The Richardson Lake marl deposit can be dated as post-Champlain Sea and post-Two Creeks in this area. If a correlation could be drawn between the occurrence of pollen zones and the mollusk assemblage, the time of marl deposition may have corresponded with what Terasmae (1959, p. 335, fig. 1) calls Zones IV, V, and VI, which ended approximately 7 500 C-14 years B. P. and are said to represent cold climate following the marine inundation.

Strict correlation of deposits such as this is nearly impossible as they are commonly isolated from each other and exact radiocarbon dates are generally unavailable. Roy (1964, pp. 144-147) concluded that the marl sites which he studied in Wisconsin may have been contemporaneous, at least in part, and that those deposits rest on Cary and Valders outwash. The Cary and Valders glaciations bracket Two Creeks time so the Champlain Sea episode was probably partially coincident with Cary glaciation. The Richardson Lake deposit may then be equivalent with those which Roy described as overlying Valders outwash. Clowers (1966, p. 56) sets similar time limits for the Box Marsh deposit; post-Champlain Sea (9,500 C-14 years B.P.) to about 7,000 C-14 years B.P., or until the termination of the cold period following the marine inundation described by Terasmae on the basis of pollen. Comparison of graphic plots of *Physa gyrina*, *Valvata tricarinata*, and *Gyraulus parvus* with those of Clowers (1966, p. 51) shows that the environmental succession in Richardson Lake was similar to that recorded in the middle third of the Box Marsh section. This similarity should not be construed as meaning a strict correlation of the two deposits.

CONCLUSIONS

The molluscan assemblage recovered from the Richardson Lake marl deposit contains 27 species of which 9 are Recent terrestrial forms not belonging to the Pleistocene communities which inhabited the lake. The fresh-water molluscan remains are not uniformly distributed throughout the sections sampled, which is a measure of the migration of benthonic environments in response to variations in water level and temperature. The decreasing water level with time was probably associated with the waning remnants of the Champlain Sea or isostatic uplift of the land. The climatic changes were in response to the influence of the Late Wisconsin ice as well as the climate-moderating effect of the Champlain Sea.

Mollusca occur in the lowest samples of both sections. Below this the sand contains very small percentages of silt and clay sized particles, no plant remains, and no mollusks. Aquatic mollusks were then present, in both sections, during the time carbonate sediments were being deposited. The water was initially 12 to 15 feet deep in the areas of the sampled sections, and with the lowering of the water level in the Ottawa-St. Lawrence Valley, was lowered in stages as shown by the high terraces on slopes adjacent to the present lake. The shallowest water during marl deposition was 2 to 3 feet over Section G. At this depth, circulation with the larger lake was negligible and the aquatic environment was probably stagnant, at least near the bottom. The ecology of the Sphaeriid clams suggests a fixed carbon dioxide ratio of between 10 and 20 ppm. The quantity of submerged, rooted aquatic vegetation was not great, that is, not dense enough to impede water circulation completely. However, the quantity of vegetation remained relatively constant throughout the duration of sedimentation with some increased growth as suggested by the appearance of *Helisoma campanulatum* in the middle of Section G.

The climate was much cooler than at present as shown by the cool water forms *Helisoma anceps striatum* and *Pisidium nitidum*, but warmed somewhat toward the end of the interval represented by the marl section. The presence of *Promenetus exacucus* in the basal portions of each section suggests a cold period during the early part of the lake development. As the climate warmed, this species disappeared and other members of the assemblage preferring cool waters prospered. With continued climatic warming even the cool water elements demonstrate decreased populations and at present the prominent Pleistocene forms are conspicuously absent from Richardson Lake. Occupying similar ecological niches in the present lake are species recovered from Pleistocene deposits farther south which were contemporaneous with that of Richardson Lake.

The time of marl deposition is thus post-Champlain Sea, post-Two Creeks and may be equated with cold climate pollen zones IV, V, and VI (Terasmae, 1959, p. 335; 1960, p. 18) which have been given C-14 age ranges of about 9,000 C-14 years B.P. to 7,500 C-14 years B.P.

The geographic distributions of species recovered from this deposit as well as those belonging to species absent here, but collected from similar deposits, suggest bands or zones of molluscan life which more or less follow the climatic isothermal lines. Therefore, with the advance and retreat of the continental ice sheets, the zones of life that are dependent on temperature fluctuate or are compressed and expanded in a roughly north-south direction. The marl section in Richardson Lake records a relatively short period of time and this migration pattern is not well developed or well demonstrated in the deposit. The mollusk assemblage recovered does however represent the pioneer community in the lake, living representatives of which species are today found in aqueous environments farther north. Species of the contemporary mollusk fauna of Richardson Lake would then be expected to be recovered from Pleistocene or post-Pleistocene deposits farther south and indeed they are.

Thus by systematically following the northward or southward advance of fresh-water mollusks through a sufficiently long period of time, a series of Pleistocene and post-Pleistocene isothermal lines could be constructed on a map, revealing the extent of the temperature influence and something of the repopulation potential of the mollusks in deglaciated areas. Likewise, the amount of compression and expansion of these life zones in time may be determined.

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MANUSCRIPT RECEIVED AND ACCEPTED FOR PUBLICATION, JANUARY, 1967.

RECENT PUBLICATIONS

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New publications have been listed or reviewed in various past numbers of STERKIANA (2:12, 4:28, 12:8, 14:44, and 21:2); however, these did not appear as regular features. We now intend to make this section a regular part of the series, if not a part of each number. Papers appearing in journals and series, such as *Nautilus, Malacologia, Proceedings of the American Malacological Union, Veliger, Basteria,* etc., that would normally come to the attention of workers in non-marine mollusks will often be omitted. Instead, papers from sources that might normally escape casual inspection by malacologists will be stressed. The listings will in no way be complete surveys of new literature but only selected items noted by people working with mollusks at the Ohio State University and the Ohio State Museum. Annotations will be a brief description of illustrations or of the topic, if this is not evident in the title.

We hope this addition will be of some help and interest to our readers.

AGUAYO, C.G. (1965) Sobre el Status de *Veronicella portoricensis* (Mollusca Pulmonata). -- Caribbean J. Sci., 5(1-2): 25-28, 2 figs. The land slug *V. portoricensis* is removed from synonymy and considered a good species.

AGUAYO, C.G. (1966) Una Lista de los Moluscos terrestres y fluviales de Puerto Rico. -- Stahlia (Misc. Publ. Mus. Biol. Univ. Puerto Rico) 5: 1-16.

van BENTHEM JUTTING, W.S.S. (1965) Non-marine Mollusca of West New Guinea Part 4, Pulmonata, 2. -- Nova Guinea, Zool., 32: 205-304, 10 figs., map. (Map of localities; 8 new species and 4 new subspecies).

BURCH, J. B. and NATARAJAN, R. (1965) Cytological studies of Taiwan freshwater pulmonate snails. -- Bull. Inst. Zool. Acad. Sinica, 4: 11-17, 2 figs. (Line drawings of shells and chromosomes).

BURCH, J. B. and PATTERSON, C.M. (1966) Key to the genera of land gastropods (snails and slugs) of Michigan. -- Mus. Zool. Univ. Mich., Circ. 5: 1-19, 46 figs. (Line drawings; illustrated section on terminology).

DANCE, S. P. (1966) Shell collecting an illustrated history. -- Univ. Calif. Press, Berkeley, 344 p., 35 pls., 31 text figs. $10.00. Includes proportionate amounts of information about non-marine collections; a guide to present locations of famous scientific collections; portraits of famous conchologists.

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land snails from Bermuda: the influence of size upon shape.--Jour. Paleont., 40(5): 1131-1141.

HABE, T. and BURCH, J. B. (1965) A new species of freshwater limpet, genus *Ferrissia*, from Japan. -- Venus: Jap. J. Malacol. 24(1): 1-7, 19 figs. *(Ferrissia japonica*, p. 2, figs. 1-8).

HARRY, H. W. (1966) Land snails of Ulithi Atoll, Caroline Islands: a study of snails accidentally distributed by man. --Pacific Sci., 20(2): 212-223, 16 figs. (Line drawings of shells).

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SOLEM, A, (1964) A collection of non-marine mollusks from Sabsh, Malaysia. -- Sabsh Soc. Jour. 2(1-2): 1-40, 5 figs. (New species: *Arinia inexpectans*, p. 16, fig. II, 15; *Opisthostoma haili*, p. 18, fig. III, 19).

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TUTHILL, S. J., LAIRD, W.M., and FRYE, C.I. (1964) Fossil molluscan fauna from the upper terrace of the Cannonball River, Grant County, North Dakota. -- Proc. North Dakota Acad. Sci., 18: 140-156, 5 figs. (Includes a list of Mollusca and discussion of paleoecology).

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TUTHILL, S.J., LAIRD, W.M., and KRESL, R.J. (1964) Fossiliferous marl beneath Lower Campbell (glacial Lake Agassiz) Beach sediments.-- Proc. North Dakota Acad. Sci., 18: 135-140, 3 figs. (List of Mollusca and brief discussion of paleoecology).

NOTE

THE THREE UNNUMBERED PAGES FOLLOWING THIS ONE MAY BE INSERTED IN STERKIANA 24, AFTER PAGE 28. THESE ARE THE FIGURES (1-231) ACCOMPANYING THE REPRINT OF BINNEY (1865) 'LAND AND FRESH-WATER SHELLS OF NORTH AMERICA, PART III' WHICH WAS COMPLETED IN STERKIANA 24, DECEMBER 1966.

A.L.

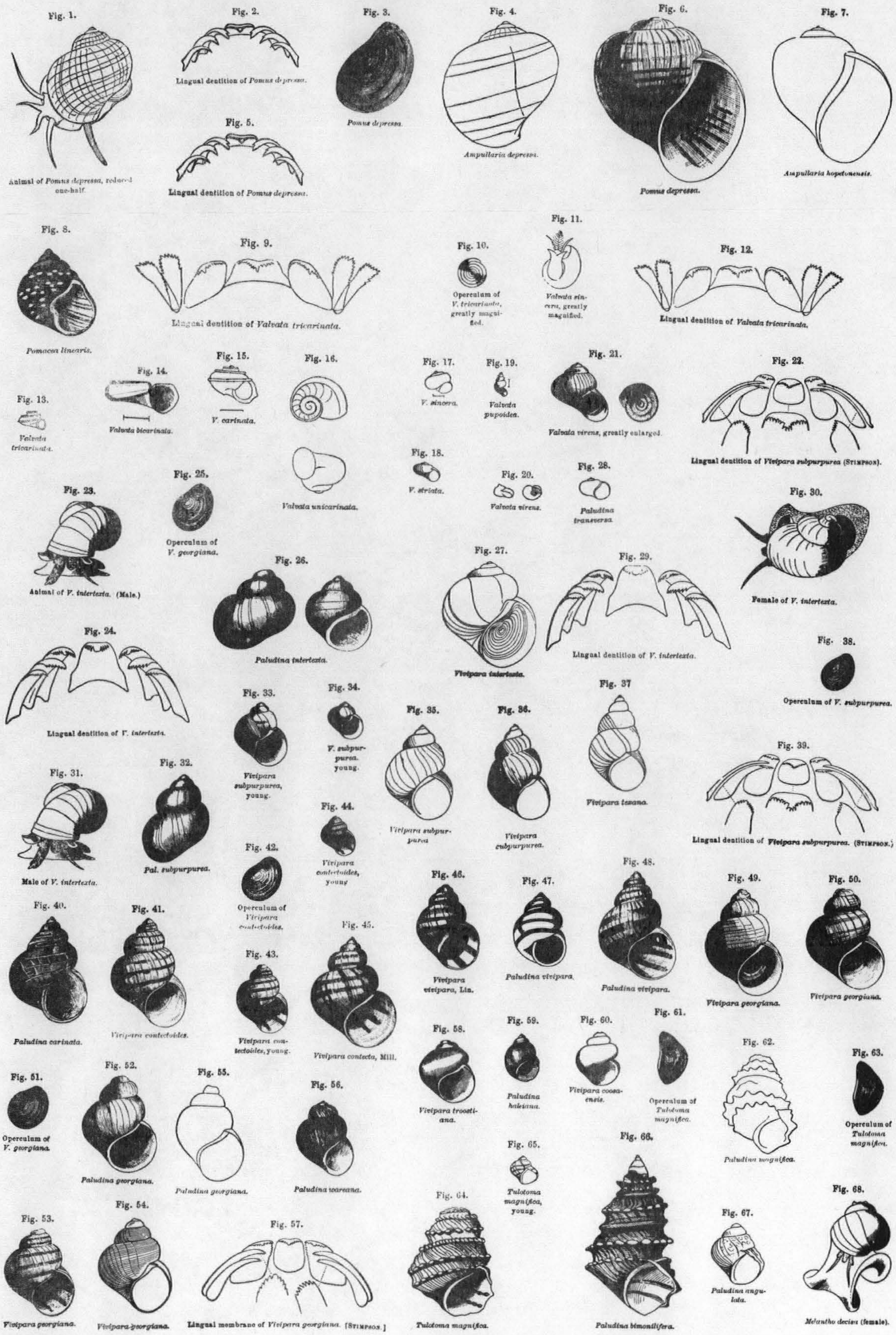

Fig. 1. Animal of *Pomus depressa*, reduced one-half.

Fig. 2. Lingual dentition of *Pomus depressa*.

Fig. 3. *Pomus depressa*.

Fig. 4. *Ampullaria depressa*.

Fig. 5. Lingual dentition of *Pomus depressa*.

Fig. 6. *Pomus depressa*.

Fig. 7. *Ampullaria hopetonensis*.

Fig. 8. *Pomacea linearis*.

Fig. 9. Lingual dentition of *Valvata tricarinata*.

Fig. 10. Operculum of *V. tricarinata*, greatly magnified.

Fig. 11. *Valvata sincera*, greatly magnified.

Fig. 12. Lingual dentition of *Valvata tricarinata*.

Fig. 13. *Valvata tricarinata*.

Fig. 14. *Valvata bicarinata*.

Fig. 15. *V. carinata*.

Fig. 16. *Valvata unicarinata*.

Fig. 17. *V. sincera*.

Fig. 18. *V. striata*.

Fig. 19. *Valvata pupoidea*.

Fig. 20. *Valvata virens*.

Fig. 21. *Valvata virens*, greatly enlarged.

Fig. 22. Lingual dentition of *Vivipara subpurpurea* (Stimpson).

Fig. 23. Animal of *V. intertexta*. (Male.)

Fig. 24. Lingual dentition of *V. intertexta*.

Fig. 25. Operculum of *V. georgiana*.

Fig. 26. *Paludina intertexta*.

Fig. 27. *Vivipara intertexta*.

Fig. 28. *Paludina transversa*.

Fig. 29. Lingual dentition of *V. intertexta*.

Fig. 30. Female of *V. intertexta*.

Fig. 31. Male of *V. intertexta*.

Fig. 32. *Pal. subpurpurea*.

Fig. 33. *Vivipara subpurpurea*, young.

Fig. 34. *V. subpurpurea*, young.

Fig. 35. *Vivipara subpurpurea*.

Fig. 36. *Vivipara subpurpurea*.

Fig. 37. *Vivipara texana*.

Fig. 38. Operculum of *V. subpurpurea*.

Fig. 39. Lingual dentition of *Vivipara subpurpurea*. (Stimpson.)

Fig. 40. *Paludina carinata*.

Fig. 41. *Vivipara contectoides*.

Fig. 42. Operculum of *Vivipara contectoides*.

Fig. 43. *Vivipara contectoides*, young.

Fig. 44. *Vivipara contectoides*, young.

Fig. 45. *Vivipara contecta*, Mill.

Fig. 46. *Vivipara vivipara*, Lin.

Fig. 47. *Paludina vivipara*.

Fig. 48. *Paludina vivipara*.

Fig. 49. *Vivipara georgiana*.

Fig. 50. *Vivipara georgiana*.

Fig. 51. Operculum of *V. georgiana*.

Fig. 52. *Paludina georgiana*.

Fig. 53. *Vivipara georgiana*.

Fig. 54. *Vivipara georgiana*.

Fig. 55. *Paludina georgiana*.

Fig. 56. *Paludina wareana*.

Fig. 57. Lingual membrane of *Vivipara georgiana*. [Stimpson.]

Fig. 58. *Vivipara troostiana*.

Fig. 59. *Paludina haleiana*.

Fig. 60. *Vivipara coosaensis*.

Fig. 61. Operculum of *Tulotoma magnifica*.

Fig. 62. *Paludina magnifica*.

Fig. 63. Operculum of *Tulotoma magnifica*.

Fig. 64. *Tulotoma magnifica*.

Fig. 65. *Tulotoma magnifica*, young.

Fig. 66. *Paludina bimonilifera*.

Fig. 67. *Paludina angulata*.

Fig. 68. *Melantho decisa* (female).

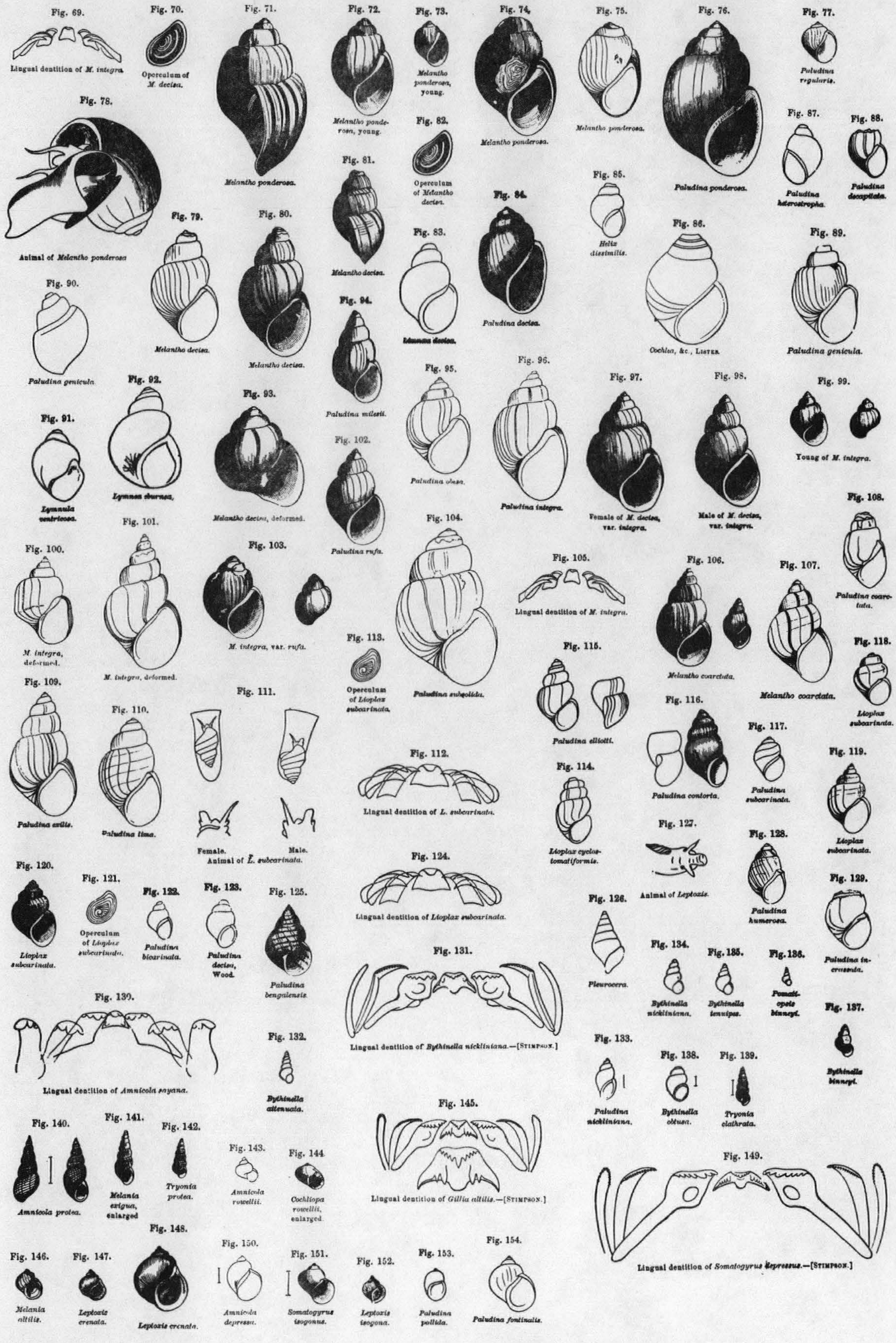
Fig. 69.
Lingual dentition of M. integra.
Fig. 70.
Operculum of M. decisa.
Fig. 71.
Melantho ponderosa.
Fig. 72.
Melantho ponderosa, young.
Fig. 73.
Melantho ponderosa, young.
Fig. 74.
Melantho ponderosa.
Fig. 75.
Melantho ponderosa.
Fig. 76.
Paludina ponderosa.
Fig. 77.
Paludina regularis.
Fig. 78.
Animal of Melantho ponderosa
Fig. 79.
Melantho decisa.
Fig. 80.
Melantho decisa.
Fig. 81.
Melantho decisa.
Fig. 82.
Operculum of Melantho decisa.
Fig. 83.
Limnaea decisa.
Fig. 84.
Paludina decisa.
Fig. 85.
Helix dissimilis.
Fig. 86.
Cochlea, &c., Lister.
Fig. 87.
Paludina heterostropha.
Fig. 88.
Paludina decapitata.
Fig. 89.
Paludina genicula.
Fig. 90.
Paludina genicula.
Fig. 91.
Lymnula ventricosa.
Fig. 92.
Lymnea eburnea.
Fig. 93.
Melantho decisa, deformed.
Fig. 94.
Paludina milesii.
Fig. 95.
Paludina obesa.
Fig. 96.
Paludina integra.
Fig. 97.
Female of M. decisa, var. integra.
Fig. 98.
Male of M. decisa, var. integra.
Fig. 99.
Young of M. integra.
Fig. 100.
M. integra, deformed.
Fig. 101.
M. integra, deformed.
Fig. 102.
Paludina rufa.
Fig. 103.
M. integra, var. rufa.
Fig. 104.
Paludina subsolida.
Fig. 105.
Lingual dentition of M. integra.
Fig. 106.
Melantho coarctata.
Fig. 107.
Melantho coarctata.
Fig. 108.
Paludina coarctata.
Fig. 109.
Paludina exilis.
Fig. 110.
Paludina lima.
Fig. 111.
Female. Male.
Animal of L. subcarinata.
Fig. 112.
Lingual dentition of L. subcarinata.
Fig. 113.
Operculum of Lioplax subcarinata.
Fig. 114.
Lioplax cyclostomatiformis.
Fig. 115.
Paludina elliotti.
Fig. 116.
Paludina contorta.
Fig. 117.
Paludina subcarinata.
Fig. 118.
Lioplax subcarinata.
Fig. 119.
Lioplax subcarinata.
Fig. 120.
Lioplax subcarinata.
Fig. 121.
Operculum of Lioplax subcarinata.
Fig. 122.
Paludina bicarinata.
Fig. 123.
Paludina decisa, Wood.
Fig. 124.
Lingual dentition of Lioplax subcarinata.
Fig. 125.
Paludina bengalensis.
Fig. 126.
Pleurocera.
Fig. 127.
Animal of Leptoxis.
Fig. 128.
Paludina humerosa.
Fig. 129.
Paludina incrassata.
Fig. 130.
Lingual dentition of Amnicola sayana.
Fig. 131.
Lingual dentition of Bythinella nickliniana.—[Stimpson.]
Fig. 132.
Bythinella attenuata.
Fig. 133.
Paludina nickliniana.
Fig. 134.
Bythinella nickliniana.
Fig. 135.
Bythinella tenuipes.
Fig. 136.
Pomatiopsis binneyi.
Fig. 137.
Bythinella binneyi.
Fig. 138.
Bythinella obtusa.
Fig. 139.
Tryonia clathrata.
Fig. 140.
Amnicola protea.
Fig. 141.
Melania exigua, enlarged
Fig. 142.
Tryonia protea.
Fig. 143.
Amnicola rowellii.
Fig. 144.
Cochliopa rowellii, enlarged
Fig. 145.
Lingual dentition of Gillia altilis.—[Stimpson.]
Fig. 146.
Melania altilis.
Fig. 147.
Leptoxis crenata.
Fig. 148.
Leptoxis crenata.
Fig. 149.
Lingual dentition of Somatogyrus depressus.—[Stimpson.]
Fig. 150.
Amnicola depressa.
Fig. 151.
Somatogyrus isogonus.
Fig. 152.
Leptoxis isogona.
Fig. 153.
Paludina pallida.
Fig. 154.
Paludina fontinalis.

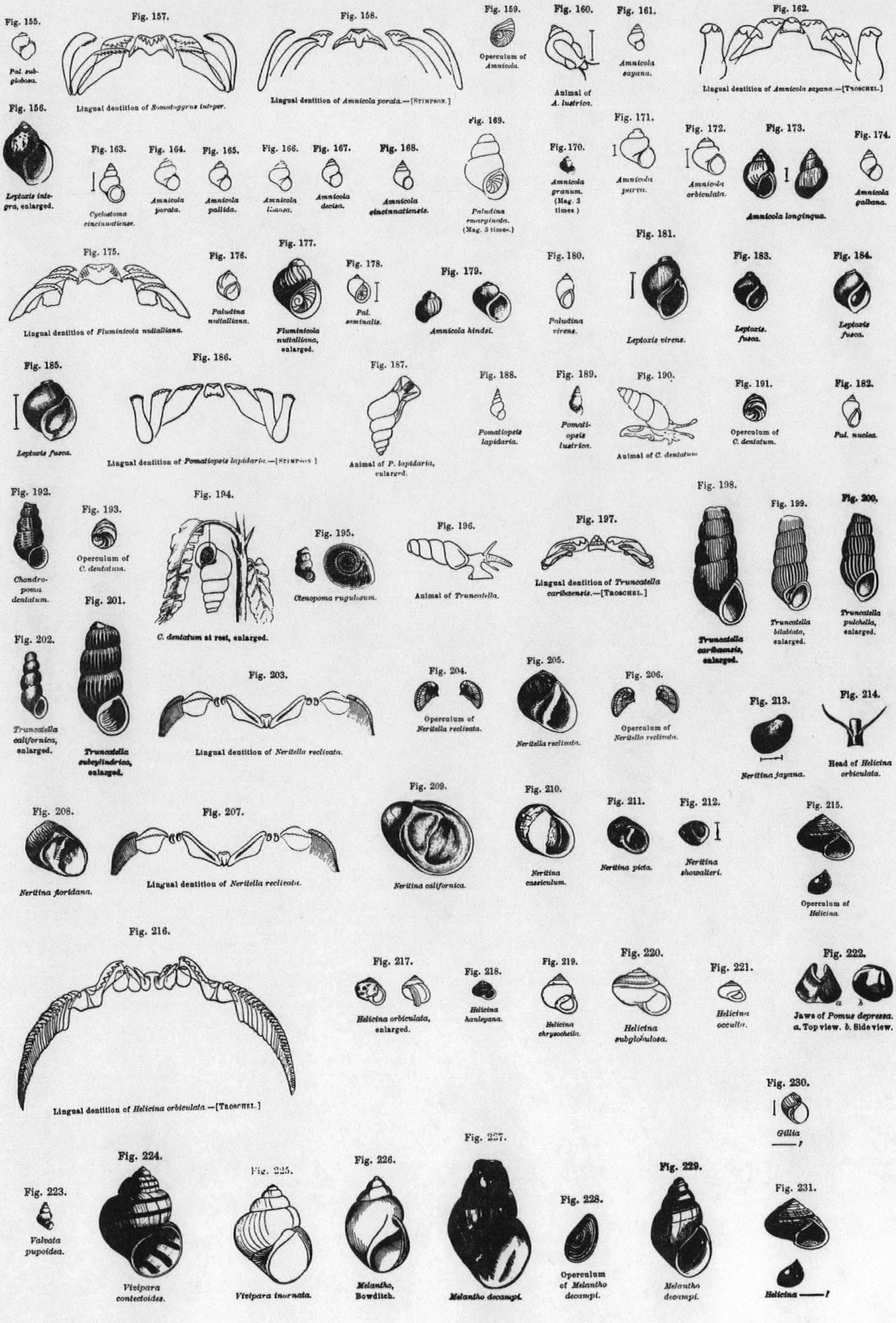

Fig. 155. Pal. subglobosa.

Fig. 156. Leptoxis integra, enlarged.

Fig. 157. Lingual dentition of Somatogyrus integer.

Fig. 158. Lingual dentition of Amnicola porata.—[STIMPSON.]

Fig. 159. Operculum of Amnicola.

Fig. 160. Animal of A. lustrica.

Fig. 161. Amnicola sayana.

Fig. 162. Lingual dentition of Amnicola sayana.—[TROSCHEL.]

Fig. 163. Cyclostoma cincinnatiense.

Fig. 164. Amnicola porata.

Fig. 165. Amnicola pallida.

Fig. 166. Amnicola limosa.

Fig. 167. Amnicola decisa.

Fig. 168. Amnicola cincinnatiensis.

Fig. 169. Paludina emarginata. (Mag. 5 times.)

Fig. 170. Amnicola granum. (Mag. 3 times.)

Fig. 171. Amnicola parva.

Fig. 172. Amnicola orbiculata.

Fig. 173. Amnicola longinqua.

Fig. 174. Amnicola galbana.

Fig. 175. Lingual dentition of Fluminicola nuttalliana.

Fig. 176. Paludina nuttalliana.

Fig. 177. Fluminicola nuttalliana, enlarged.

Fig. 178. Pal. seminalis.

Fig. 179. Amnicola hindsi.

Fig. 180. Paludina virens.

Fig. 181. Leptoxis virens.

Fig. 182. Pal. nuclea.

Fig. 183. Leptoxis. fusca.

Fig. 184. Leptoxis fusca.

Fig. 185. Leptoxis fusca.

Fig. 186. Lingual dentition of Pomatiopsis lapidaria.—[STIMPSON.]

Fig. 187. Animal of P. lapidaria, enlarged.

Fig. 188. Pomatiopsis lapidaria.

Fig. 189. Pomatiopsis lustrica.

Fig. 190. Animal of C. dentatum.

Fig. 191. Operculum of C. dentatum.

Fig. 192. Chondropoma dentatum.

Fig. 193. Operculum of C. dentatum.

Fig. 194. C. dentatum at rest, enlarged.

Fig. 195. Ctenopoma rugulosum.

Fig. 196. Animal of Truncatella.

Fig. 197. Lingual dentition of Truncatella caribaeensis.—[TROSCHEL.]

Fig. 198. Truncatella caribaeensis, enlarged.

Fig. 199. Truncatella bilabiata, enlarged.

Fig. 200. Truncatella pulchella, enlarged.

Fig. 201. Truncatella subcylindrica, enlarged.

Fig. 202. Truncatella californica, enlarged.

Fig. 203. Lingual dentition of Neritella reclivata.

Fig. 204. Operculum of Neritella reclivata.

Fig. 205. Neritella reclivata.

Fig. 206. Operculum of Neritella reclivata.

Fig. 207. Lingual dentition of Neritella reclivata.

Fig. 208. Neritina floridana.

Fig. 209. Neritina californica.

Fig. 210. Neritina cassiculum.

Fig. 211. Neritina picta.

Fig. 212. Neritina showalteri.

Fig. 213. Neritina jayana.

Fig. 214. Head of Helicina orbiculata.

Fig. 215. Operculum of Helicina.

Fig. 216. Lingual dentition of Helicina orbiculata.—[TROSCHEL.]

Fig. 217. Helicina orbiculata, enlarged.

Fig. 218. Helicina hanleyana.

Fig. 219. Helicina chrysocheila.

Fig. 220. Helicina subglobulosa.

Fig. 221. Helicina occulta.

Fig. 222. Jaws of Pomus depressa. a. Top view. b. Side view.

Fig. 223. Valvata pupoidea.

Fig. 224. Vivipara contectoides.

Fig. 225. Vivipara inornata.

Fig. 226. Melantho, Bowditch.

Fig. 227. Melantho decampi.

Fig. 228. Operculum of Melantho decampi.

Fig. 229. Melantho decampi.

Fig. 230. Gillia

Fig. 231. Helicina

NOTE ON THE LINGUAL DENTITION OF THE STREPOMATIDÆ.*

As lingual dentition has been adopted as a very important character (somewhat hastily, I think) in the classification of the Mollusca, it may be well to ascertain how far it may be corroborative with other differences in the genera of North American *Strepomatidæ*. Troschel, in his magnificent work "Das Gebiss der Schnecken," divides the *Melanians* into several groups, of which the following contain American species:

Ancyloti. The peculiarity of the dentition of the forms belonging to this group is that the Rhachidian tooth is broader than long, rounded behind, and swollen out before (*ausgebuchtet*). The laterals have a rhombic form with the outer posterior angle somewhat drawn out, and the inner Uncini always possess a smaller quantity of denticulations than the outer ones. The jaw exhibits numerous small scales which appear of a polygonal, mostly hexagonal form.

In this group are included *Ancylotus*, *Melania depygis* (*Goniobasis*), *Gyrotoma* and *Io*.

We copy the figure given by Troschel:—

Fig. 17.	*Ancylotus prærosus.*	Fig. 20.	*Melania depygis.*
" 18.	" *costatus.*	" 21.	*Gyrotoma ovoidea.*
" 19.	" *dissimilis.*	" 22.	*Io spinosa.*

It will be noticed, by an inspection of these figures, that the differences in the form of the dentition are so slight as to be of no value for the purpose of separating the genera. Indeed Troschel acknowledges that he can find no difference of sufficient importance for the separation of *Melania depygis*, or of *Gyrotoma*† from *Ancylotus*.

*From American Journal of Conchology, ii, 134, 1866.

Pachychili. There is in this group also a marked distinctness of form. As we have excluded this genus from the family *Strepomatidæ* on considerations entirely conchological, it is very interesting to find in the dentition differences quite as marked as those existing in the shell. To show the very peculiar form of the Rhachidian tooth, we copy from Troschel the following for comparison:—

Fig. 23. *Pachychilus lævissimus.*
Fig. 24. " *Schiedeanus.*

It is curious, however, and shows how little dependence can be placed on any one character in the grouping of Mollusca, to find *Pirena* and *Melanopsis* placed by this author together with *Pachychilus*, on account of their almost identical dentition, when they differ so much in conchological characters and in geographical distribution.

Dr. William Stimpson, nearly two years since, published a paper in the "American Journal of Science and Arts, "On the Structural Characters of the so-called Melanians of North America," containing the results of observations of the animals of several of our species, including an *Io*, *Anculosa*, and *Goniobasis*. The individuals of these three very distinct genera were not found to differ one from another in any structural character, although readily distinguished from Oriental species. We will state the differences in their relative importance, as they appear to us. 1st. By being oviparous, while the latter are ovo-viviparous. 2d. By the mantle-margin being plain in the American, and fringed in the exotic family. 3d. By difference in dentition. To these may be added a sufficient conchological difference to justify the separation into two families, even if the soft parts were undistinguishable.

†He curiously regrets that the nearly-allied genus *Schizostoma*, Lea, is unknown to him!

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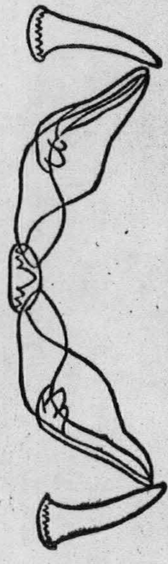
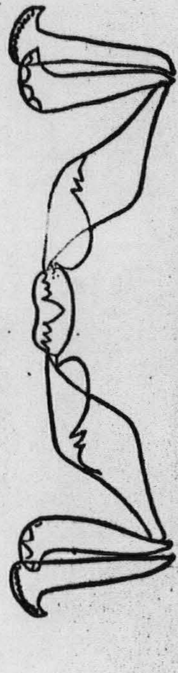
Fig. 17.



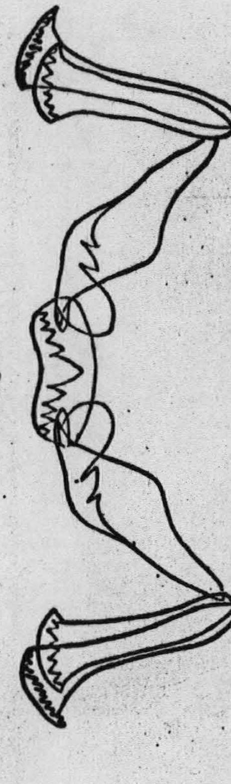
Ancylotus prærosus.

Fig. 18.



Ancylotus costatus.

Fig. 19.



Ancylotus dissimilis.

Fig. 20.

Melania depygis.

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Fig. 21.

Gyrotoma ovoidea.

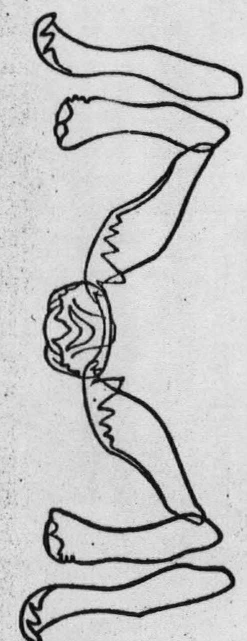
Fig. 22.

Io spinosa.

Fig. 23.

Pachychilus lævissimus.

Fig. 24.



Pachychilus Schiedeanus.

MONOGRAPH OF STREPOMATIDÆ.

FAMILY STREPOMATIDÆ, HALDEMAN.

Strepomatidæ, HALD., Proc. Acad. Nat. Sci., Sept., 1863.
Melaniana, LAM., Extr. d'un Cours., 1812. Hist. Anim. sans. Vert., vi, p. 163, 1822; edit. 2, viii, p. 425, 1838. DESHAYES, Encyc. Meth., iii, pp. 431 and 553, 1832. REEVE, Zool. Proc., p. 76, 1841. Conch. Syst., ii, p. 119, 1842. SOWERBY, Conch. Man., ed. 2, p. 187, 1842. CATLOW, Conch. Nomenc., p. 185, 1845.
Melanidæ (part), LATREILLE, Fam. Nat., 1825. LEA, Proc. Philos. Soc., iii, p. 164, 1843.
Melanianæ (part), SWAINSON, Malacol., pp. 198, 340, 1840.
Melaniadæ (part), GRAY, Syn. Brit. Mus., 1840. Zool. Proc., part 15, p. 152, 1847. TURTON'S Manual, ed. 2, p. 79, 85.
Melaniidæ (part), ADAMS, Genera, p. 293, 1854.
Ceriphasinæ, GILL, Proc. Acad. Nat. Sci., pp. 34, 35, Feb., 1863.

IO, LEA.

Io, LEA, Trans. Phil. Soc., iv, p. 122, 1831.* SOWERBY, Conch. Man. 2d edit., p. 167, 1842. DEKAY, Moll., New York, p. 103, 1843. HERMANNSON, Indicis Generum Malacozoorum, p. 562, 1846.
Io (sp.), Lea, GRAY, Proc. Zool. Soc., pt. 15, p. 153, 1847. JAY, Catalogue, 4th edit., p. 277, 1852. H. and A. ADAMS Genera, i, p. 299. CHENU, Man. de Conchyl., i, p. 290, 1859. ANTHONY, Proc. Acad. Nat. Sci., p. 69, 1860. REEVE, Monog. Io, April, 1860. BINNEY, Check List, June, 1860. BROT, Cat. Syst. des Mélaniens, p. 29, 1862.
Melafusus, SWAINSON, Malacol., pp. 201, 341, 1840. WOODWARD, Manual, p. 131, 1851.
Fusus (sp.), SAY, Jour. Acad. Nat. Sci., 1st series, v, pt. 1, p. 129, Nov., 1825.
Melania (sp.), CATLOW and REEVE, Conch. Nomenc., 1845.

* Date of title page of the volume, 1834, but the part containing Mr. Lea's Memoir was printed and distributed in 1831.

Description.—Shell fusiform; base canaliculate; spire elevated; columella smooth and concave.—*Lea.*

Fig. 25.

Geographical Distribution.—The few species comprising this genus appear to inhabit exclusively the waters of Middle and East Tennessee and southwestern Virginia.

Observations.—Mr. Lea has recently described eight species which he proposes to consider a distinct group of *Io*, but I cannot distinguish them from *Pleurocera*. The longer fuse, sharp lip and fragile texture of most of these species, show them to be immature shells, and in several instances I had no difficulty in proving them identical with mature shells described by Mr. Lea as *Trypanostoma* (= *Pleurocera*), by means of series of specimens of different ages.

Excluding these, twelve species have been described; of which we propose to retain five, regarding the others as synonymes. Many naturalists consider the genus to be restricted to one valid species, and cite the nearly uniform size of the shells, their similar ornamentation and restricted habitat as proofs of the correctness of their opinion; there appears to me to be a well-founded division of the species into two groups, the one containing shells which are smooth or obscurely tuberculate, and the second those developing distinct spines. Endeavors have been made to connect *Io fluvialis* and *spinosa*, the respective types of the two groups, by series of specimens, but no *fluvialis* has been found with better developed protuberances than the shell described by Mr. Reeve as *verrucosa*, which is still a long way from the *spinosa*. In the young shells the differences are very much better shown than in mature individuals, and no one would think of connecting the quite young of the two.

Species.—There are very many groups in the other genera of Strepomatidæ in which the species resemble one another quite as closely as in *Io;* we may instance the close resemblance of *Angitrema armigera* and *Duttoniana;* of *verrucosa* and *lima;* of *geniculata, salebrosa* and *subglobosa;* of *Anculosa prærosa* and *tæniata;* of the species of *Schizostoma;* of the heavy cylindrical *Goniobases* of North Alabama; and many like instances will occur to those who have studied the family. —*Am. Jour. Conch.*, i, p. 41, 1865.

In a figure included in the introductory portion of this work will be found the lingual dentition of a species of this genus, *Io spinosa*, Lea (fig. 22).

SYNOPSIS OF SPECIES.

A. Shell smooth or somewhat tuberculated.

1. Io FLUVIALIS, Say.
   - *Io tenebrosa*, Lea.
   - *Io verrucosa*, Reeve.
2. Io INERMIS, Anthony.
   - *Io lurida*, Anthony.

B. Shell spinose.

3. Io SPINOSA, Lea.
   - Var. *Io crassa*, Anthony.
     - (Monstrosity) *Io gibbosa*, Anthony.
   - Var. *Io recta*, Anthony.
   - Var. *Io rhombica*, Anthony.
4. Io BREVIS, Anthony.
   - *Io spirostoma*, Anthony.
5. Io TURRITA, Anthony.

SPECIES.

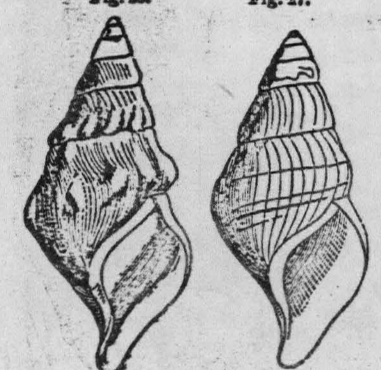
A. *Shell smooth or only slightly tuberculate.*

1. I. fluvialis, SAY.

Fusus fluvialis, SAY, Jour. Acad. Nat. Sci., v, p. 129, Nov., 1825. CONRAD, New Fresh-Water Shells, p. 12, 1834.
Io fluvialis, Say, BINNEY, Check List, p. 12, June, 1860.
Io fluviatilis, Say, WOODWARD, Manual, t. 8, f. 27. HANLEY, Conchological Misc. Melania, t. 6, f. 50. REEVE, Monog. Io, t. 1, f. 5. H. & A. ADAMS. Genera, i, 299. BROT, Cat. des Mélaniens, p. 29. BROT, Malacol. Blatt, ii, 114, 1860.
Pleurocera fluvialis, Say, HALDEMAN, Iconog. Encyc., ii, p. 84.
Io fusiformis, LEA, Philos. Trans., iv, p. 122, t. 15, f. 37a, b; Observations, i, p. 132, t. 15, f. 37a, b. RAVENEL, Catalogue, p. 11. TROOST, Catalogue Shells of Tennessee. CHENU, Man. Conchyl., i, f. 1977. DEKAY, Mollusca New York, p. 103. WHEATLEY, Cat. Shells U. S., p. 28. SAY, Catalogue, 4th edit., p. 277. REEVE, Monog. Io, t. 1, f. 6.
Io tenebrosa, LEA, Philos. Proceedings, ii, p. 34, April, 1841; Philos. Trans., ix, p. 17; Observations, iv, p. 17. WHEATLEY, Cat. Shells U. S., p. 29. BINNEY, Check List, No. 404. H. & A. ADAMS, Genera, i, 299.
Io verrucosa, REEVE, Monograph Io, t. 1, f. 2, April, 1860. BROT, Cat. des Mélaniens, p. 29.

Description.—Shell fusiform, olive-green or brownish; spire much elevated, gradually tapering; volutions nearly six, wrinkled across, and with a series of elevated undulations on the middle; suture consisting only of an impressed line; aperture somewhat fusiform, within whitish, more or less with dull reddish, and with several lines of that color sometimes confluent; labrum on the inner margin immaculate, edge undulated; canal rounded at tip; columella very concave.

Fig. 28. Fig. 27.



Length, 1 8-10 inches; aperture, 19-20 of an inch; greatest breadth, 19-20 of an inch.

Observations.—Professor Vanuxem found this curious and highly interesting shell (Fig. 27) on the north fork of the Holston River, near the confluence of a brook of salt water. From the name of the genus it might reasonably be supposed to be a marine shell, but it has never been discovered on the coast, and seems to be limited to a very small district of the Holston River, in company with *Unio cariosus, subtentus*, nobis, *Melania subglobosa*, nobis, and no doubt other fluviatile shells. When the inhabitant becomes known it may authorize the formation of a new genus, but there appears no character in the conformation of the shell that would readily distinguish it from *Fusus*.—*Say*.

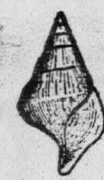
Mr. Lea, upon instituting the genus *Io*, renamed *fluvialis* as *fusiformis*, Lea, in accordance with a custom very usual among naturalists, but very reprehensible. He has recently done Mr. Say and himself the justice of restoring the original name — an example worthy to be followed.

A young, very dark colored specimen of this species, Mr. Lea named *Io tenebrosa*. He now agrees with me in considering it to be a synonyme of *fluvialis*.

The following is the description, together with a figure from the type specimen, of

Io tenebrosa.—Shell fusiform, rather thin, nearly black, smooth; spire conical; sutures scarcely impressed; whorls six, flattened; aperture irregularly pear-shaped; within purple.

Fig. 28.



Habitat.—Tennessee.

Diameter, ·48; length, ·75 of an inch.

Observations.—A single specimen only was brought by Mr. Edgar from Tennessee. It is a small specimen, and may be immature. After a good deal of hesitation I have determined to give it a place among the species. It seems to me to be very distinct in color. The channel is more curved to the left and backward than in Mr. Say's species. It has no trace of spines or tubercles, and is dark all over. I do not know if it ever occurs banded.—*Lea*.

The two accompanying figures represent respectively smaller and larger specimens than Mr. Lea's type. The full grown shell is very frequently entirely smooth, though it sometimes develops a few nodules upon the periphery, but these do not attain to the size of the "spines" which characterize *Io spinosa*, and I have not found, among numerous specimens, any that would connect the two species. The color of *fluvialis* varies from yellow through various shades of light and dark green and brown to black. Some specimens are

Fig. 29.

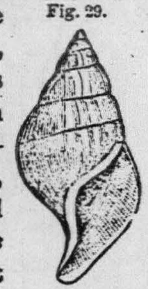


Fig. 30.

beautifully banded. The following description by Mr. Reeve is founded on a shell more than usually noduled; the figure is a copy from his plate.

Fig. 31.

Io verrucosa.—Shell fusiform, greenish-olive, purple tinged and banded; whorls six, sloping, the first plicately crenulated, the rest tumidly noduled at the periphery; columella attenuately elongated.

Habitat.—Tennessee.

Observations.—In this species, which is of a greenish hue, the periphery of the whorls is furnished with a row of swollen, wart-like nodules, the early whorls of the shell being rippled with small concentric folds.—*Reeve*.

2. I. inermis, Anthony.

Io inermis, Anthony, Proc. Acad. Nat. Sci., Feb. 1860, p. 70. Binney, Check List, No. 401. Reeve, Monog. Io, t. 3, f. 21.
Io lurida, Anthony, Reeve, Monog. Io, t. 3, f. 20.

Description.—Shell conical, smooth, thick; moderately elevated; composed of 7–8 flattened whorls; suture very distinct; upper whorls slightly coronated by an obscure row of low spines, nearly concealed by the preceding whorl; shell otherwise perfectly smooth, or only occasionally or obscurely nodulous on the body-whorl; lines of growth very strong and much curved; aperture pyriform, curved to the left, banded within; columella twisted, callous, thickened above; sinus long and curved.

Fig. 32.

Length of shell, 2 1-16 inches; breadth of shell, 1 inch; length of aperture, 1 inch. Breadth of aperture, ½ inch.—*Anthony*.

Remarkable mainly for its plain, unadorned exterior, and smooth epidermis; its color also is lighter than "*spinosa*" or "*fluviatilis*." No spines are visible on the body-whorl of this species generally, but I have a few specimens which may perhaps belong to it,

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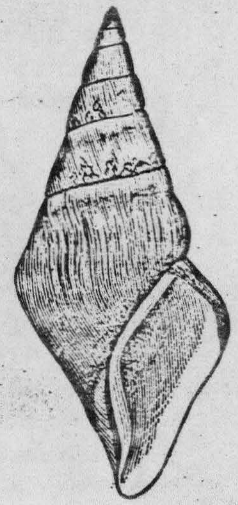
and which have a few obscure spines near the aperture. These are, however, little more than knobs. Some hundreds of this species have come under my notice. *Io lurida* was first described by Mr. Reeve. It is only a dark variety of *inermis*. Indeed, Mr. Anthony himself writes to me to that effect.

Fig. 33.



The following is the description and figure from the type specimen of

Io lurida. — Shell straightly fusiform; lurid-purple within and without; whorls smooth, unarmed, concavely impressed round the upper part, tumidly gibbous round the middle; columella scarcely twisted.

Habitat.— Southern United States.

Observations.— A smooth, straightly fusiform shell, of a dull, lurid-purple color throughout.—*Reeve.*

This species is considered by many conchologists to be a variety of *fluvialis*: it may be so, but the material before me does not enable me to make a decision against its specific weight, and I think decidedly that it is a good species.

Fig. 34.

3. I. spinosa, Lea.

Io spinosa, Lea, Philos. Trans., v, p. 112, t. 19, f. 79. Obs., i, p. 224. Troost, Cat. Wheatley, Cat. Shells U. S., p. 29. Jay, Cat., 4th edit., p. 277. Binney, Check List, No. 402. Reeve, Monog. Io, t. 1, f. 7. Hanley, Conch. Misc., t. 6, f. 51.
Io gibbosa, Anthony, Reeve, Monog. Io, t. 3, f. 17.
Io recta, Anthony, Reeve, Monog. Io, t.3, f.21.
Io rhombica, Anthony, Reeve, Monog. Io, t. 3, f. 16.

Description. — Shell obtusely turreted, wide, horn-color, under the epidermis banded, furnished with large spines; whorls seven; mouth elongate, one-half the length of the shell.

Habitat.— Holston River, Washington county, Virginia.

Observations.— This species resembles very much the *Io fusiformis* (nobis), *Fusus fluviatilis*, Say, but may be distinguished by its large, transversely compressed spines, the *fusiformis* having some longitudinal tubercles. I am not acquainted with any fluviatile shell which has such large spines (there being about seven on each whorl), nor any which has such a general resemblance to a marine shell.

Prof. Troost informs me that they are rare in the river, that they had been observed in the graves of the aborigines; and as it was generally believed that these were "conch shells," consequently coming from the sea, it was urged that the inhabitants who possessed them must have come over the sea. It does not appear that they had been observed in their native element, though living at the very doors of the person who had remarked them in the tumuli.— *Lea.*

The accompanying figure is from a half-grown specimen in the Smithsonian Collection. In the shells described by Mr. Reeve, quoted in the above synonymy, I cannot recognize specific characters, although *Io recta* may possibly rank as a variety.

Fig. 35.

The descriptions of the various synonymes are appended, with figures from the type specimens.

Io gibbosa.— Shell stoutly fusiform, fulvous; whorls rudely obliquely plicated, obtusely tubercled in the middle, last whorl spirally plicately ribbed around the lower part, rib swollen, gibbous; columella arcuately twisted, canal broadly effused.

Fig. 36.

Habitat.— Southern United States.

Observations.—The gibbous ridge which encircles the lower portion of the body-whorl of this species "is not," writes Mr. Anthony, "a mere accidental aberration; I have seen others like it."— *Reeve.*

The extensive suite of *spinosa* that I have examined proves that the gibbous ridge *is* "a mere accidental aberration," being found in all stages of development on specimens which are otherwise distorted in growth, as Mr. Anthony's type, figured above, undoubtedly is.

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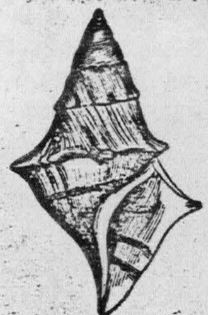
Io recta.— Shell somewhat elongately fusiform, straight, rather solid, fulvous-olive, whorls concavely sloping around the upper part, conspicuously tubercled at the angle; tubercles rather small; columella arcuately twisted; canal broadly appressed; aperture oblong; interior banded and stained with reddish-purple. — *Reeve.*

Fig. 37.

Fig. 38.



Habitat.— Tennessee.

Io rhombica. — Shell striately fusiform, fulvous-olive, encircled with four bands of purple-brown; whorls concavely sloping, conspicuously angled and tubercled in the middle; columella but little twisted; canal rather short, attenuately appressed.

Habitat.— Southern United States.

Observations.— The specimen which Mr. Anthony has here named *I. rhombica*, is of more regular growth than *I. spinosa*, with less twist in the columella, and the whorls are more concavely sloping.—*Reeve.*

4. I. brevis, Anthony.

Io brevis, Anthony, Proc. Acad. Nat. Sci., Feb., 1860, p. 69. Binney, Check List, No. 399. Reeve, Monog. Io, t. 1, f. 4.

Io spirostoma, Anthony, Proc. Acad. Nat. Sci., Feb., 1860, p. 70. Binney, Check List, No. 403. Reeve, Monog. Io, t. 1, f. 1.

Fig. 39.

Description. — Shell conic, ovate, horn-colored, spinous; spines short, thick, five on each whorl; whorls about seven; aperture elliptical or pyriform, one-half the length of the shell; columella rounded and sinuous near the base, forming with the outer lip a broad, well defined canal at the base.

Length of shell, 2 in.; breadth of shell, 1½ in. Length of aperture, 1 in.; breadth of aperture, ¾ inch.

Habitat.— Tennessee.

Observations.— Another of the short, heavy forms in this genus, so unlike the normal type of *Io spinosa*; we think no one need confound it with any other species; its short, heavy, flattened spines jutting out like so many miniature spear-heads, and its peculiarly twisted columella will readily characterize it. The columella is also covered with a dense callous deposit, increased in thickness at its upper part and often blotched with dark red at that point; irregular, ill-defined, but broad bands are seen in the interior, often faintly visible on the epidermis. Appears to be a rather common species in some localities, of which I possess some hundreds of specimens.—*Anthony.*

Dr. Brot considers this, and all the other species of *Io* identical with *I. fluvialis.*

Mr. Reeve suspects the specific identity of *Io brevis* and *spirostoma*, and I am convinced that the latter is only an aberration of growth like *I. gibbosa;* it is, however, a very graceful and beautiful shell.

The following is the description, together with a figure from the type specimen, of

Io spirostoma.— Shell conical, broadly ovate, horn-colored, spinous; spines short, thick, seven to eight on each whorl; whorls about nine; aperture ovate, about half the length of the shell; columella and outer lip much and regularly twisted, and forming a well-defined sinus at base.

Fig. 40.

Length of shell, 1¾ inches; breadth of shell, 1¼ in. Length of aperture, 15-16 of an inch; breadth of aperture, ½ inch.

Habitat.— Tennessee.

Observations.— This is truly a most remarkable species of this highly interesting genus of mollusks; its difference from the ordinary type of *Io spinosa* is too marked to admit of its being confounded with that, or indeed with any other species; its stout, ovate form, short, heavy spines, and, above all, the peculiar and graceful curvature of its outer lip, are prominent characteristics and readily distinguish it.-

Among several thousand specimens of *Io* in my possession, but three adult individuals of this species have been noticed, although I have a dozen or more which seem to be immature forms of it; it may therefore be considered as not only one of the most aberrant and beautiful forms of *Io*, but also one of the rarest.—*Anthony.*

5. I. turrita, Anthony.

Io turrita, Anthony, Proc. Acad. Nat. Sci., Feb., 1860, p. 69. Binney, Check List, No. 405. Reeve, Monog. Io, t. 3, f. 19*a*.

Description.—Shell conic, elevated, horn-colored, spinous; spines rather short and heavy, about seven on each whorl; whorls nine; aperture pyriform, about one-third the length of the shell, and irregularly banded within; columella rounded, slightly twisted and forming a short, narrow canal at base.

Fig. 41.

Habitat.—Tennessee.

Length of shell, 2½ inches; breadth of shell, ⅞ inch. Length of aperture, ⅝ inch; breadth of aperture, 7–16 of an inch.

Observations.—This is the most slender and elongate species of this genus which has come under my notice, and although a single specimen only has yet been discovered, its claims to rank as a species will hardly be questioned; its long, slender form, stout, closely-set spines, and small aperture will at once distinguish it from its congeners; two faint bands traverse each whorl, one of which lies precisely in the plane of the spines; lines of growth very distinct, nearly varicose.

This species is farther removed from *Io fluvialis* than any of the others, and appears to be very distinct. Mr. Reeve's figure 19*b*, of which I have seen the original specimen, I would refer to *spinosa* rather than *turrita*. Numerous specimens occur in the collection of Mr. Lea, who is well assured, also, of its specific weight. The illustration is from the type specimen.

SPURIOUS SPECIES.

Io nodosa, Lea.	Pleurocera.
Io robusta, Lea.	
Io variabilis, Lea.	
Io Spillmanii, Lea.	
Io modesta, Lea.	
Io viridula, Lea.	
Io gracilis, Lea.	
Io nobilis, Lea.	

Mr. Lea proposes to consider the above a distinct group of *Io*, but I cannot distinguish them from *Pleurocera*. The longer fuse, together with the sharp lip and fragile texture of most of the shells, shows them to be immature, and indeed, as already stated, I have had no difficulty in several instances in identifying them with species of *Pleurocera*, by the comparison of specimens in various stages of growth.

Besides the above, numerous species of *Angitrema*, etc., have been referred to *Io* by European authors.

Genus ANGITREMA, Haldeman.

Angitrema, Haldeman, Cover of No. 2, Monog. Limniades, Jan., 1841.
Potadoma (sp.), Swainson, H. & A. Adams, Genera, i, p. 299, 1854.
Glotella, Gray, Zool. Proc., pt. 15, p. 154, 1847.
Io (sp.), Lea, H. & A. Adams, Genera, i, p. 299, 1854. Chenu, Man. Conchyl., i, p. 290, 1859. Reeve, Monog. Io, April, 1860. Brot, Syst. Cat. Mel., p. 29, 1862.
Lithasia (sp.), Haldeman, H. & A. Adams, Genera of Recent Mollusca, i, p. 308, 1854.
Anculotus (sp.), Say, Jay, Cat. Shells, 4th edit., p. 276, 1850.
Melania (sp.), Authors.
Juga (sp.), Chenu, Man. de Conchyl.

Description.—Shell spinous; aperture subrhomboidal, with an anterior sinus; columella with a callous deposit anteriorly and posteriorly.—*Hald.*

Geographical Distribution.—With two exceptions, the typical species of this genus are confined in their geographical range

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to Tennessee and Northern Alabama. These exceptions are *A. verrucosa* and *armigera*, both of which extend northward into Indiana, inhabiting the Wabash River.*

Unlike the species of *Pleurocera*, those of this genus are with one or two exceptions well defined and easily distinguishable one from another.

SYNOPSIS OF THE SPECIES OF ANGITREMA.

A. Body-whorl with a coronal of tubercles, with frequently an inferior row revolving parallel with it.

1. *A. geniculata*, HALD.
2. *A. salebrosa*, CONR.
3. *A. subglobosa*, LEA.
4. *A. Tuomeyi*, LEA.

B. Body-whorl encircled above the aperture by two rows of tubercles, of which the inferior one is the more prominent.

5. *A. Jayana*, LEA.

C. Body-whorl with a central row of tubercles.

6. *A. rota*, REEVE.
7. *A. armigera*, SAY.
8. *A. Duttoniana*, LEA.
9. *A. Wheatleyi*, TRYON.
10. *A. stygia*, SAY.

D. Body-whorl with numerous tubercles, in parallel rows.

11. *A. lima*, CONR.
12. *A. verrucosa*, RAF.

A. *Body-whorl with a coronal of tubercles.*

1. A. geniculata, HALDEMAN.

Lithasia geniculata, HALDEMAN, Suppl. to No. 1, Monog. of Limniades, Oct., 1840. BINNEY, Check List, No. 299.
Anculotus geniculatus, Haldeman, JAY, Cat. Shells, 4th edit., p. 276. HANLEY, Conch. Misc., t. 5, f. 41. REEVE, Monog. Anculotus, t. 1, f. 7.
Leptoxis geniculata, Haldeman, BROT, List, p. 24.
Lithasia genicula, Lea, WHEATLEY, Cat. Shells U. S., p. 28. ADAMS, Genera, i, 308.

*It is a curious fact that many of the tuberculate and plicate species of *Strepomatidæ* inhabit the Wabash, so far north of their geographical centre. Mr. Lea informs me that the same curious distribution prevails with certain southern species of *Unionidæ*.

Description.— Shell short and ponderous; body-whorl crowned

Fig. 43.

Fig. 42.

Fig. 44.

with a row of conical tubercles; labium with a callus above and below; aperture elliptic, with a sinus at each extremity.

Length, ¾ inch.

Habitat.—East Tennessee.

Observations.—Differs from *Melania salebrosa*, Conrad, in having but a single row of tubercles, and a more abrupt shoulder.—*Haldeman.*

Generally but one row of tubercles is developed on this species, but occasionally a second and less prominent row is visible. The whorls are more shouldered, and the tubercles larger and less numerous than in *L. salebrosa*, Conrad. In general form it approaches *L. Tuomeyi*, Lea. It is the largest and most ponderous species of the genus.

Mr. Lea considers *geniculata* to be the same as *salebrosa*.

2. A. salebrosa, CONRAD.

Melania salebrosa, CONRAD, New Fresh-Water Shells, p. 51, t. 4, f. 5, 1834. CHENU, Reprint, p. 24, t. 4, f. 13. DEKAY, Moll. N. Y., p. 100. WHEATLEY, Cat. Shells U. S., p. 25. JAY, Cat., 4th edit., p. 274.
Anculotus salebrosus, Conrad, REEVE, Monog. Anc., t. 1, f. 6 (bad figure).
Leptoxis salebrosa, Conrad, BROT, List, p. 25.
Lithasia salebrosa, Conrad, BINNEY, Check List, No. 303. ADAMS, Genera, i, 308.

Description.— Shell short suboval; thick, ventricose, with a series of very elevated nodes on the shoulder of the body-whorl, and generally two series of smaller nodes beneath; spire very short; apex much eroded; aperture about half the length of the shell, contracted; within purplish; columella with a callus above, and another near the base.

Fig. 45.

Fig. 46.

Observations.—This singular shell approaches the genus *Anculotus* in

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form, but the aperture is that of a *Melania*. I found it adhering to logs in the Tennessee River, at Florence, where it is abundant. My friend, Wm. Hodgson, Jr., found it also in the Holston River, in Tennessee.— *Conrad.*

This species is allied to No 1, but may be distinguished by its smaller size and much smaller shoulder, by its crowded tubercles, and by the constant presence of one or more inferior rows. On the other hand it is closely allied with *L. subglobosa*, Lea. Like the former, it is a very abundant species. I think the locality in East Tennessee, quoted by Mr. Conrad, an error.

3. A. subglobosa, Lea.

Lithasia subglobosa, Lea, Proc. Acad. Nat. Sci., p. 55, Feb., 1861. Jour. Acad. Nat Sci., v, pt. 3, p. 261, t. 35, f. 70. Obs., ix, p. 83.

Description.— Shell tuberculate, subglobose, thick, yellowish horn-color, double-banded; spire scarcely exserted; sutures impressed; whorls five, the last very large, towards the shoulder tuberculate; aperture large, rhomboidal, within white and double-banded, channelled at the base; columella very much thickened above and below; outer lip expanded, acute at the margin.

Fig. 47.

Fig. 48.

Operculum rather small, very dark brown, subovate, with the polar point within the lower left edge.

Habitat.— Tennessee; Prof. G. Troost.

Diameter, ·48; length, ·60 inch.

Observations.— Two specimens of this remarkably globose species have been in my possession for a long time. I had doubts of their being only the young of *Melania* (*Lithasia*) *salebrosa*, Conr., but they are so different from any young of that species which I have seen that I cannot now doubt their being entirely distinct. I know of no species which has so obtuse a spire. In this it resembles *Anculosa*, but the well characterized columella forbids its being at all confounded with any species of that genus. The callus above and below is unusually strong; below it amounts almost to a fold. One of the specimens is full grown, and has five turbercles on the shoulder of the outer half of the last whorl, and near the edge there are three above those five. The smaller one is little more than half grown, and has not as yet formed any tubercles. The two broad bands are below the row of tubercles. The last whorl is so large that it nearly covers all the others, leaving merely a point to mark the vertex. The two bands are well pronounced interiorly as well as exteriorly.— *Lea.*

Over fifty specimens of this species are before me. They are closely allied to *salebrosa*, but uniformly much smaller, and generally wider. Besides, the spire is shorter, and but very few of them exhibit a slight tendency towards tuberculation below the upper row. The whorls are not shouldered except in very old individuals. A very constant character of the species consists in the two broad, revolving bands of brown; a few specimens, however, have instead four narrow bands approximating in pairs, and two or three are of uniform color, without bands. The young differ much from the adult shells in appearance.

4. A. Tuomeyi, Lea.

Lithasia Tuomeyi, Lea, Proc. Acad. Nat. Sci., p. 55, Feb., 1861. Jour. Acad. Nat. Sci., v, pt. 3, t. 35. f. 68. Obs., ix, p. 8'.
Anculotus Florentianus, Lea, Reeve, Monog. Anc., t. 1, f. 4.

Description.— Shell tuberculate, much inflated, rather thick, dark horn-color, spire obtusely conoidal; sutures impressed; whorls five, the last large, below the sutures obliquely tuberculate; aperture large, rhomboidal, whitish within, obscurely banded, channelled at the base; columella very much incurved, thickened above and below; outer lip expanded, acute at the margin.

Fig. 49.

Habitat.—North Alabama; Prof. Tuomey.

Diameter, ·64; length, 1·04 inches.

Observations.— A single specimen only was sent to me by Prof. Tuomey. It was with *L. imperialis*, herein described. Being 1·04 inches in length and ·64 in diameter, it will be seen that the proportions differ very much from that species. It cannot be confounded with *Lithasia semigranulosa*, for that species is always more raised in the spire and studded with numerous rather small tubercles. It is more closely allied to *Lithasia salebrosa*, Conr.,* but that species has a lower spire, has larger and usually more tubercles, and these,

*Mr. Lea considers *L. salebrosa* and *L. geniculata* dentical. It is with the latter species that the comparison is intended to be made.

if not vertical, incline to the left, while those on *Tuomeyi* are irregular and incline very much to the right, the number on the specimen before me being five on half of the last whorl. It is closely allied to *Lithasia Florentiana*, nobis, but differs much in the tubercles, in being a heavier shell, less acuminate, in being thicker on the columella and open in the channel. The *Tuomeyi* is much thicker above and below on the columella, has the obscure band within, and the outer lip is thickened and white inside the edge.

This species and *imperialis* were accompanied by many specimens of *semigranulosa* and *Florentiana*. The exact habitat was not mentioned. I have peculiar pleasure in dedicating this species to my friend, the late Professor Tuomey, whose able report on the geology of South Carolina and Alabama has justly gained him so much reputation.—*Lea.*

B. *Body-whorl encircled above the aperture by two rows of tubercles, of which the inferior one is most prominent.*

5. A. Jayana, Lea.

Melania Jayana, Lea, Philos. Proc., ii, p. 83. Philos. Trans., ix, p. 20. Obs., iv, p. 20. Wheatley, Cat. Shells U. S., p. 25. Jay, Cat. Shells, 4th edit., p. 274, Binney, Check List, No. 154.

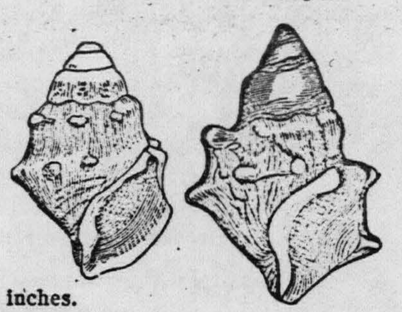
Io Jayana, Lea, Brot, List, p. 29. Mal. Blatt., v, 115, 1860.

Melania robulina, Anthony, Bost. Proc., iii, p. 263, Dec. 1850. Binney, Check List, No. 230.

Io robulina, Anthony, Reeve, Monog. Io, sp. 15. Chenu, Man. Conchyl., i, f. 1976.

Description.— Shell tuberculate, subfusiform, thick, pale horn-color; spire exserted; sutures linear and curved, whorls rather convex; impressed in the middle, surrounded by a double series of tubercles; columella incurved, thickened above; aperture trapezoidal, whitish within.

Fig. 51. Fig. 50.



Habitat.— Caney Fork, De-Kalb county, Tennessee.

Diameter, ·78; length, 1·20 inches.

Observations.— Dr. Jay had two specimens of this species, and I owe to his kindness the possession of one of them. It very closely

resembles the *M. armigera* (Say), in most of its characters, but may at once be distinguished by the double row of tubercles, the *armigera* never possessing distinctly more than one row; below the sutures, however, there are sometimes imperfect tubercles, which are caused by the protrusion of the tubercles of the superior whorl. This protrusion also takes place in the *Jayana*, but causes in it only a constant curvature in the linear suture.

The apex of the specimen is much eroded, and consequently I am not sure of the number of the whorls, probably eight or nine. The aperture may be rather more than one-third the length of the shell, and is acutely angular at the base, with rather a deep sinus. The callus above causes a considerable sinus there.

The operculum is dark brown, the radii converging at the lower interior edge.—*Lea.*

This shell and Mr. Anthony's *M. robulina* are entirely identical in every respect, the species being a very constant one in all its characters, as I am unable to select from a considerable number of specimens any which exhibit variations from the type form. It is an exceedingly abundant species, and very remarkable for its peculiar armature and the narrowed canal, suggestive of the genus *Io*.

The following is the description of

Melania robulina. — Shell solid, ovately rhomboidal, corneous, encircled with brown bands; whorls six, bearing a double series of nodules, the upper one immersed in the suture; aperture rhomboidal produced into a rostrum, callous behind.

Habitat.— Cumberland River, Tennessee.

Long. 1; lat. 5–8 poll.

Observations.—Of the same size as *M. armigera*, Say, but differs in coloration; the rostrum is much longer, and the posterior series of tubercles much more developed.—*Anthony.*

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C. *Body-whorl with a central row of tubercles.*

6. A. rota, Reeve.

Io rota, Reeve, Monog. Io, sp. 13, April, 1860. Brot, List, p. 29.

Description.— Shell globosely turreted, thick, ponderous, yellowish, encircled at the base by a brown band, olive; whorls few, rudely concavely sloping, faintly striated, encircled round the periphery with large, obliquely compressed tubercles; columella short, but little twisted.

Fig. 52.

Habitat.— United States.

Observations.— A solid, globosely turreted shell, prominently armed with tubercles, which are compressed obliquely into fans, like the fans of a water-wheel.— *Reeve.*

The figure is copied from Reeve. I have never seen this species, the type of which was in the collection of the late Hugh Cuming, Esq., London; it may be only a remarkable specimen of *A. Jayana*, Lea.

7. A. armigera, Say.

Melania armigera, Say, Jour. Acad. Nat. Sci., 1st ser., ii, p. 178, Jan., 1821. Binney's Reprint, p. 71. Binney, Check List, No. 21. DeKay, Moll. N. Y., p. 93. Jay, Cat., 4th edit., p. 272. Troost, Cat. Wheatley, Cat. Shells U. S., p. 24. Catlow, Conch. Nomenc., p. 185. Hanley, Conch. Misc. Melania, t. 7, f. 60.
Io armigera, Say, Reeve, Monog. Io, f. 11. Adams, Genera, i, 299.

Description.— Shell tapering, brownish horn-color; volutions about six, slightly wrinkled; spire near the apex eroded, whitish; body-whorl with a revolving series of about five or six distant, prominent tubercles, which become obsolete on the spire, and are concealed by the revolution of the succeeding whorls, in consequence of which arrangement there is the appearance of a second, smaller, and more obtuse subsutural series of tubercles on the body-whorl; two or three obso-

Fig. 53a.

Fig. 53.

lete revolving reddish-brown lines; aperture bluish-white within; a distinct sinus at the base of the columella.

Habitat.—Ohio River.

Length about one inch.

Distinguished from other North American species, by the armature of tubercles.— *Say.*

This beautiful and extensively distributed species is allied only to *L. Duttoniana*, Lea (for distinctive characters see description of that species); from all others it is very distinct. Besides the original locality, Jay and Troost give Tennessee, and Mr. Wheatley, Kentucky, as its habitat. I have before me a series of the young shells presented to the Philad. Acad. Nat. Sciences, by Mrs. Say, which were collected in the Wabash River, Ind.

This shell Prof. Haldeman has made the type of his subgenus *Angitrema*. He has also (Icon. Encyc., ii, p. 84) referred it to Rafinesque's genus *Pleurocera*.

8. A. Duttoniana, Lea.

Melania Duttoniana, Lea, Philos. Proc., ii, p. 15. Philos. Trans., viii, p. 189, t. 6, f. 54. Obs., iii, p. 26. Catlow, Conch. Nomenc., p. 186. Binney, Check List, No. 92. Jay, Cat. 4th edit., p. 273.
Io Duttoniana, Lea, Reeve, Monog. Io, f. 9. Brot, List, p. 29. Chenu, Man. Conchyl., i, f. 1974.
Io fasciolata, Reeve, Monog. Io, f. 14.

Description.— Shell tuberculate, fusiform, rather thick, yellowish, banded; spire elevated, pointed at the apex; sutures irregularly lined; whorls seven, depressed above; aperture elongated, angular and channelled at the base, within whitish.

Fig. 54.

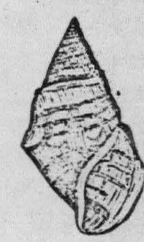
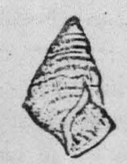


Fig. 54a.



Habitat.— Waters of Tenn. Duck River, Maury Co., Tenn.

Diameter, ·57; length, 1·09 inches.

Observations.— This is a beautiful species. The most perfect specimens are remarkable for their fusiform shape and their long aperture, which presents a curved columella and extended sinus somewhat like the genus *Io*. The bands in some individuals are numerous and distinct, the largest being nearest the base. The tubercles form a row round the middle of the whorls of