THE RECENT AND FOSSIL FRESHWATER GASTROPOD FAUNA OF TEXAS

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By

Richard W. Fullington, B. S., M. S.
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Twelve freshwater gastropod families, 39 genera and 70 fossil and Recent species are recognized and systematically treated. Keys to the families, genera and species were constructed and all species are illustrated. The purpose of this study was to synthesize and update the taxonomy, zoogeography, origins and correlations with drainage systems of the entire Recent and fossil freshwater gastropod fauna of Texas.

Recent snail distributions appear to best fit Blair's (1950) Biotic Province division of the State. Only *Physa virgata*, *Gyraulus parvus* and *Stagnicola bulimoides techella* occur statewide and with the exception of *Tryonia pecosensis* along the Pecos River, no species are characteristic of a particular river system.

Twenty-three species occur only as fossils. During the Pleistocene, Texas freshwater snail communities were larger and had greater diversity than existing fauna. Nearly all fossil species are northern in origin. Texas aquatic snail communities have been profoundly affected in species composition and distribution by the 4 major Pleistocene glacial advances and retreats, that led to an alternating wet-cool and dry-hot period.

During the wet, cool full glacial periods (Nebraskan, Kansan, Illinoian, and Wisconsin Ages, cool-adapted species such as Valvata tricarinata, Stagnicola elodes, Planorbula armigera and Aplexa hypnorum invaded north and northwestern Texas where clear, heavily vegetated streams and large bodies of standing water must have occurred.

Presumably, during warmer, drier interglacial periods, several subtropical genera such as Biomphalaria, Drepanotrema, Tryonia and Cochiliopina moved northward through the State. The pleurocerid, Elimia comalensis appears to be the only western form to have moved into Texas. Strangely, no eastern nearctic pleurocerids nor any members of the eastern viviparidae apparently migrated across the State. Except for the first record here of a fossil viviparid, no fossil specimens of these two families are known.

The present freshwater snail fauna is mostly composed of relicts from the north and south, and these can be generally considered geologic transients. With the possible exceptions of Physa virgata, Helisoma trivolvis lenta and Horatia micra, there are no indigenous species. Judging from the present climatic trend toward dryness, and from the fossil record, most northern species that occurred here during the last glacial advance have been exterpated and several more species are losing ground. The gill-breathing element of the neotropical group appear to be largely suppressed southward although the lung-breathing species, such as *Biomphalaria* and *Gundlachia*, appear to be moving northward. The eastern nearctic fauna remains confined to austroriparian areas of east Texas. The unique, subterranean fauna of central Texas remains unstudied and largely unknown.

Acknowledgements

This publication culminates the unrealized dream of one of the Southwest's leading malacologists, the late Dr. E. P. Cheatum. After joining Southern Methodist University in 1921, he labored to monograph the mollusca of Texas until his death in 1972. The chaos was so great, that he concentrated on the land fauna and worked on the freshwater fauna as time allowed. His last major work with freshwater snails was in 1947. Some of that data is incorporated here. The remembrance of Dr. Cheatum's spirit and drive has been a great stimulus for completion of this work.

Appreciation is expressed to the many scientists, paleontologists, archaeologists, teachers, students, and amateurs who, perhaps unknowingly, helped to shape the content and format through their questions and needs, brought to me over the years. I hope that their expectations are partially met. This work is intended to be a tool for use both as a reference, and as a stimulus for further investigations on Texas freshwater gastropods.

Greatly appreciated technical assistance was furnished by the United States National Museum, University of Michigan Museum of Zoology, Philadelphia Academy of Sciences, and Florida State Museum, in the persons of Dr. Joseph Rosewater, Dr. J. B. Burch, Dr. Robert Robertson, and Dr. Fred G. Thompson. The following authorities, to whom I am greatly indebted, kindly gave advice, specimens, and critical review: Dr. D. W. Taylor (Hydrobiidae), Dr. W. J. Clench (Viviparidae, Pleuroceridae), Dr. Emile Malek (Planorbidae), Dr. H. W. Harry (Planorbidae), and Dr. P. F. Basch (Ancylidea). Special thanks go to the Dallas Museum of Natural History staff who for nine years have unhesitatingly followed me through Texas murky swamps and across mountains to collect snails.

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CHAPTER I

INTRODUCTION

Scope

This paper represents an analysis of all current knowledge of Texas fossil and recent freshwater gastropod fauna, resulting from 16 years of research. Much new biological and distributional information is incorporated into a compilation of heretofore scattered literature.

Throughout the study, I have attempted to fulfill the following objectives:

1. Through comparative morphological study, to produce keys, illustrations and descriptions for the 38 fossil and recent aquatic snail genera, and 70 species and subspecies recognized from Texas.
2. Through intensive collecting, to determine the distribution patterns of aquatic snails within the state, in light of their geologic range, Nearctic distribution and fossil record.
3. To provide a major synoptic reference work on Texas snails for students of malacology. This includes treatment of worldwide distribution of taxa, parasitological importance, potential value as biological pollution indicators, floral and community associations and biological and ecological knowledge.

4. To review and update the systematic position of Texas and southwestern snail fauna, utilizing all available data.

Previous Work

Ferdinand von Roemer, a German geologist and naturalist, sent to Texas late in 1845 at the request of Prince Solms and Baron Alexander von Hunboldt primarily to investigate possible mineral resources, published the first known list of 27 Texas mollusks in an article titled "Texas" in 1849. W. G. Binney (1865) included Texas mollusks in his "Land and Freshwater Mollusks," listing most distributions merely as "Texas." J. A. Singley, in 1893, while working for the State Geological Survey, published the first serious list of Texas mollusks, including 39 freshwater gastropod species. Most of the information was based upon his personal collection, and some specimens from private collectors. Mitchell (1895) published a similar list, and Pilsbry and Ferriss (1909) recorded 39 freshwater gastropod species.

The next major Texas list was compiled by Strecker (1935), published after his death. In it, he listed 58 aquatic species, based upon his own collections and Singley's (1893) data. A portion of Strecker's collection is in the Strecker Museum at Baylor University, Waco, Texas.

Other reports of Texas gastropod fauna, and portions of the state covered, included Wetherby (1878), East Texas Counties; Vaughn (1893), Harrison County; Dall (1897),

U. S.-Mexico boundary line; Singley (1893), Northwest Texas; Strecker (1908), McLennan County; Sterki (1912), Somervell County; Walker (1915) West and Northwest Texas; Clench (1925), Southwest Texas; Vanatta (1928, 1933), Travis, Bastrop, Live Oak, Frio, and Maverick Counties; Cheatum and Burt (1931, 1934), Ellis and Dallas Counties; Cheatum (1935), Jeff Davis County; Parks, Cory and others (1923, 1936), Southeast Texas Counties; Clarke (1938),Palo Duro Creek; Pilsbry (1944), Taylor County; Branson (1960), San Patricio County; and Wurtz and Roback (1955),Gulf Coast Rivers.

The most recent check list of gastropods by Murray and Roy (1968) principally represented earlier citations, although several previous records were omitted and much of the fossil species and literature were not treated.

Literature on Texas mollusca since 1957, primarily concerned with the Pleistocene fauna, has included Call (1884), Great Basin area; Frye and Leonard (1957), Great Plains regions, including Northwest Texas, Armstrong to Howard Counties; Taylor (1960, 1966b), High Plains; Allen and Cheatum (1961), Clay County, Wendorf (1961), Llano Estacado portions of Texas; Dalquest (1962a, 1962b, 1965), Good Creek Formation, Foard and Hardeman Counties; Leonard and Frye (1962) upper Pecos Valley; Cheatum and Allen (1963, 1965), Ben Franklin and Clear Creek faunas, North Texas; Cheatum (1966), Amistad Reservoir along the Rio Grande River; Hibbard and Dalquest (1966), Knox and Baylor Counties; Miller (1966), Southern Great Plains; Slaughter

(1966), Moore Pit local fauna; Cheatum and Slaughter (1966), Lampasas River; Metcalf (1967), near El Paso; Willimon (1972), North Central Texas.

The latest investigations by McMahon (1976, 1977) have centered around Texas freshwater gastropod population dynamics and life cycles, primarily of the Physidae and Ancylidae.

Zoogeography

Preliminary analysis indicated that Texas aquatic snail distributions did not generally pattern themselves according to specific geologic surface exposures, river systems, biomes or physiographic provinces with the exception of Blair's (1950) biotic Province concept for Texas. Most species are rather habitat specific and their distributional patterns are dictated by a combination of the above-mentioned environmental parameters. Thus, a brief discussion of Texas physiography is presented here as a basis for later analysis of Texas freshwater gastropod distribution.

Annual rainfall decreases from east to west with deep east Texas annually averaging more than 55 inches while El Paso receives less than 8 inches annually. Usually, there are more years of below-normal rainfall than there are above, and droughts are frequent (Gould, 1969). Consequently, Texas water system levels fluctuate continually, affecting especially littoral zone vegetation where most aquatic snail species occur (Hubendick, 1958).

The mean annual temperature in the lower Rio Grande Valley is 74^{o}F, while the mean in the Panhandle is 54^{o}F. The average annual frost-free period (growing season) for these two areas are 330 and 179 days, respectively. Temperatures across the state are subject to rapid changes due to fast-moving fronts year round.

Temperature does not directly eliminate snail species living within their normal geographic ranges, but the indirect effects are considerable (Harman, 1974). Primary productivity, in both the amount and quality of the produced biomass, is affected by temperature. Thus, temperature and the types and quantities of available food appear to have profound effects on the vigor, shell size, reproductive patterns and community composition of freshwater snails (Cairns, 1970; Butler et. al., 1969; Catlow, 1970; Harman and Berg, 1971; Clampitt, 1970). The interactions between temperature, dissolved oxygen and alkalinity upon aquatic snails were discussed by Hutchinson (1957).

The surface features of Texas have not appreciably changed since the last period of tectonic activity during the Miocene, roughly 15 million years B. P. This knowledge presents an interesting aspect to the origin of Texas freshwater snails, and will be discussed under that section.

The general surface relief dips from northwest to southeast. Mountains and alluvium-filled basins characterize Trans-Pecos Texas. The soils are podzolic and basic. The

Panhandle region is flat and covered with late tertiary continental debris; the soils are also basic. Central Texas from the Red River to the Balcones Escarpment, including the Edwards Plateau, is covered with extensive Cretaceous limestone exposures. The river valleys develop deep terrace deposits, usually of black, basic humus. The Coastal Plain, extending from Beaumont to Brownsville, is a broad, low region covered with Late Quaternary and Tertiary sands. The river valleys contain deep alluvial deposits of mixed soils. Tertiary and Quaternary acidic sands characterize east Texas.

The only natural lentic or near-lentic systems in Texas are Caddo Lake in northeast Texas, and some bayous and oxbows in southeast Texas. Apparently, during the Pleistocene, Texas had no large natural lakes, which has had significance for gastropod species composition. A few temporary lakes may have existed in North Central Texas, and numerous large playas were probably present in the Panhandle.

Most Texas rivers, except the Sabine, Angelina, and Neches in east Texas flow from northwest to southeast (Fig. 1), through alternating acidic and basic geologic exposures, leading to alternating substrate zones. The surface relief through which they flow is not particularly great, so even the headwater streams have moderate to slow flow, and quickly coalesce into potamon rivers. While the smaller east Texas and the springfed Balconian streams are relatively clear, most Texas lotic systems are quite turbid. Large rivers flow through alluvium-filled valleys, developing steep banks, and therefore exhibit almost no vegetated littoral zones. Aquatic gastropods are rare along these sections.

Several Texas biome or biotic province classifications have been described, principally utilizing terrestrial plant and vertebrate distributions. The major classifications are as follows: (1) Plants, Bray (1901, 1905), Carter (1931), Tharp (1939), and Gould (1962, 1969); (2) life zones, Cope (1880), Bailey (1905), and Dice (1943).

The most recent Texas biotic province classification (Fig. 2) was devised by Blair (1950), in which he divided the state into seven provinces based upon terrestrial-plant, reptile and mammal distributions. The province boundaries also roughly correspond to distinct topographic regions. Characteristic freshwater gastropod communities may also be described for each province and will be more full discussed throughout this report.

The Austroriparian Province encompasses most of east Texas west to a line from Red River County south to Harris County on the coast. The acidic sand-clay soil supports a pine and hardwood forest. Species of the eastern American freshwater family Viviparidae do not occur west in Texas beyond this province.

The Texan Province extends westward from the Austroriparian. The Balcones Escarpment forms the central boundary while the southwestern limits are determined by soil types changing from pedalfers to pedocals. To the northwest of the escarpment, the border corresponds to the western boundary of the Western Cross Timbers. The entire region constitutes a broad "ecotone" with a mixture of soil types and plant and animal species from surrounding biotic provinces. There are no unique snail species for this region. Within this province, diversity of shell size, shape and coloration within populations is more pronounced than in any other province.

The Tamaulipan Province extends from the Rio Grande River to the Balcones Escarpment to the north, and from Del Rio to near New Braunfels. The predominant vegetation is thorny brush which to the northeast grades into the prairie and hickory-oak associations of the Texan Province near the Guadalupe River. The aquatic snail species are predominantly Mexican or Caribbean in origin with the genera *Pyrgophorus* and *Drepanotrema* being the most characteristic of the province.

The Chihuahuan Province, in Texas, is an arid region extending from the Pecos River westward to El Paso. Although this province has the greatest diversity of physiographic features, vegetation, and animal species of all the state provinces, the aquatic snail fauna is depauperate. The species are all Mexican or southwestern United States in origin and are generally confined to springs (Hydrobiidae) or to artificial impoundments (Planorbidae).

The Navahonian Province is represented in the state only by the Guadalupe Mountains in Culberson County. The region contains only a few widely distributed aquatic species, and for the purposes of this paper will be considered with the Chihuahuan Province.

The Kansan Province includes all of the Panhandle to the north, the Permian Basin, south to the Edwards Plateau and east to the edge of the Western Cross Timbers. The entire surface is relatively flat and featureless, as well as being subhumid. The aquatic snail fauna is the poorest in the state. Paradoxically, during the Pleistocene, this area supported a large and diverse aquatic snail community.

The Balconian Province as first defined by Blair (1950), encompasses the Edwards Plateau, the Comanche Plateau, and the Central Mineral (Llano Uplift) region of Texas. Most of the province is covered with Commanchean Cretaceous limestone. The topography principally consists of steep-sided canyons with shallow, clear streams. The dominant vegetation is a scrub forest of Mexican Cedar-Spanish Oak-Live Oak associations. The area is extensively underlain with limestone caverns accompanied by many springs. Large subterranean aquifer systems are also present, particularly along the edge of the Balcones Escarpment.

This province, like the Texan, represents an "ecotone" with relictal sonoran and austroriparian plant and animal populations present. The only pleurocerid species, Elimia comalensis, in the state occurs in this province as well as the subterranean hydrobiid genera Horatia and Paludiscala.

CHAPTER II

MATERIALS AND METHODS

Most of Texas, except some deep eastern and southern regions, was intensively collected during 1962-1978. Potential lentic and lotic habitats were sampled, with over 50,000 miles logged on major collecting trips.

A fine mesh kitchen sieve, mounted on a long handle, was used at each collection site to sample aquatic vegetation containing snails, or to sieve mud. Vegetation and mud were examined in a white porcelain pan containing water, and snails, eggs, and egg masses were removed.

Field notes were kept, and information recorded included vegetation present, water conditions (water chemistry occasionally), bank and substrate types, associated mollusks, relative mollusk abundance, presence and abundance of egg masses and/or young, weather conditions, landowners' names and addresses, and other ecological notes for each collection locality. Collection sites were recorded in sequence in a field catalogue, which corresponded with the labels kept with specimens until material was curated into the Mollusk Collection at the Dallas Museum of Natural History.

Snails from each locality were divided into three groups for preservation. The first group was killed and held in a 70 percent isopropanol or 45 percent ethanol solution. The second was allowed to die out of water, for later removal of the animal from its shell. The third group was relaxed in a weak solution of menthol in water (made up by adding a few menthol crystals to water at time of collection). This prevented distortion of the soft animals, and when they no longer responded to a needle touch, they were placed in 70 percent isopropanol.

In addition, some live specimens were occasionally returned to the laboratory for observation in aquaria. Operculated gill-breathers were transported in aereated water, and pulmonates were kept in containers with wet mosses or sphagnum. Eggs were kept in water until studied in the laboratory. Most freshwater snail eggs badly distort when placed in any preservative; thus no attempt was made to preserve collected egg samples.

Identification of material was based primarily on dissected and prepared radulae and genitalia, and shell characteristics. Heads containing radulae were removed and kept overnight in a 5 percent NaOH solution. Tissues around the radula were thus dissolved, and the cleared radula was removed. It appeared as a thin, reflective piece of clear chitinized material. Radulae were examined in that form, prepared for SEM study, or mounted in Permount. Bash (1963) suggested immersing the buccal mass in household Clorox for preparation.

Genitalia were removed with fine dissecting scalpels, forceps and probes, and iris scissors. They were measured as follows: (1) with a Bausch and Lomb eyepiece micrometer; (2) with a Mitutoyo microcaliper. After measurement, genitalia were dehydrated through a graded ethanol series of 10, 20, 40, etc, percent, and stained for 24 hours with Delafield's Hematoxylin. They were then rinsed in water and destained in a 2 percent aqueous solution of HCl until the color became faint pink. They were then dehydrated again through the same alcohol series, cleared in xylene, and mounted in Permount or retained in a small vial in 70 percent isopropanol plus 3 percent glycerin, with the shell. Malek and Cheng (1974) gave an excellent step-by-step procedure for gastropod dissection.

Shell characters were used in differentiating taxa and in key constructions. The characters used depended upon each family under study, such as the presence or absence of apical striae in the family Ancylidae. It is now well known that external morphological characters vary widely even among members of a single population and are reliable taxonomic tools only through the generic level in most cases. Genital characters were used as much as possible, although even these characters are not totally reliable, as has recently been discovered in the family Hydrobiidae (Thompson,1977). SEM analysis of the embryonic whorl is the newest taxonomic approach to species analysis (Solem, 1974), but was not used as a taxonomic tool in this study.

The above procedures were followed with my own snail collections and almost 10,000 catalogued lots in the Dallas Museum of Natural History (DMNH) Collection. Much of this material came from the collections of E. P. Cheatum, C. D. Orchard, S. S. Haldeman, and H. A. Pilsbry. Several private collections were made available for study by C. M. Mather, E. E. Winford, G. A. Sala, and D. Harrington. Other institutional collections from the U. S. National Museum (USNM), Philadelphia Academy of Sciences (ANSP), and University of Michigan Museum of Zoology (UMMZ) were also studied.

Specimens studied by SEM were cleaned by immersing in detergent, and sonicated for 2-3 minutes. They were then mounted on a stub, placed in a vacuum evaporater and coated with 200-300 A^o gold paladium. The specimens were then studied under an ISI Scanning Electron Microscope.

Direct quotations of original species descriptions were frequently used. I simply could foresee no advantage in redescribing each species, possibly adding more confusion to the North American freshwater snail taxonomy. Also, since the paper summarizes almost all the current knowledge of Western freshwater gastropod ecology and biology, quotations from these sources were often used. The synonomies of each species reflect the original described name, major generic changes, and synonomous species cited in the Texas freshwater snail literature.

CHAPTER III

RESULTS AND DISCUSSION

Approximately 65 freshwater gastropod genera and 155 species and subspecies have been cited in the literature from Texas. I consider 38 genera and 70 species as valid taxa. Twenty-three species occur only as fossils. The Recent and Fossil groups are discussed separately.

Recent Texas Freshwater Gastropods

The present freshwater snail fauna of Texas is mostly composed of relicts, and can be generally considered geologic transients. With possible exceptions of *Physa virgata*, *Helisoma trivolvis lenta* and *Horatio micra*, there are no indigenous species. Northern species that occurred here have been extirpated, and the Mexican element is largely suppressed southward. Neotropical and Carribean species (except *Gundlachia* and *Biomphalaria*) occupy a narrow zone along the Coastal Plain. Eastern snails occur only in extreme East Texas.

Physa virgata, *Gyraulus parvus* and *Lymnaea bulimoides* are the only pulmonates that are widely distributed across the state. Only one, *Tryonia pecosensis*, is characteristic of a particular river system. Distributional associations seem to best fit Blair's (1950) Biotic Provinces. Characteristic species in each Province (Fig. 2) are (1) Kansan: *Physa virgata*, *Gyraulus parvus*, (2) Chihuahuan: *Assiminea*, *Cochiopina texana*, *Tryonia cheatumi*, *Tryonia* sp. and *Fontelicella palomasensis*, (3) Tamaulipan: *Cochliopina riograndensis*, *Drepanotrema cimex*, *Cincinnatia comalensis* and *Pyrgophorus coronatus*, (4) Austroriparian: *Viviparus georgianus*, *Viviparus intertextus*, *Viviparus subpurpureus* and *Campeloma crassula*, (5) Texan: "*Amnicola*" *peracuta*, *Helisoma trivolvis lenta*, *Gyraulus parvus* and *Stagnicola bulimoides techella*, (6) Balconian: *Horatia micra*, *Paludiscala*, *Orygoceras*, *Elimia comalensis* and *Biomphalaria obstructa*.

Living Texas Aquatic Gastropod Species
(with Regional Origins Indicated)

Subclass Prosobranchia (operculates)	
Family Assimineidae	Origin
Assiminae taylori, new species	Unknown
Family Hydrobiidae	
Fontelicella palomasensis (Pilsbry)	Neotropical
Pyrgophorus coronatus (Pfeiffer)	Neotropical
Tryonia cheatumi (Pilsbry)	Neotropical
Cincinnatia comalensis (Pilsbry and Ferriss)	Nearctic
Cochliopina riograndensis (Pilsbry and Ferriss)	Neotropical
Tryonia matheri, new species	Neotropical
"*Amnicola*" *peracuta* (Pilsbry and Walker)	Unknown
Cochliopina texana (Pilsbry)	Neotropical

Paludiscala sp.	Unknown
Horatia micra (Pilsbry and Ferriss)	Unknown
Family Orygoceratidae	
Orygoceras sp.	Unknown
Family Pilidae (introduced)	
Pomacea paludosa (Say)	Neotropical
Family Pleuroceridae	
Elimia comalensis (Pilsbry)	Western Nearctic
Family Thiaridae (introduced)	
Thiara granifera (Lamarck)	Ethiopian (Asia)
Thiara tuberculata (Muller)	Ethiopian (Asia)
Family Viviparidae	
Viviparus georgianus (Lea)	Eastern Nearctic
Viviparus intertextus (Say)	Eastern Nearctic
Viviparus subpurpureus (Say)	Eastern Nearctic
Viviparus subpurpureus tamaulipanensis, new species	Unknown
Cipangopaludina chinensis malleatus (introduced)	Ethiopian (Asia)
Campeloma crassula Rafinesque	Eastern Nearctic
Subclass Pulmonata	
Family Ancylidae	
Ferrissia californica (Rowell)	Nearctic
Ferrissia walkeri (Pilsbry and Ferriss)	Nearctic
Gundlachia radiata (Guilding)	Neotropical
Laevapex fuscus (Adams)	North and East Nearctic

Family Lymnaeidae

Stagnicola bulimoides techella (Haldeman)	Southern Nearctic
Fossaria obrussa (Say	Nearctic
Fossaria dalli (Baker)	Northern Nearctic
Pseudosuccinea columella (Say)	Nearctic

Family Physidae

Physa virgata (Gould)	Southwestern Nearctic

Family Planorbidae

Biomphalaria obstructa (Morelet)	Neotropical
Drepanotrema kermatoides (d'Orbigny)	Neotropical
Drepanotrema cimex (Moricand)	Neotropical
Antillorbis aeroginosus (Morelet)	Neotropical
Gyraulus parvus (Say)	Nearctic
Micromenetus dilatatus (Gould)	Eastern Nearctic
Micromenetus sampsoni (Ancey)	Nearctic
Helisoma trivolvis lenta (Say)	Southeastern Nearctic
Helisoma duryi (Wetherby) - introduced	Florida
Helisoma anceps (Menke)	Nearctic
Helisoma foveale (Menke)	Neotropical

Fossil Texas Freshwater Gastropods

Climatically, Texas has been profoundly affected by the 4 major North American glacial advances and retreats that have occurred since the Late Tertiary, a span of approximately 15 million years. Accordingly, Texas has experienced a continual change in the composition and quantity of its freshwater gastropod fauna even into the present.

During wet, cool, (full glacial) periods such as the Nebraskan, Kansan, Illinoian and Wisconsinan glaciations, cool-adapted northern species such as Valvata tricarinata, Stagnicola elodes, Planorbula armigera and Aplexa hypnorum invaded northern and northwestern Texas, inhabiting the clear, heavily vegetated streams. These forms were periodically removed during the hot-dry interglacial periods.

Presumably, during warmer, drier periods (interglacials), several subtropical genera such as Biomphalaria, Drepanotrema, Tryonia and Cochliopina moved northward through the State, although exact climatic conditions surrounding these dispersals can only be theorized.

Western aquatic Elimia comalensis occurred in the State during the Pleistocene, even though Pleuroceridae family distribution is mainly in the eastern United States. The absence of eastern Nearctic snails such as Viviparus and Campeloma in Texas Pleistocene deposits continues to be perplexing.

Frye and Leonard's (1957) report on 55 Texas High Plains fossil mollusks included 18 aquatic snails and 4 sphaeriid pelecypods, indicating more abundant aquatic habitats during that period. They stated that "more than 90 percent of the Kansan species no longer live" in that area of Texas. Their Illinoian fossil mollusks comprised 29 species, including 6 aquatic pulmonates and one sphaeriid pelecypod. This Illinoian fauna in Texas suggested a wetter environment with scattered timber and woody undercover vegetation. The absence of branchiate snails and the few aquatic pulmonates led to their conclusion that the water supply was either meager or unstable, unlike that of the Kansas glaciation.

Thirty-six Early Wisconsin mollusks were represented in Frye and Leonard's (1957) findings. They occurred more in lacustrine than fluviatile deposits, and were generally similar to the Illinoian fauna. Only 9 fossil mollusks were found in the Late Wisconsin, indicating increasing aridity.

The exact distributions of many of these Pleistocene aquatic species in Texas cannot be determined, for several reasons. The carbonate shell dissolves rather quickly in the acidic east and south-central Texas sands. The limestone rock-lined streams of the Edwards Plateau are not conducive to shell and alluvium deposition, and the alluvium that does occur is constantly shifted by frequent flash-flooding. Thus, the only areas in the state that do allow long-term shell preservation are in the much-studied North Central Texas, Panhandle, and Trans-Pecos regions. The southernmost fossil aquatic snail sites were discovered by Leonard and Frye (1962) in Terrell County, along the lower Pecos River. Interestingly, most of the species were northern, while very few Mexican forms were present. The deposits were Late Wisconsin in age; this leads to the speculation that perhaps the Mexican groups migrate northward during the drier, interglacial periods. Gundlachia radiata and Biomphalaria obstructa may represent extant examples of this theory. Both species presently occur in north-central Texas although neither have been found in Wisconsin deposits in this area.

Known Texas Fossil Freshwater Gastropods

a. Fossil Only:

Lymnaea stagnalis appressa (Say)

Stagnicola exilis (Lea)

Stagnicola caperata (Say)

Stagnicola elodes (Say)

Stagnicola reflexa (Say)

Birgella subglobosa (Say)

Tryonia circumstriata (Leonard and Ho)

Valvata tricarinata (Say)

Ferrissia parallela (Haldeman)

Ferrissia rivularis (Say)

Aplexa hypnorum (Linnaeus)

Armiger crista (Linnaeus)

Gyraulus circumstriatus (Tryon)

Planorbula armigera (Say)

Promenetus kansasensis (F. C. Baker)

Pomatiopsis cincinnatiemsis (Say)

b. Fossil, potentially recent:

Cincinnatia cincinnatiensis (Anthony)

Pomatiopsis lapidaria (Say)

Somatogyrus depressus (Tryon)

Tryonia pecosensis (Leonard and Ho)

Physa gyrina (Say)

Promenetus exacuous (Say)

Promenetus umbilicatellus (Cockerell)

KEY TO TEXAS FRESH-WATER GASTROPOD FAMILIES

1.a. Shell uncoiled, almost a straight tube. . .Orygoceratidae
  b. Shell patelliform (tent-shaped); almost circular with bottom side completely open; non-operculated . . . . Ancylidae, p.
  c. Shell coiled. 2

2.a. Shell sinistral (aperture opens to the left when spire is held up); non-operculated; spire elevated. . . . . Physidae, p.
  b. Shell appearing dextral (if sinistral, then spire flattened). 3

3.a. Spire flattened or depressed; shell planispiral (all whorls in one plane); non-operculated. .Planorbidae, p.
  b. Spire elevated; shell not flattened (if flattened, height less than 1 mm). 4

4.a. Shell large, height varies from approximately one to over two inches; operculated 5
  b. Shell much smaller; height less than one inch 6

5.a. Shell very large, globose; diameter of the greatly inflated body whorl almost equal to the shell height; operculum concentric; spire depressed . . . . Pilidae, p.
Note: if shell is over two inches but the spire is pointed (elevated). . . . . . Cipangopaludina (Viviparidae), p.
  b. Shell smaller; diameter about four-fifths or less of the height; outer lip not widely flared; operculum concentric; spire elevated . . . . .Viviparidae, p.

6.a. Shell turbinate; last whorl rapidly enlarging and carinated or keeled . . . . .Valvatidae, p.
  b. Shell conic, but not depressed or turbinate in form . . 7

7.a. Shell non-operculated; usually thin; conic to globose; peristome (outer lip) not forming a complete circle. . . . . .Lymnaeidae, p.
  b. Shell operculated, usually thickened; sharply conic to globose; peristome continuous or discontinuous 8

8.a. Shell length usually 10 mm or more 9
  b. Shell length 10 mm or less; surface not beaded or flatsided. 10

9.a. Shell tapering to a point; whorls flatsided and smooth; usually carinate; operculum paucispiral. . . . . Pleuroceridae, p.

b. Shell tapering to a point; whorls slightly rounded; surface beaded or with interrupted raised lines. . . . . .Thiaridae, p.

10.a. Shell conic; a single, spiral ridge along periphery of whorls; suture lines not heavily indented; surface smooth. . . . . .Assimneidae, p.

b. Shell conic or globose; surface sculpture variable but not as above. . . . . .Hydrobiidae, p.

CHAPTER IV

SYSTEMATIC ACCOUNT

Family Assimineidae H. and A. Adams, 1856

The Assimineidae belongs to the super-family Rissoacea Gray, 1847, which also includes the freshwater family Hydrobiidae and the brackish-water family Truncatellidae. Generally, most species of Assimineidae occur on mud flats in brackish and intertidal waters along coast lines. One species, *Assiminea succinea* (Pfeiffer), lives along the Texas coast and normally would not be considered in a treatment of freshwater mollusks. Recently, however, at least two isolated colonies of *Assiminea*, perhaps closely allied to *A. succinea*, have been discovered in brackish pools in the Texas Trans-Pecos area, a considerable distance from the Gulf Coast (J. Landye and D. W. Taylor, personal correspondence). The only other reports of inland occurrence of this family in the United States are from Death Valley and Inyo County, California (Taylor, 1966).

DISTRIBUTION: Although world-wide in distribution, *Assiminea* species are most diversified in eastern Asia. In North America, there are two coastal species: *Assiminea succinea* (Pfeiffer, 1840), which occurs from Massachusetts to Texas, and *A. californica* (Tryon, 1865), which lives on mud in grassy marsh areas from Vancouver Island, British Columbia, to Baja California (Abbott, 1974).

Of the known Recent North American inland forms, Berry (1947) described _A. infima_ from "Bad Water," the salt-saturated pool in Death Valley, and lowest point on the continent. Morrison (1965) suggested that another species occurred at Saratoga Springs, located near the south end of Death Valley. Taylor (1966) found an undescribed species from Panamint Valley, Inyo County, California, in the United States Geological Survey collection; fossil records have also been reported from that county (Taylor, 1966).

FAMILY CHARACTERS: A full, diagnostic family description of these amphibious snails is unnecessary, since the description of _Assiminea_ herein is also representative of the generally distributed world species. Shells are less than 10 mm in height, less than 5 mm in diameter, surface smooth with lip unexpanded along outer margin; shell brown with suture lines not deeply impressed. The spire is pointed and the umbilicus is imperforate. Larger, sculptured species, some with color bands, occur in eastern Asia (Taylor 1966). American forms were termed the _nitida_-complex by Abbott (1958).

ECOLOGY: All known inland colonies of _Assiminea_ in the United States occur around saline seeps or springs; snails may be found in or out of the water. Berry (1947) found Death Valley specimens in "saline seepage, and just out of the water crawling on blocks of salt or roots." Abbott (1958) found one strictly freshwater species, _A. thielei_, in the Phillippines, and Jutting (1963) noted that one New Guinea species,

A. *riparia*, lived on the bank of a freshwater lake. Taylor (1966) reported *Assiminea sp*. shells sent to him by C. L. Hubbs from a freshwater pool at Pozos de la Becerra, 14 km southwest of Cuatro Cienagas, Mexico. The two Texas localities appear to be brackish pools on caliche soil.

MAJOR REFERENCES: See Abbott (1958, 1974), Berry (1947), Taylor (1966).

Genus *Assiminea* Fleming, 1828

GENUS DESCRIPTION: Small, ovate, smooth shells with rounded whorls; simple outer lip and with or without a slit-like umbilicus; operculum paucispiral, chitinous; eyes on small, stubby peduncles. *Syncera* Gray is a nomen dubium (Abbott, 1974).

Assiminea succinea (Pfeiffer) (Fig. 3a).

GENERAL DISTRIBUTION: Boston, Massachusetts, to Texas, Brazil, and Bermuda (Abbott 1974).

TEXAS DISTRIBUTION: Common on intertidal mudflats along the entire Texas coast.

DESCRIPTION: 1 to 2.5 mm, ovate, smooth, light translucent-brown; about 5 rounded whorls. A single, raised, microscopic spiral ridge lies just below the neatly impressed suture. The columella flattens out over the parietal wall to form a narrow, slightly raised callus. Umbilicus very small, chinklike; outer lip thin, sharp and smooth. Shell may rarely be banded with a light brown; a common species (Abbott 1974).

ECOLOGY/BIOLOGY: unknown.

Assiminea succinea is included here primarily for future comparisons. Specimens collected in West Texas have remained undescribed, but most likely will be closely related to this coastal species. The Pecos River and Rio Grande Valleys have had long and repeated connections with Gulf waters from the Cretaceous into the Cenozoic. These colonies therefore may represent ancient relict *A. succinea*-related forms. Other such rissoid species occur in these two valleys.

Assiminea taylori new species (Fig. 3b).

TYPE LOCALITY: "Point Spring," Humble Oil Co., Fort Stockton unit; 12.5 miles North Forth Stockton, Pecos County, Texas. Holotype - DMNH 1509.

DESCRIPTION: Shell light brown to tan; height 1.84 mm; diameter 1.36 mm; spire attenuated; whorls 4.5-5, well rounded, and suture lines deeply impressed making each whorl shouldered; protoconch and first whorl clear, shiny and unsculptured; remaining whorls covered with irregularly spaced growth lines; entire surface appears reticulated, dull; lip circular; peristome complete and unreflected; umbilicus widely perforate and deep; parietal wall of peristome covers one-half of umbilical opening; lip attaches well below periphery of body whorl; faint ridges on inner whorl periphery.

HABITAT DESCRIPTION: Small, spring-fed pond almost completely choked with *Typha* sp.

DISCUSSION: *A. taylori* is smaller than *A. succinea* and the whorls are much more rounded. The aperture is smaller and more circular. The small, spiral ridge characteristic of *A. succinea* is absent in *A. taylori*. Shell color is identical. Protoconch and first whorl of *A. succinea* is not smooth and hyaline; *A. succinea* is also imperforate.

Family Hydrobiidae Troschel

The family Hydrobiidae is large, including over 100 genera and a myriad of species. About 25 genera and 175 species have been described from the United States (Thompson, 1968). The systematics of this world-wide group has recently been in a state of flux, considerably complicating my systematic treatment of Texas species. The construction of a key to the Texas species, based upon shell characters, was discouraged by Taylor and Thompson (personal communication). The use of internal structures such as the genitalia was also deemed inadvisable, due to wide ranges in individual variation recently discovered by myself and Thompson (1976).

Various members of the Hydrobiidae are notorious intermediate hosts for many human-infecting parasites. In the Orient, *Oncomelania* is the intermediate host for *Schistosoma japonicum*. In the United States, the closely related *Pomatiopsis* is a potential host for this blood fluke, and is a known host for *Paragonimus kellicotti*. *Parafossarulus* is the intermediate host for *Clonorchis sinensis* in China and Japan.

One interesting hydrobiid, *Bithynia tentaculata*, introduced around the Great Lakes in the 1800's came to be called the

"Faucet Snail." It became abundant in the antiquated water lines of several cities and frequently arrived in homes via the kitchen faucet.

FAMILY CHARACTERS: The shells of all hydrobiids are less than 15 mm, and differ greatly in form and sculpturing. They are usually small and conical, dextral, and the aperture may be complete or incomplete across the parietal wall. Shells may be transparent or opaque, and their surfaces may be smooth or highly sculptured. The periostracum usually lacks a color pattern. The operculum is simple (non-sculptured), paucispiral, multispiral or concentric, and may be membranous, chitinous, or calcarious. Its inner surface is usually smooth, and lacks a peg- or wing-like projection. The animal has two slender or stocky tentacles in which they eyes are sessile at their external bases. The otocysts contain a single otolith. The foot is longer than wide, is truncate anteriorly with projecting corners, and is rounded posteriorly. The foot does not extend beyond the snout while in locomotion. The operculigerous lobes are well developed and usually extend over the lateral margins of the foot. The gills are located on the inner surface of the mantle. The left gill is reduced to a small vestige or is absent. The right gill consists of a series of 20-50 laminae which are usually wider than high. This series begins at or near the middle of the mantle collar and extends posteriorly and to the left of the pericardium. The animals are dioecious.

The male copulatory organ (verge) originates on the middle or the right side of the nape, beneath the mantle, and may be simple and tubular, or complicated with accessory ducts, dermal glands, and appendates. In this paper, the functional end of the verge through which the vas deferens terminates is referred to as the penis. This may or may not be distinguishable from the rest of the verge as a small appendage. The female is oviparous or ovoviviparous. The eggs are laid singly or in clusters. Ovoviviparous genera in Florida have embryos in the uterus throughout the year. A free-living veliger stage is lacking, since embryonic development is completed within the egg capsule. The denticle formula of the radula is 2-1-1-1-2. The central tooth has one or more basocones on each side of the face, a large mesocone, and three or more ectocones on each side of the reflection. The lateral tooth has a large trapezoidal body with a long shaft that extends laterally. The cusps are usually differentiated into entocones, a single mesocone, and ectocones. The two marginal teeth have simple, undifferentiated cusps on the reflection. The bases of the shafts of the lateral teeth and the marginal teeth insert close together and are remote from the central tooth (Thompson, 1968).

ECOLOGY: The Hydrobiidae inhabit fresh, brackish and marine waters around the world. Species occur in rushing waters to stagnant swamps.

PALEONTOLOGY: Mexozoic to Recent.

Genus _Amnicola_ Haldeman, 1840

Amnicola limosa (Say), (Fig. 3c, d).

Paludina limosa, Say, 1817, J. Acad. Natur. Sci. Phil., 1:1 (Binney reprint, 1858).

Amnicola limosa porata (Say, 1821), Baker, 1928, Wisc. Acad. Sci., Arts and Letters pt. 1:100.

Amnicola limosa parva (Lea, 1841), Frye and Leonard, 1963, Bur. Econ. Geol. Univ. Tex. Rept. Invest., 49:16.

TYPE LOCALITY: "muddy shores of the rivers Delaware and Schuykill, between low and high water marks" (Say, 1817).

GENERAL DISTRIBUTION: "New England and New Jersey west to Utah, Manitoba south to Texas" (Baker, 1928); "from Labrador to Florida" (Berry, 1943) and westward to Utah.

TEXAS DISTRIBUTION: Fossil County Records: FOARD (Dalquest, 1962); HARDEMAN (Dalquest, 1965) (localities repeated in Cheatum and Allen, 1965); CLAY and FOARD (Frye and Leonard, 1963); KAUFMAN (Thurmond); DALLAS (Willimon, 1972). Recent County Records: "Texas" (Baker, 1928), Barton Creek, Austin, TRAVIS County (UMMZ Catalogue No. 119923); RAINS (Sala Collection).

DESCRIPTION: Shell about 4.5 mm high and 3 mm wide, thin, yellowish or greyish-brown or tan, with an ovate aperture which is about one-half its height. Whorls about 4.5, convex, slightly shouldered in many specimens, and separated by deep sutures. Spire blunt with the nuclear whorl planorboid; later whorls rounded, slightly shouldered, and gradually increasing in size. Aperture ovate, narrower at the top, and joined to the penultimate whorl by a thin callus. Umbilicus deep and of medium width. Sculpture consisting of narrow, low, crowded collabral lines. Operculum suboval, thin, pale yellowish-brown, with about 2.5 revolutions, sculptured with spiral and transverse striae and with a dark, spiral line inside of the outer border (Clarke, 1973).

ECOLOGY/BIOLOGY: Amnicola limosa (including the numerous "subspecies") occurs in lotic and lentic aquatic environments, always in association with macroscopic aquatic vegetation. It is apparently quite susceptible to forms of pollution (Clarke, 1973). It is found on sand or mud substrates. The anatomy of A. limosa has been well described by Baker (1928) and Berry (1943). The soft body is white or pinkish, with a brown streak extending down the side of each tentacle. Brown splotches occur between the eyes and on the rostrum. The verge is bifid, and the forks become very elongated when the verge is extended (Berry, 1943).

The eggs are laid singly and are usually attached to solid objects such as Typha stems. They are ovoid in shape, with both ends pointed, and with a laminate crest extending across the dorsal surface from end to end. The extended egg-laying period occurs during the warm-water season (Baker, 1928).

The shell form apparently varies in response to environmental stress. River specimens are larger than those from lake populations, and several subspecific names have been applied to these ecophenotypes. A. l. porata is the river form name and A. l. parva occurs in small lakes (Berry, 1943).

Frye and Leonard (1963) listed _A. l. parva_ from two fossil sites in Clay and Foard Counties. Baker (1928) stated that _A. l. porata_ occurred as far south as Texas.

DISCUSSION: Barton Creek was searched during this study to verify the UMMZ locality. The creek is now used as a commercial swimming area, and the colony of snails could not be relocated. Thus, it could not be determined if _A. limosa_ was natural or introduced.

Other than Baker's (1928) general distributional statement of "Texas" for _A. limosa_, this is the first report for this species in the State. It now appears that _A. limosa_ is generally distributed in east Texas.

Genus _Birgella_ F. C. Baker, 1926

Birgella (_Somatogyrus_) _subglobosa_ (Say), (Fig. 3e).

Paludina subglobosa Say, 1825, J. Phil. Acad. Natur. Sci., 5:25.

Birgella subglobosa (Say), F. C. Baker, 1928, Wisc. Geol. and Natur. Hist. Surv. Bull. 70, pt. 1:154.

TYPE LOCALITY: "Northwestern Territory" (Say, 1825).

GENERAL DISTRIBUTION: Living forms are probably confined to the Great Lakes Region (Baker, 1928).

TEXAS DISTRIBUTION: Fossil County Records - Gifford-Hill 2a Local Fauna, DALLAS (Willimon, 1972). No modern records.

DESCRIPTION: Shell subglobose to globose, rather solid, depressed; color yellowish-horn to grayish, under a corneous periostracum; sculpture of fine to coarse, oblique crowded growth lines; whorls four, convex, separated by deep sutures, rapidly increasing in diameter, the last whorl very large, ventricose; spire broad, depressed-conic, usually much shorter than the aperture; apex slightly raised above the second whorl, the nuclear whorl rounded, sculptured, at first wrinkled or malleated, then punctate, punctate-lirate above, and lirate below; aperture roundly ovate, somewhat angular above, somewhat produced below; peristome sharp, thin, continuous, flattened and appressed to the parietal wall above; the columellar lip forms a sharp, erect emargination to the narrow but distinct and deep umbilicus (Baker, 1928).

ECOLOGY/BIOLOGY: *Birgella subglobosa* is a lake-dwelling hydrobiid, according to Baker (1928), occurring primarily on sand-gravel substrates.

DISCUSSION: The specimens identified by Willimon as *B. subglobosus* cannot be located (personal communication). However, due to its distinctive form (10 mm diameter, swollen body whorl, flared lower and outer lip), there is no reason to doubt the identification.

Genus *Cincinnatia*, Pilsbry, 1891

Cincinnatia (*Amnicola*) *comalensis* (Pilsbry and Ferriss), (Fig. 3f).

Amnicola comalensis Pilsbry and Ferriss, 1906, Proc. Phil. Acad. Natur. Sci. Phil., 58:171, fig. 37.

Cincinnatia comalensis (Pilsbry and Ferriss), Taylor, 1975, unpublished.

TYPE LOCALITY: "Comal Creek, near New Braunfels, Comal County, Texas. Also from the Guadalupe River about four miles above New Braunfels" (Pilsbry and Ferriss, 1906).

GENERAL DISTRIBUTION: Endemic to Texas.

TEXAS DISTRIBUTION: Recent County Records: Coastal Plain, Frio River, Nueces River; from the Guadalupe River southward to the Rio Grande drainage (Taylor, 1975, in litt.); COMAL (Walker, 1918), Strecker (1935); KERR (DMNH Coll.).

DESCRIPTION: "Shell distinctly perforate, ovate, thin, corneous, the apex obtuse. Whorls 4.5, regularly convex, not shouldered, the suture well impressed. Aperture ovate, subangular above, the peristome adnate for a short distance above the perforation. Height 2.9 mm, diameter 2 mm; length of aperture 1.3 mm" (Pilsbry and Ferriss, 1906).

ECOLOGY/BIOLOGY: C. comalensis appears to be restricted to the streams and rivers flowing across the Texas southern coastal plains and up onto the Edwards Plateau. It is usually found in soft mud-detritus where algae is abundant. Otherwise, there is no knowledge of its anatomy, ecology, or life history.

DISCUSSION: Taylor found *C. comalensis* abundant in the Frio and Nueces Rivers on the Coastal Plain. Pilsbry and Ferriss (1906) stated that, "this species is much smaller than *A. limosa*, *decisa*, or other forms resembling it in color and shape. *A. cincinnatiensis* Anthony and the very closely related *A. peracuta* both have more shouldered whorls, and are much larger than *C. comalensis*." Taylor (1975, unpublished) stated than C. comalensis is a Texas coastal plain species. It is most common in this region, but I also found it in the larger streams on the Edwards Plateau.

Cincinnatia cincinnatiensis (Anthony), (Fig. 3g, h).

Paludina cincinnatiensis Anthony, 1840, Boston. J. Natur. Hist., 3(1-2):279, pl. 3:3.

"Cincinnatia (Paludina) integra (Say, 1821)" of authors Cincinnatia cincinnatiensis (Anthony), Baker, 1898, Nautilus, 12:65,

TYPE LOCALITY: "Canal at Cincinnati, Ohio" (Anthony, 1840).

GENERAL DISTRIBUTION: New York and Pennsylvania, west to southern Manitoba, southern Saskatchewan, North Dakota, Utah and Texas (Clarke, 1973); "Texas," (Baker, 1928).

TEXAS DISTRIBUTION: Fossil County Records, all records as Cincinnatia or Amnicola integra (Say): DENTON and DELTA (Cheatum and Allen, 1961, 1963); KAUFMAN (Thurmond, 1967); MOTLEY and DELTA (Cheatum and Allen, 1965); HARDEMAN, MOTLEY, BELL, DALLAS, FOARD, COOKE, HALL, DELTA and DENTON (DMNH Coll.); BROOKS (Hubricht Coll.).

DESCRIPTION: Shell up to 6 mm height, approximately 70 percent as wide as long, solid, light brown in color, with roundly ovate aperture that is about one-half as wide as height of the shell. Whorls up to about 6, convex, shouldered, and separated by deeply incised sutures. Spire broadly conic with nuclear whorl elevated and forming a roundly pointed apex. Aperture roundly ovate, narrowed above, and with a continuous peristome. Umbilicus wide and deep.

Sculpture consisting of fine collabral lines and striae. Operculum thin, paucispiral, and like that of Amnicola limosa, but without spiral striations (Clarke, 1973).

ECOLOGY/BIOLOGY: Cincinnatia cincinnatiensis inhabits streams, usually with moderate to slow flow. The substrate may be soft mud or sand-gravel, always with abundant algae and macrophytic vegetation present (Baker (1928) and Branson (1961). The food is chiefly diatoms (Berry, 1943). Leonard (1959) found C. cincinnatiensis in only three counties in Kansas, while Branson (1961) recorded it in nine Oklahoma Counties. Branson (1961) also stated that immature snails could be found the year round.

DISCUSSION: Cincinnatia cincinnatiensis is a fairly common fossil in Pleistocene deposits across a large portion of North Texas and southward to Bell County. However, it probably will be found alive in the streams of northeastern or central Texas. Its former southernmost range in the state cannot be determined from the fossil records, but it is strongly suspected that relict colonies might exist in some northern Hill County streams. It was determined during this study that most live specimens previously cited as C. cincinnatiensis were C. comalensis.

Genus Cochliopina Morrison, 1946

Cochliopina riograndensis (Pilsbry and Ferriss), (Fig. 5a, b).

Cochliopia riograndensis Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil., 58:171, pl. IX, Figs. 10-13.

Cochliopina riograndensis (Pilsbry and Ferriss), Taylor, 1975, unpublished.

TYPE LOCALITY: "Drift debris of Rio San Felipe near the Rio Grande, Val Verde County, Texas, thirty-six specimens" (Pilsbry and Ferriss, 1906).

GENERAL DISTRIBUTION: Gulf of Mexico drainages from Nueces River, Texas, southwestward to Rio Panuco, San Luis Potosi, Mexico.

TEXAS DISTRIBUTION: Fossil County Records: TERRELL (Leonard and Frye, 1962). Recent Records: VAL VERDE (Pilsbry and Ferriss, 1906); ? (Walker, 1918); Devil's, Pecos and Neuces Rivers (Strecker, 1935); VAL VERDE (Taylor, 1966); KINNEY and VAL VERDE (UMMZ Coll.); UVALDE and ZAVALA (Taylor, 1975, in litt.).

DESCRIPTION: Shell depressed-turbinate shaped, openly umbilicate, of a slightly olivaceous, corneous tint. Surface faintly marked with growth lines, and sculptured with unequal spiral threads, a few of the larger ones dark colored. One thread at the shoulder is usually the most prominent. In some shells, the spirals are very weak, hardly perceptible. Whorls 3.5, moderately convex, flattened and sloping below the suture, elsewhere rounded. Aperture quite oblique, rotundly ovate, peristome thin, equally arched near the outer and columellar insertions, where noticeably straightened. Ends connected across parietal wall by a thin or thick callus. Columella not noticeably thickened. Measurements of type lot series by Pilsbry and Ferriss (1906), height 2.0, diameter 2.8 mm, height 1.65, diameter 2.65 mm (Pilsbry and Ferriss, 1906).

ECOLOGY/BIOLOGY: Leonard and Ho (1960) recorded the first living colony of *C. riograndensis* in Independence Creek, Terrell County, Texas. The snails appeared restricted to areas of relatively sluggish water in the fast-moving stream. They stated that it was abundant under limestone rocks, logs, and in the aquatic vegetation.

Taylor (1966) found it in a similar habitat beside the Devil's River at Bakers Crossing, Val Verde County. Snails were most abundant in the soft mud bottom of a seepage-fed pool where *Chara* and *Myriophyllum* were abundant. He also discovered that specimens out in the stream were smaller and less conspicuously banded than those in the pool. Taylor (1975, unpublished) also found living colonies along the upper East Nueces and Nueces Rivers. Ecology of this species is otherwise unknown.

DISCUSSION: *Cochliopina riograndensis* is easily recognized by the banding on the tiny shell. The genus is almost exclusively Central American in distribution, with *Cochliopina riograndensis* representing the northernmost species. Isolated colonies occurred sporadically along rivers, although individuals were abundant within each colony.

Cochliopina (*valvata*) *guatemalensis* (Morelet), (Fig. 5c), was reported by Mearns (*in* Strecker, 1935) from Fort Clark, Kinney County. This species resembles *C. riograndensis*, and its type locality is Rio Michatoya, near Istapa, Guatemala. I have examined shells of both species, and *C. riograndensis* is smaller with a more elevated spire. Thus, *C. guatemalensis* can be discarded as a valid Texas species.

Cochliopina texana (Pilsbry), (Fig. 5d).

Cochliopa texana Pilsbry 1935, Nautilus 48(3):91-92.

Cochliopina texana (Pilsbry), Taylor, 1966, The Veliger, 9(2):214.

TYPE LOCALITY: "Phantom Lake near Toyahvale, Reeves County, Texas. Collected by Prof. E. P. Cheatum" (Pilsbry, 1935). Holotype: ANSP 163887.

GENERAL DISTRIBUTION: Endemic to Texas.

TEXAS DISTRIBUTION: Known only from the Type Locality cited above, and nearby Balmorhea Springs.

DESCRIPTION: "The shell is minute, umbilicate, turbinate; olive to olive-brown, the first 1.5 whorls white or nearly so. Whorls 3-1/3, convex, the last evenly rounded peripherally. Suture rather deeply impressed. Sculpture of very weak growth lines, not everywhere visible. Umbilicus narrow within, somewhat funnel-shaped in the last whorl, bounded by an angle which defines a lunate, excavated area behind the columellar lip. The aperture is oblique, broadly ovate, subangular posteriorly. Columellar margin adnate to the preceding whorl for only a short distance, thickened within, far less arcuate than the outer margin. Length 1.45 mm, diameter 1.5 mm" (Pilsbry, 1935).

ECOLOGY/BIOLOGY: Cochliopina texana and Tryonia cheatumi occur together in Phantom Lake. Dundee and Dundee (1969) found C. texana outnumbering T. cheatumi 12:1. Cheatum (1935) made this same observation. They also found that Pilsbry's (1935) holotype measurements were much larger than the measurements they made on a series of *C. texana*. Apparently, both species feed almost exclusively on the diatom, *Opephora martyi*.

I have periodically collected this site from 1971 to 1977 and have observed no change in the above ratio of *C. texana* to *T. cheatumi*. Both species occur along the cement viaduct from the lake to just beyond Toyahvale, about five miles distant.

Genus *Horatia* Bourguinat, 1887

Horatia micra (Pilsbry and Ferriss), (Fig. 5e).

Valvata micra Pilsbry and Ferriss 1906, Proc. Acad. Natur. Sci. Phil. 58:172, pl. 5-9.

Valvata micra nugax Pilsbry and Ferriss 1906, Proc. Acad. Natur. Sci. Phil. 58:17, pl. IX, Fig. 6.

Horatia micra (Pilsbry Ferriss), Pilsbry, 1916, The Nautilus, 30:83.

TYPE LOCALITY: "Drift debris of the Guadalupe River about four miles above New Braunfels, collected by Pilsbry and Ferriss, 1903" (Pilsbry and Ferriss, 1906).

GENERAL DISTRIBUTION: Subterranean aquatic systems of Central Texas and near Fort Payne, DeKalb County, Alabama.

TEXAS DISTRIBUTION: Recent County Records: (all as drift specimens) San Marcos, HAYS (Hubricht, 1940); TRAVIS (Hubricht, personal communication); Helotes Creek, BEXAR (Walker, Wetherby, *in* Strecker, 1935); KENDALL (DMNH Coll.) Live specimens - REAL (Taylor, 1974); HAYS and BEXAR (DMNH Coll.).

DESCRIPTION: "Shell excessively small, composed of 2.5 tubular whorls; spire nearly flat; the last whorl is nearly round, barely or not quite in contact with the preceding at the aperture, near which it enlarges more rapidly. Suture deep; surface finely, weakly striate. Aperture moderately oblique, subcircular, the peristome simple, continuous. Umbilicus ample but rapidly narrowing within. Alt. .48 mm, diameter 1.15 to 1.2 mm.

Horatia micra nugax, a slightly larger form, height .9 mm, diameter 1.5 mm, with three whorls and a projecting spire, may prove to be a distinct species; but for the present, until more specimens are found, it may be placed under V. micra as a variety or form" (Pilsbry and Ferriss, 1906).

ECOLOGY/BIOLOGY: Unknown.

DISCUSSION: This intriguing subterranean genus Horatia is the least-known group of Texas freshwater snails. They apparently inhabit an extensive portion of the Hill Country underground aquifer systems. I have not found them in any of the large number of Central Texas "wet" caves I have searched.

Genus Paludiscala Taylor, 1966

Paludiscala sp., (Fig. 5f).

GENERAL DISTRIBUTION: Cuatro Cienagas, Coahuila, Mexico and San Antonio, Bexar County, Texas.

TEXAS DISTRIBUTION: Verstraeten Well, San Antonio, Texas.

DESCRIPTION: Genus: "Shell turriform, about 2.1 to 2.5 mm long, 1.0 to 1.2 mm wide, with 6.5 to 7.5 whorls ovate in cross-section and separated by a deeply incised suture.

Sculpture consists of opisthocyrt lamelliform costae, about 12 per whorl, that are crescentic in profile and highest on the shoulder of the whorl. Base narrowly phaneromphalous. Aperture ovate, in adult shells simple, with no flare of outer lip or callus inside; simply adnate to preceding whorl. Apex blunt; protoconch of 1 whorl, smooth" (Taylor, 1966).

ECOLOGY/BIOLOGY: Unknown.

DISCUSSION: Taylor found the first shells of *Paludiscala* around springs at Cuatro Cienagas, Mexico. In April, 1977 Mr. H. Karnei recovered shells from a very fine mesh net placed over the artesian well pipe outlet in San Antonio.

Details of this exciting discovery are in press by Fullington and Longley and will not be elaborated here. The tiny shell is strongly similar to the marine genus *Epitonium*. No live specimens have been recovered.

Genus *Pomatiopsis* Tryon, 1862

Pomatiopsis lapidaria (Say), (Fig. 4i).

Cyclostoma lapidaria Say 1817, J. Phil. Acad. Natur. Sci., I:13.

Pomatiopsis lapidaria (Say), Binney, 1865, Land and F. W. Shells N. A., III:93.

TYPE LOCALITY: Unknown.

GENERAL DISTRIBUTION: Widely distributed over the eastern United States, east of the Rocky Mountains, including New Mexico, Oklahoma and Louisiana.

TEXAS DISTRIBUTION: Fossil County Records: WILBARGER (Hanna, 1923); DELTA (Cheatum and Allen, 1961); CLAY (Cheatum and Allen, 1965); COOKE (DMNH Coll.).

DESCRIPTION: "(Shell) elongated, turreted; color dark brownish horn or chestnut; surface dull to shining, lines of growth crowded, slightly wrinkled in some specimens, rather fine; apex rounded, flattened, depressed; nuclear whorl not emergent, partly embraced by the second whorl, not much constricted by the suture, sculpture very finely granular, almost smooth; whorls 7, well rounded, slowly and regularly increasing in diameter; sutures deeply impressed; spire acute, about three times as long as aperture; aperture elongate ovate, somewhat narrowed and angled above, rounded below, slightly expanded, somewhat purplish within; peristome simple or slightly thickened within, upper terminations connected on the parietal wall by a callus of greater or lesser thickness; umbilicus well marked, emargined by the inner lip which is slightly reflected over the umbilical region; base rounded" (Baker, 1928).

ECOLOGY/BIOLOGY: Pomatiopsis lapidaria is anatomically similar to the Asiatic Oncomelania, an intermediate host of Schistosoma japonica. Abbott (1948) suggested that P. lapidaria might also be a host in the Americas. Berry and Rue (1948) demonstrated that it could serve as a host under laboratory conditions. The snail is also host for the American lung-fluke Paragonimus kellicotti. Thus, P. lapidaria has received considerable attention, and its ecology and biology are well known (Baker, 1931; Ameel, 1938; Abott, 1948; Berry and Rue, 1948; DeWitt, 1952 and Dundee, 1957).

DISCUSSION: I believe that *P. lapidaria* exists in east Texas. Sogandares-Bernal and Abdel-Malek (1961) reported it in Louisiana, as did Branson (1961) for southeastern Oklahoma. Like most of the North American hydrobiids, it is quite small and often overlooked. It particularly prefers fallen mats of *Typha*.

Getz and Hibbard (1965) reported *Pomatiopsis lapidaria* from a deposit in Baylor and Knox Counties. I was not able to examine the specimens which may have been a young *P. lapidaria*.

P. lapidaria is limited to marshy seepages accompanied by dense growths of grasses, sedges and especially cattails (*Typha*). It lives a semiaquatic life, often found in large numbers at the water's edge. Getz (1962) stated that northern *P. lapidaria* is always associated with the meadow vole *Microtus pennsylvanicus*. The Rice Rat (*Oryzomys palustris*) occupies a similar habitat in Texas and might provide a clue in finding *P. lapidaria* alive in the state.

Genus *Pyrgophorus* Ancey, 1888

Pyrgophorus coronatus (Pfeiffer), (Fig. 3i-m).

Paludina coronata Pfeiffer, 1849, Wiegem. Archiv. fur Naturg., 1:253. Not *P. coronatus* (Ancey, 1888).

Pyrgophorus (*Pyrgulopsis*) *spinosus* Call and Pilsbry, 1886, Proc. Davenport, Acad. Natur. Sci., 5:14. Type Locality: Comal Creek, New Braunfels, Comal County, Texas.

Pyrgophorus spinosus brevispira (Ancey, 1888), Bull. Soc. Mala. France 5:193. Type Locality: Comal Creek, New Braunfels, Comal County, Texas.

Hydrobia texana Pilsbry 1887, Proc. Davenport Acad. Natur. Sci. 5:33, pl. 3, Figs. 1-6. Type Locality: Guadalupe River and Comal Creek, Comal County, Texas. Referred by Pilsbry (1891) as P. spinosus.

TYPE LOCALITY: Matanzas, Prov. Matanzas, Cuba (according to Aguays and Jaume, 1947).

GENERAL DISTRIBUTION: The exact range is unknown. Cuba, Mexico and South Texas.

TEXAS DISTRIBUTION: Recent County Records - Frio River, McMullen and Nueces River, JIM WELLS (Taylor 1975, in litt.); COMAL (Call and Pilsbry, 1886); HIDALGO and CAMERON (DMNH Coll.).

DESCRIPTION: The shell is spinose to smooth (Pilsbry's Hydrobia texana). Spines, when present, are calcerous, blunt projections from the shoulder of the shell. Smooth shells have shallower sutures, and usually have a broadly conical form and larger aperture, than in smooth Tryonia. The strong plicate, cancellate, or lirate sculpture of many forms of Tryonia is unknown in Pyrgophorus (Taylor 1966, description of the genus Pyrgophorus).

Shell finely perforated, conoidal-elongate, delicate, pellucid, grayish, under an epidermis that is greenish-horn, very finely striated, and supplied with spiral lines; the spire is conic, pointed; first 5.5 to 6 whorls of the spire convex, separated by a rather deep suture, depressed on its upper part and displaying a series of spiniform tubercles which show themselves upon the epidermis and consequently form a part of the shell; the last turn of the spire equals about 2/5 of its total length; furnished with either a spiny carina or a simple straight one; the prominences on the carina may be arranged spirally and more or less elevated. The aperture is oval, little angulated on its upper portion; the lip re-united by a delicate callus and acute, slightly sinuous; operculum thin, translucent, few spirals. Length of the shell 5 mm; greatest diamter is 2.5 mm. Length of aperture 2.0 mm; breadth 1.5 mm.

ECOLOGY/BIOLOGY: *P. coronatus* appears to be an exclusively lotic snail; its ecology and biology are otherwise unknown.

DISCUSSION: The spinose and smooth shell variation has led to much taxonomic confusion in this species. Two names were applied to these variations along Comal River, less than three miles long. Dall (1896) and Goodrich (1934) have suggested that the tendency toward spination in freshwater snails relates to increasing alkalinity. Boycott (1929, 1930) found that the inheritance of spines in *Hydrobia jenkinsi* was correlated with "bad" conditions. Unfortunately, the Comal River has been destroyed as a natural habitat by commercialism, along with its aquatic snails, precluding investigations on the above problem. Along the Guadalupe River I have generally found smooth forms in quieter backwaters, and the spinose forms in faster waters, particularly in riffle areas.

Martens (1899) and Pilsbry (1934) first suggested the synonomy of *P. spinosus* and *P. coronatus*. The suggestions have not been generally accepted although the two forms are identical. *P. coronatus* was described from Cuba while *P. spinosus* was described from Texas, and there has been a tendency to retain the two species simply because of this. I found no significant differences between Texas shells and Cuban shells made available to me; thus, I am applying the earliest name, *P. coronatus* to Texas forms. The penial complex in *P. coronatus* was found to be quite variable (Figs. 16a-e).

Genus *Somatogyrus* Gill, 1863

Somatogyrus deppressus (Tryon), (Fig. 4a).

Amnicola depressa Tryon 1862, Proc. Phil. Acad. Natur. Sci., p. 276.

Somatogyrus deppressus (Tryon), Gill, 1863, Proc. Phil. Acad. Natur. Sci., p. 34.

TYPE LOCALITY: "Mississippi River, Davenport, Iowa" (Tryon, 1862).

GENERAL DISTRIBUTION: "Not clearly known. Authentic material. . . . Wisconsin, Iowa and Illinois" (Baker, 1928).

TEXAS DISTRIBUTION: Fossil County Records - Ben Franklin Local Fauna, DELTA 9,550 B. P. (Cheatum and Allen, 1965).

DESCRIPTION: Suborbicular, somewhat elongated, rather solid; color whitish corneous, subhyaline; sculpture of fine, close-set striae of growth; whorls about 4, convex, somewhat turban-shaped, rapidly increasing in diameter; sutures well impressed;

spire broadly conic, a trifle shorter than the aperture; apex rather blunt, slightly everted above the second whorl; nuclear whorl rounded, obliquely flattened, not constricted by the suture, the sculpture punctate or malleated, without lirae; body whorl large, convex; aperture roundly ovate, very slightly constricted above, where it projects forward conspicuously; peristome continuous, appressed to the parietal wall for a short distance above; inner lip flattened, rather wide, reflected over the small, narrow umbilical chink which it emargines (Baker, 1928).

ECOLOGY/BIOLOGY: Somatogyrus depressus is primarily a lake inhabitant, although it does occur in river backwaters. The substrate is most often mud under abundant vegetation.

DISCUSSION: The single Pleistocene deposit in far northeast Texas indicates that S. depressus was an eastern snail that barely entered Texas during glacial periods. Its shell is easily identified by small size, enlarged body whorl and greatly flared outer lip.

Genus Tryonia Stimpson, 1865

Tryonia cheatumi (Pilsbry), (Fig. 4b).

Potamopyrgus cheatumi Pilsbry, 1935, Nautilus, 48:91, text fig. 4.

Tryonia cheatumi (Pilsbry), Taylor, 1966, the Veliger, 9(2):214.

TYPE LOCALITY: "Phantom Lake, near Toyahvale Reeves County, Texas" (Pilsbry, 1935).

GENERAL DISTRIBUTION: Genus *Tryonia*: high Plateaus of southwestern North and Central America. *Tryonia cheatumi* is known only from the type locality.

TEXAS DISTRIBUTION: REEVES County (Cheatum, 1935, Strecker, 1935, Dundee and Dundee, 1969).

DESCRIPTION: The shell is imperforate, long-conic, brownish olive to a grayish olive, the early whorls white by erosion of the surface. Surface rather dull; where unworn, showing very weak lines of growth, usually scarcely visible. The whorls are strongly convex. The aperture is ovate, contained about three times in the length in large specimens, relatively larger in immature shells. The columella is slightly thickened, spreading a little in the umbilical region. Parietal callus thin, adnate. Height 3.75 mm, diameter 1.75 mm, aperture is 1.3 mm; 5.5 whorls.

ECOLOGY/BIOLOGY: Dundee and Dundee (1969) found the digestive system of *T. cheatumi* packed with the diatom *Opephora martyi*. Specimens were taken from the type locality where Cheatum (1935) had mentioned that the original stream was covered with *Chara* and a marl-forming alga. Dundee and Dundee in 1969, found little *Chara*, even though the water hardness was 830 ppm, the apex of most *T. cheatumi* shells were eroded, as were those of co-inhabitant "*Cochliopa*" *texana*.

I last visited Phantom Lake in August, 1976, and found abundant populations of *T. cheatumi* and "*C.*" *texana* at the type locality, and further down the connecting cement irrigation canal.

DISCUSSION: Other hydrobiid populations have recently been discovered by the author around the east side of the Davis Mountains. This area is also a major migratory waterfowl pathway, and most probably the tiny hydrobiid populations, like *T. cheatumi* and "*C.*" *texana* at Phantom Lake, all are of Mexican origin.

Tryonia circumstriata (Leonard and Ho), (Fig. 4f).

Calipyrgula circumstriata Leonard and Ho 1960, Nautilus 73:125, pl. figs. 1-3.

Tryonia circumstriata (Leonard and Ho), Taylor, 1966, the Veliger, Vol. 9(2):214.

TYPE LOCALITY: "Surface IV sediments situated a quarter of a mile above the mouth of Independence Creek on the Chandler Ranch, Terrell County, Texas" (Leonard and Ho, 1960).

GENERAL DISTRIBUTION: Late Pleistocene Terrace deposits along the lowest Pecos River, Texas.

TEXAS DISTRIBUTION: Fossil County Records: TERRELL (Leonard and Ho, 1960); TERRELL and PECOS (Leonard and Frye, 1962); VAL VERDE (Hubricht Coll.).

DESCRIPTION: Shell minute (less than 5 mm in length), narrowly conic, imperforate, having 7 well-rounded whorls; aperture ovate, narrower and angulate above; peristome simple, slightly reflected over umbilicus and adherent to last whorl above; protoconch of one and one-half whorls finely granulose, remaining whorls bearing narrow, somewhat irregularly spaced spiral ridges ranging in number from 3 on second whorl to 12 on last; last three whorls having a few indistinct vertical ridges crossing spiral sculpture; extremely fine and numerous vertical growth lines apparent on all whorls save protoconch; suture simple, well incised (Leonard and Ho, 1960).

ECOLOGY/BIOLOGY: Tryonia pecosensis is abruptly replaced by T. circumstriata in lotic deposits along the Pecos River (Leonard and Frye, 1962). They concluded that T. circumstriata must have been an inhabitant of clear, fast water, since it was associated with fossil Cochliopina riograndensis, which still occurs in the rapidly flowing Independence Creek.

Tryonia diaboli (Pilsbry and Ferriss).

Paludestrina diaboli Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil. 58:170.

Tryonia diaboli (Pilsbry and Ferriss), Taylor, 1975, Univ. Mich. Mus. Paleon., No. 10:74.

TYPE LOCALITY: "Drift debris of the Devil's River, about four miles from its mouth, Val Verde County, Texas" (Pilsbry and Ferriss, 1906).

GENERAL DISTRIBUTION: Endemic to Texas.

TEXAS DISTRIBUTION: 1 drift shell from Rio San Felipe, near Del Rio, VAL VERDE (Pilsbry and Ferriss, 1906); Phantom Lake and Balmorhea State Park, REEVES (Berry, 1947); SOMERVELL (Sterki, 1912).

DESCRIPTION: "Shell very slender, turrite, shaped about like P. seemanni; composed of 4.5 very convex whorls separated by a deep suture. Surface smooth. Aperture vertical, oval, a trifle narrower above than below, but not angular there.

Peristome continuous, barely in contact with the preceding whorl for a short distance near the upper end. Umbilicus small but distinct." Length 1.3 mm, diameter .62 mm (Pilsbry and Ferriss, 1906).

ECOLOGY/BIOLOGY: Unknown.

DISCUSSION: The inclusion of _T_. _diaboli_ in this report is for historical purposes only. No specimens could be located in any Museum or University contacted during this study. The hand-drawn illustration in Pilsbry and Ferriss (1906) closely resembles an immature _T_. _pecosensis_, except that it appears to be smooth-surfaced. The validity of this taxon will remain uncertain until living material or empty shells can be collected for study. The Somervell and Reeves Counties reports are doubtful. Dundee and Dundee (1969) stated that they could not find _T_. _diaboli_ at Phantom Lake, nor could I after several attempts.

Tryonia _matheri_, new species.

A tiny, undescribed fossil hydrobiid was discovered in the private freshwater snail collection of Dr. Charles M. Mather, loaned to me for use in this study. The specimen was taken from drift along the Nueces River in Zavala County by Dr. Mather on 18 April, 1975. Its shell approaches _Tryonia_ _diaboli_ (Pilsbry and Ferriss) in size, but has surface sculpturing similar to _Tryonia_ _circumstriata_. Otherwise, the specimen is quite distinct and clearly deserves specific rank.

TYPE LOCALITY: Drift, Nueces River, about 12 miles south of Uvalde at Highway 83, Zavala County, Texas.

Holotype: Holotype - DMNH 1201.

DESCRIPTION: Shell turriform; minute, height 1.7 mm, diameter 0.82 mm; umbilicate; 5.5 whorls; protoconch swollen, 1.5 turns, surface smooth, with fine granulations; remaining whorls with regularly-spaced, raised growth lines; large, medial spiral ridge continues to aperture, but not affecting its shape; two smaller, evenly-spaced spiral carinae lie below large ridge but none above; spiral threads between smaller carinae, 3 threads lie above ridge; raised growth lines do not cross over spiral ridge but do cross over spiral threads. Whorls well rounded, and suture deeply impressed; aperture holostomous and rounded; lip simple, thin and slightly reflected, barely extending to umbilicus; lip separated from body wall except barely adnate along upper parietal section.

DISCUSSION: Several similar-sized and shaped hydrobiids have been reported in south Texas, east of the Pecos River. _Tryonia protea_ and _Durangonella seemanni_ (Frauenfield) were reported from drift in the Nueces River drainage (see Discussion under _T. pecosensis_). _T. protea_ is larger than _T. matheri_ and is unsculptured. It also occurs no further east than Arizona. _D. seemanni_ is known only from Durango, Mexico and is also much larger (height 10 mm). Both of these species are about the size and general shape of _T. pecosensis_ and _T. circumstriata_, and I share the opinion of D. W. Taylor that Ferriss mixed field labels between his Pecos River and Nueces River material, and had actually collected _T. pecosensis_ and _T. circumstriata_, two species undescribed until 1960.

The minute _T. diaboli_ described by Pilsbry and Ferriss (1906) is similar to _T. matheri_ but has more whorls and is completely smooth. _T. matheri_ most closely resembles _T. circumstriata_ in shell sculpture, but is a fraction of its size and is broadly umbilicate, whereas _T. circumstriata_ is imperforate. The new species is named after its discoverer, Dr. Charles M. Mather.

Tryonia pecosensis (Leonard and Ho), (Fig. 4e).

Calipyrgula pecosensis Leonard and Ho 1960, Nautilus p. 125, pl. 12, figs. 1-3.

Tryonia pecosensis (Leonard and Ho), Taylor, 1966, the Veliger, 9(2):214.

TYPE LOCALITY: "Surface IV sediments exposed in Channel bank of Pecos River, 3.5 miles northeast of Imperial, in Crane County, Texas" (Leonard and Ho, 1960).

GENERAL DISTRIBUTION: Springs at Roswell, New Mexico. Pleistocene or Holocene, thence down the Pecos River Valley, Texas (Taylor, unpubl.).

TEXAS DISTRIBUTION: Fossil County Records: CRANE (Leonard and Ho, 1960); TERRELL, REEVES, CRANE and WARD (Leonard and Frye, 1962); PECOS and WARD (Taylor, 1966).

DESCRIPTION: "Shell elongate-conic, imperforate, small (total length, 4.42 mm, diameter, 1.27 mm), last whorl relatively large, comprising approximately one-half the total length of shell; spire narrow, slender, tapering gradually to relatively blunt apex; aperture ovate, higher than wide (height, .0197 mm, diameter 0.71 mm); peristome simple, inner margin reflected over umbilicus, and closely adherent to last whorl above; whorls 8, well rounded at periphery; suture simple, deeply incised; one and one-half apical whorls finely granulose having waxy texture, remaining whorls having closely spaced, delicate, vertical growth ridges not clearly visible without magnification, and with delicately incised spiral grooves, visible only with high magnification" (Leonard and Ho, 1960).

ECOLOGY/BIOLOGY: Based only upon fossil data, Leonard and Frye (1962) postulated that T. pecosensis must have inhabited slack-water streams, ponds, or ox-bow lakes. However, discovery of living populations around unnamed springs at Roswell, New Mexico, indicates that it is a crenophile.

DISCUSSION: Literature records on the slender, highly coiled Tryonia complex in the Trans-Pecos region are confusing, and a detailed discussion is in order to clarify the situation. Pilsbry and Ferriss (1906) reported Durangonella (Paludestrina) seemanni (Frauenfield) from drift in the Pecos River, Val Verde County. Later, Ferriss (1924) reported D. seemanni and Tryonia protea (Gould), (Fig. 4g), from drift in the "Nueces River drainage" (Uvalde County?). Later, in 1960, Leonard and Ho described T. pecosensis and T. circumstriata from Pleistocene deposits along the lower Pecos River. All these species are very similar in shell shape.

It is now fairly well established that D. seemanni occurs only around Durango, Mexico and slightly westward , and T. protea occurs in California and Arizona. D. W. Taylor (personal communication) and I agree that almost certainly Pilsbry and

Ferriss alone based their distributions on the then undescribed *T. pecosensis*. Superficially, the two species are quite similar except that, under high magnification, *T. pecosensis* has fine spiral grooves and vertical growth ridges. *D. seemanni* is completely smooth.

Taylor (1975, in. litt.) collected the Nueces River specifically to verify Ferriss' (1924) records of *D. seemanni* and *T. protea*, but did not find them. It is known that, on the same trip in 1924, Ferriss also collected on the Pecos River but did not record any *Tryonia* from there. Again, Taylor and I feel that Ferriss must have mixed his field labels between his Nueces and Pecos Rivers collections and actually collected *T. pecosensis* and *T. circumstriata* along the Pecos River. *T. circumstriata* and *T. protea*, without magnification, are similar.

Pilsbry and Ferriss (1906) also described *Tryonia (Paludestrina) diaboli* from drift along the Devil's River, Val Verde County. It apparently has a smooth shell, like *D. seemanni* but less than half its length. All species discussed here are crenophiles, and further collecting of live material from springs in the entire Trans-Pecos is needed to completely resolve these problems.

Hydrobiidae Species, *incerta sedis*

Fontelicella palomasensis (Pilsbry), (Fig. 4c).

Bythinella palomasensis Pilsbry, 1895, the Nautilus 9:68-69.

Fontelicella palomasensis (Pilsbry), Taylor, 1975, unpublished.

TYPE LOCALITY: Springs at Las Palomas, Chihuahua, Mexico.

TEXAS DISTRIBUTION: Cheatum (1935) reported this species "in abundance in a small stream tributary to Limpia Creek, near Fort Davis (JEFF DAVIS County), Texas."

DESCRIPTION: Shell small, ovate, rapidly tapering above from the periphery of body-whorl to a blunt apex; composed of four very convex whorls, the last about five-sixths the entire length of the shell, well rounded. Surface showing faint growth-wrinkles only. Aperture ovate, subangular above, its only axis about half the length of the shell; peristome thin, continuous across parietal wall and nearly straight there, although not appressed to body-whorl. Umbilicus minutely perforated. Color whitish, corneous and somewhat translucent (Pilsbry, 1895). Shell measurement by Cheatum (1935); diameter 1.9 mm, length 2.9 mm.

DISCUSSION: Taylor (personal communication) visited the type locality, and stated that this species is now extinct there. The type description was based on two empty shells sent to Pilsbry by Dr. E. A. Mearns. Type material is unavailable for study; therefore, *F. palomasensis* should be considered *nomen dubium*. Cheatum based his identification of Fort Davis specimens on the literature description, and no live material was preserved.

"*Amnicola*" *peracuta* (Pilsbry and Walker), (Fig. 4d).

Amnicola peracuta Pilsbry and Walker 1889, Proc. Acad. Natur. Sci. Phil., p. 33, pl. 3, fig. 20.

TYPE LOCALITY: "Spivey's Lake," Navarro County, Texas.

GENERAL DISTRIBUTION: Known only from Texas.

TEXAS DISTRIBUTION: Recent County Records: Reportedly widespread in east and central Texas.

DESCRIPTION: "Shell ovate-conoidal, rather thin, narrowly perforate, light olivaceous or a little tinged with yellowish-green, quite smooth, surface shining. Whorls about 5, or a trifle less, convex, the sutures well impressed. The spire is slender, acute at the apex. Aperture about 0.5 the total length of the shell or a little less, ovate, angular above, broadly rounded beneath; peristome adnate to the whorl above the umbilicus. Altitude 4.0 mm, diameter 2.8 mm." (Pilsbry and Walker, 1889).

DISCUSSION: Proper generic assignment of "Amnicola" peracuta will await collection of live specimens at the type locality, if it is still present. No records of "Spivey's Lake" have been found through my inquiries to the Texas Water Control Board, Texas Geological Survey nor Navarro County officials. Shells conforming to the original description appear to be widely spread through east and east-central Texas.

I examined Texas shell series from the UMMZ, USNM and DMNH collections labeled "A." peracuta, and all conformed very well to C. cincinnatiensis in shell shape. However, it is not thought advisable at this time to synonomize the two species until living material of "A." peracuta can be examined. The actual existence of C. cincinnatiensis in Texas also has yet to be proven.

Summary of Texas Hydrobiidae

Undoubtedly, the family Hydrobiidae is the most taxonomically complex of all Texas Freshwater snail families. Many problems remain unsolved, and further study is necessary.

A total of 21 hydrobiid genera and 28 species have been recorded in Texas. I considered only 12 genera and 18 species valid for the State. Four species (Birgella subglobosa, Somatogyrus deppressus, Tryonia pecosensis and T. circumstriata) are found only as fossils. Two species (Cincinnatia cincinnatiensis and Pomatiopsis lapidaria) are tentatively listed as fossils but living colonies probably exist.

Most West Texas hydrobiids appear to be obligate crenophiles, while Central Texas forms inhabit lotic systems and east Texas species are more lentic in habitat preference. The subterranean hydrobiid fauna appears much more diverse than was previously thought.

Texas has been periodically invaded by hydrobiid faunas from the north, east, west and particularly from Mexico. The species in the Pecos River Valley, Rio Grande Valley, and most of Texas from San Marcos southward, are Mexican in origin. Most of the northern species are now extinct in the State. The endemic Cincinnatia comalensis is a relict, with a northern origin.

MAJOR REFERENCES: Pilsbry and Miller (1927), F. C. Baker (1928), Berry (1943), Thiele (1931), Morrison (1949), Taylor, (1966), Thompson (1968) and Davis (1968).

Family Orygoceratidae (?)

Brusina (1882) applied the name *Orygoceras* to a series of small, uncoiled shells, both from late Tertiary (*Pliocene*) deposits in southern Idaho and in southeastern Europe. He placed the genus in a monotypic family, *Orygoceratidae* under the subclass Pulmonata, the lung-breathers.

Later, Wenz (1939) considered the shells to be uncoiled valvatids, thus gill-breathing prosobranchs. Finally, Papp (1962) also felt that *Orygoceras* was an uncoiled pulmonate related to *Gyraulus*.

On July 10, 1973, Dr. Dwight W. Taylor found one living *Orygoceras* (Fig. 5g), in pool sand at Roaring Springs, Real County. He had initially discovered a single, fresh, empty shell in June, 1973 from fine-screened sand. Both visits occurred after heavy rains and local flooding. Several more empty, fresh shells and three living *Horatio* were found at the site.

DESCRIPTION: Taylor (1974) briefly described both shell and animal, but deferred more formal describing until a larger series of live specimens could be obtained. Shell - the protoconch is defined by an abrupt change in sculpture after a coil of about 225 degrees. The later, relatively straight part of the shell (teleoconch) has a sculpture of axial growth lines only. Protoconch sculpture is at first irregular, with neither spiral nor axial element on the apical bulb. It consists of irregular, oval, elongate or worm-like raised elements that are seldom branched, but complexly interlocked, do not overlap or cross, and are separated by intervals narrower than the raised elements. On the later half of the protoconch these raised elements may become transverse wrinkles near the sutures. On the peripheral surface they become generally aligned spirally, are unbranched but not straight, and are more widely spaced. These raised elements thus appear as spiral sculpture, but they do not form striae as they are not parallel and are short, discontinuous, and may be waved. The interactions of spiral and axial sculpture on the later part of the protoconch is an alignment of ends of the raised sculpture. None of the sinuous or linear elements overlap or cross. Length is less than 2 mm (Taylor, 1974).

The body of the animal is practically colorless, with several internal structures visible through the shell as described by Taylor; (1) food in the stomach, being rotated by, (2) the style, (3) fecal pellets in the intestine, (4) much of the esophagus, (5) the pale yellow-brown digestive gland filling the coiled apex, (6) the pale-yellow-brown ovary lying dorsally and on the right side of the digestive gland, (7) the pulsating heart, on the lower left side, (8) kidney (not separable from the bursa), (9) anus, (10) the enormously developed subintestinal sinus enclosing the intestine like a sleeve, and (11) proximal body stalk and columellar muscle.

Externally, the slender, rod-like tentacles lacked eyes but had a few setae on the tips. The rostrum contained a faintly pink buccal mass. The narrow foot had an anterior transverse slit into which emptied the principal mucous glands. Larger ganglia and statocysts were also visible through the body. No trace of ctenidium or osphradium could be seen in the mantle. The operculum was paucispiral and round with a central nucleus (Taylor, 1974).

ECOLOGY/BIOLOGY: Taylor believed Orygoceras to be hypogean, phreatic and crenobionic due to the animal's transparency, lack of eyes and occurrence only in the coarse gravel close to the spring source. It appears to be well adapted to living in the interstitial space between larger sand grains. Thus, search in open spaces of larger caves probably will not reveal Orygoceras.

Fossil Orygoceras from the Balkans in Europe, and Idaho in the United States, are much larger (10-12 mm), and occur in lake deposits. The Texas material may not be Orygoceras, but eventually may prove to be a highly adapted hydrobiid, related to Horatio, that also occurs in Central Texas subterranean waters. It may even turn out that Orygoceras and Horatio are ecological variants of a common ancestor, with Horatio living on submerged large rocks or other flat surfaces and Orygoceras occupying the rheophilic bottom sand-gravel layers of the Hill Country aquifer systems.

With the discovery of Orygoceras, and more recently by Dr. G. Longley, of Paludiscala and other new Horatio in these aquifers, the complex and varied Texas subterranean molluscan fauna is just beginning to be apparent.

DISCUSSION: Roaring Springs is not a particularly impressive rheocrene spring. The outflow is about 15 m above the floor of the immediate stream bed with a springbrook about 75 cm long, up to 4 cm wide, and in pool to 30 cm deep (Taylor, 1974). He added that the white shells were very visible in the dark mud by the spring, but that the live specimen was in the marshy coarse sand-gravel.

I have collected several similar sites in Central Texas over several years, and have never collected Orygoceras or Horatio. Hubricht (personal communication) has collected live Horatio from caves near Austin, Texas. As Taylor stated, the heavy rains that occurred just before his visit to Roaring Springs must have flushed the snails from well below the ground.

Family Pilidae (Ampullaridae)

The "Apple Snails" belong to a world-wide family and have the unusual ability, among the gill-breathing, operculate freshwater snails, to extract oxygen from water and air. Some species are also amphibious and oviparous. Several South American species, particularly the planorbid-shaped Marisa cornunarietis, are popular in pet store aquaria, and are often mislabeled as "Mystery Snails," which are actually species of the viviparid genus Cipangopaludina.

FAMILY CHARACTERS: The shell is very large, smooth, green-brown in color, and umbilicate. The spire is short, and the body whorl is inflated and the aperture is simple (not reflected). The operculum is large, calcareous or corneous, and is concentric with a subcentral nucleus. The tentacles are long and filiform (Malek and Cheng, 1974). The shell is globose, except in the genus *Marisa*, where the whorls are flattened in one plane, and is found in South America and the West Indies.

Other genera included in this family are: *Pila* Roding (Africa and Asia), *Pomacea* Perry (Southern United States to South America), *Lanistes* Montfort (the only sinistral genus, Africa), *Afronponus* Pilsbry and Bequaert, *Saulea* Gray, *Asolene* D'Orbigny.

ECOLOGY: Most species of this family live in marshy areas, occurring in or out of the water, often crawling about on the mud. *Marisa*, however, is strictly aquatic. The family is primarily distributed in the tropics and sub-tropics. Oviposition sites vary from banks or mud flats near water (*Pila*), to emergent vegetation extending above the water (*Pomacea*).

Only the genus *Pomacea* occurs in inland marshy areas along the Texas coast, and is represented by one species, *P. paludosa* Say; the question is entirely open as to whether the colonies are introduced or are long established.

Genus *Pomacea* Perry, 1810

Pomacea paludosa (Say), (Fig. 5h).

Ampullaria deppressa Say (1824 - in Keating, W. H.), a narrative of an expedition to the source of the St. Peters River, Appendix 2, p. 264. *Non A. deppressa* Lamarck 1804 or Risso, 1826.

Pomacea paludosa (Say), Clench and Turner, 1956, Bull. Florida. Ste. Mus., 1(3):120.

TYPE LOCALITY: The upper St. Johns River and Lake George, Florida.

Lectotype, ANSP 50580 (both as selected by Clench and Turner, 1956).

GENERAL DISTRIBUTION: The genus is widely distributed in South and Central America, and in Cuba, Jamaica, Mexico certain of the Lesser Antilles and the Southern United States. In the United States, only the species *P. paludosa* occurs and is distributed in southern Georgia and Florida (Clench and Turner, 1956). Dundee reported it from Louisiana, and Branson (1961) listed it as an introduced species in Oklahoma. Although known to be in Texas since 1936 (E. P. Cheatum, personal communication), this is the first published report of *P. paludosa* in Texas.

TEXAS DISTRIBUTION: Recent County Records - Matagorda Island, MATAGORDA (Live taken by Hildebrand), Cedar Bayou, HARRIS (Live taken by Hildebrand), Harlingen, CAMERON (Live taken) - all specimens were in the E. P. Cheatum personal collection, now at the Dallas Museum of Natural History. Also, all lots were labeled as *Pomacea calignosa* (Reeve).

DESCRIPTION: "Shell globose, rather large, reaching about 65 mm (2-1/2 inches) in length, thin in structure and perforated. Color: a dark olivaceous green to straw yellow, generally having about 10 to 15 narrow spirals of reddish brown. These bands are generally separate, though occasionally groups of bands may become fused. Occasional specimens are found that are semi-albinistic with the green and reddish bands absent, the color remaining being a light straw yellow. Whorls 5, and strongly globose. Spire depressed, only slightly elevated above the body whorl. Aperture large, subovate. Outer lip thin, inner lip consists of a thin glaze on the parietal wall. Columella thin and slightly arched. Umbilicus narrow and partially covered by the columella reflection. Suture slightly indented. The shell is generally smooth, but occasional examples show faint malleation and fine axial growth lines. Operculum corneous, thin, with concentric growth lines around a submarginal nucleus. This species shows a wide range of variation in the size, color, and thickness of the shell" (Clench and Turner, 1956).

ECOLOGY/BIOLOGY: In northern Georgia and southern Florida, P. paludosa is restricted to large springs and spring-fed creeks, presumably due to the fact that these springs remain warmer during the winter months than do those carrying surface runoff. In southern Florida, it occurs from lakes and rivers to roadside ditches (Clench and Turner, 1956). Colonies are usually very abundant.

This species is able to breath air by winding part of its mantle into a tube and extending it above the water surface. It lays small, hard-shelled white eggs in large numbers on wood, boats or plants just above the water (Emerson and Jacobson, 1976). The animals are most active at night.

Its close association with the Florida Everglade Kite (Rostrhamus sociabilis plumbeus) is well known. Apparently pollution and marsh draining are causing the snail population to decline. The limpkin (Aramus guarauna pictus) feeds on P. paludosa in Florida.

In Louisiana and Texas, the species occurs in marshy, bayou areas with abundant grass. On Matagorda Island, the colony occurs in freshwater pools behind the dunes.

DISCUSSION: All of the specimen lots in the E. P. Cheatum collection were labeled as Pomacea calignosa (Reeve). Apparently, Cheatum took this name from Pennak (1953), as it appears nowhere else in recent literature. However, in Singley's (1893) report on Texas Mollusca, the names Ampullaria deppressa Say and Ampullaria calignosa (Reeve) appear in the Pelecypods section with the listing "Texas" (Dall). Taylor (1975) listed calignosa under the unionid genus Ligumia (Unio), but cites Singley (1893).

Marisa cornunarietis will likely become established, or at least observed as ferrile, in the coastal section of the state. It has invaded Florida and other regions in the Neotropics. The species has two conflicting attributes in regards to its feeding habits. Emerson and Jacobson (1976) stated that it is a voracious feeder on the water hyacinth (Eichornia crassipes), and was welcomed in Florida. Malek and Cheng (1974) noted that it is a voracious feeder on Biompholaria glabrata, the intermediate host for the human-infecting shistosomes. Generally, gastropods are less euryphagic.

Family Pleuroceridae

The family Pleuroceridae was considered strictly a North American family until the genus Semisulcospira from North Korea, Japan and Taiwan was transferred to this family, from the Thiaridae. Pleurocerids occur in the eastern United States, except for a few species in the Northwest Pacific States (Malek and Cheng, 1974).

The approximately 300 species of Pleuroceridae have highly variable shells, but similar genitalia. The opposite situation is found in the Physidae and Hydrobiidae where the shells are monotonously similar while the reproductive organs are quite variable (Baker, 1928). Common genera include Eurocoelon, Anculosa and Leptoxis. Some genera have restricted distributions, such as Gyrotoma and Apella to the Coosa River in Alabama, and are either extinct or nearly so. Some are quite spectacular, like Io fluviatalis with its large shell and pronounced spines. It occurs in the Tennessee River systems in eastern Tennessee and Virginia (Clench, 1918). The genera with the widest distributions and largest number of species are Pleurocera and Goniobasis. Pleurocera occurs primarily in the rivers of Kentucky, Tennessee, Alabama, the

Great Lakes and to the west side of the Mississippi Valley. Goniobasis species generally live in rivers and streams with rushing waters and shoals, with sand or gravelly bottoms, in Alabama, Kentucky, Tennessee and throughout the mountainous regions of the southeast. Clench and Turner (1956) cited the genus as occurring from the Mississippi Valley eastward to western New England and from Florida northward to the Great Lakes. A few species are found from northern California to Washington.

FAMILY CHARACTERS: The shell is dextral, elongated or globose, thick and solid; aperture is entire or more or less caniculated below; operculum corneous and subspiral. The sexes are separate. Carination of the eight whorls varies from all being carinate to all whorls being smooth. The epidermis is brownish or streaked with faint greenish-brown; the shell is most often completely covered with Cladophora; sutures deeply impressed, and the aperture is sub-oval.

"The animal has a large rostrum, small squarish foot, elongated, tapering tentacles with the eyes placed on swellings at the outer base: edge of the mouth is smooth; no external verge, genital duct composed of two laminae forming a closed canal; oviparous. The rhachidian tooth is large, broader than long, rounded below; 7-9 cuspid, one cusp very large; marginal teeth elongated, more or less sole-shaped, multi-cuspid. The gill is comb-like (pectinate). The female with a pit on the neck near the right tentacle" (Baker, 1928). Species may be oviparous or ovoviviparous.

ECOLOGY/BIOLOGY: Pleurocerids are commonly called "River Snails," as they principally inhabit lime-rich, well-oxygenated rivers. Some species of Pleurocera do inhabit the shoals and splash zones of northern lakes. These fairly specific habitat-requirements are found in species of the Ohio River and Alabama-Coosa River systems, where the greatest number of pleurocerids occur.

Populations are often sporadic in a river system, but where they do occur, individuals may be found in vast numbers clinging tightly to rocks, or semi-buried in the gravelly substrate. Most species are bottom feeders (detritus), but some are found on aquatic plants, feeding on algae and dead vegetable matter (Clench and Turner, 1956).

Pleurocerids are important intermediate hosts for trematodes infecting a wide range of vertebrates from fish, birds, and reptiles to mammals such as raccoons, dogs, cats and foxes (Malek and Cheng, 1974).

Genus Elimia (Goniobasis) Adams, 1854

The shells of Elimia may be distinguished from those of Pleurocera by their non-caniculate (channeled) aperture, non-twisted columella and the callus on the parietal wall. Their general shell shapes are similar.

Elimia (Goniobasis) comalensis (Pilsbry), (Fig. 5i-k).

Goniobasis comalensis Pilsbry, 1890, Nautilus, IV:49.

Melania rufa Lea ?, Roemer, Texas, p. 457 ("In den Quellen des Comal Spring bei New Braunfels sehr haufig.").

Melania pleuristriata Say, A. G. Weatherby (Wetherby), Amer. Natur., April, 1878, p. 254, with var. marmocki (springs of southwestern Texas).

Goniobasis pleuristriata Say and G. comalensis Pilsbry, Singley, 1893, Geol. Surv. Tex. Ann. Rep., pp. 311-312.

Goniobasis comalensis fontinalis Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil., pp. 169-170.

Oxytrema comalensis (Pilsbry), Morrison, 1954, Proc. U.S.N.M., 103(3325):360.

Elimia comalensis (Pilsbry), Taylor, 1975, (unpublished).

TYPE LOCALITY: Comal Creek, New Braunfels, Comal County, Texas.

GENERAL DISTRIBUTION: Texas.

TEXAS DISTRIBUTION: Recent County Records: Guadalupe River, COMAL, San Marcos River at San Marcos, HAYS (Pilsbry and Ferriss); San Marcos, HAYS (Singley, Strecker), Helotes Creek, BEXAR (Walker, Wetherby), in Strecker (1935); San Felipe Springs, Del Rio, VAL VERDE, Rio River, REAL (as Elimia comalensis, Taylor, 1975, in litt.); SAN SABA, MENARD (Cheatum, et. al., 1972); COMAL, VAL VERDE, HAYS, BELL, REAL, KERR and SOMERVELL (DMNH Coll.).

DESCRIPTION: "Shell conic-turrite, thin but strong, covered with an olive-brown cuticle. Whorls of the spire with a distinct keel which projects a short distance above the suture, and is usually wanting on the last two whorls; the whole surface showing fine sigmoid growth-striae, and in the best specimens very faint, minute, spiral striae. Aperture ovate, the outer lip thin, sigmoid, retracted below the upper insertion; basal lip rounded or subangular. Columella arcuate, somewhat thickened. Whorls about 7 in the most perfect shells, but usually fewer, the upper ones being eroded. Length 18 mm, diameter 7.3 mm, aperture 7.3 mm." (Pilsbry and Ferriss, 1906).

The form referred to as G. c. fontinalis (Pilsbry and Ferriss, 1906) was described from a small spring in the Pleasure Garden near New Braunfels, one of the fountains of Comal Creek. There they found only very small shells, the largest 7 to 8.3 mm long, 4.3 to 4.7 mm wide and of a markedly short, conic shape. In a larger spring they discovered another dwarf colony, "though somewhat larger than those from the smaller spring." They further stated that the snails of these springs evidently constituted physiologic rather than morphologic varieties.

ECOLOGY/BIOLOGY: Stansberry (1970), stated that Goniobasis was a typically headwater genus. In Texas, E. comalensis also occurs only in headwaters or spring areas where the water is very clear and fast-flowing and the substrate is gravelly or rocky.

Taylor (1975, in litt.), felt that the colony at San Felipe Springs, Del Rio, was introduced. The colony along Squaw Creek, Highway 114, about 5 miles north of Glen Rose was discovered by Dr. John Ubelaker, and it may also have been introduced. This area needs further investigation, as other gastropods (Metastoma roemeri) have been reported from this area that are far removed from their normal ranges.

Fecal pellet analysis revealed that the food of the Goniobasis consisted of diatoms and those desmids which inhabit alkaline waters (Goodrich, 1945). Sand found in the feces and alimentary tract led Bailey et. al. (1932) to believe that the sharp particles of inorganic matter serve as triturating agencies, whereas "finer and smoother particles of argillaceous alluvium" serve poorly in this aspect.

Morrison (1954) placed all American pleurocerid species in the subfamily Pleurocerinae, which are characterized by oviparous females, with the egg-laying sinus in the right side of the foot. Males have no intromittent structures. Flat, spirally shaped egg mass clusters with 3 to 10 egg capsules per mass are deposited, and the whole is covered with sand grains (Van Cleave, 1932).

During, or before, the Quaternary, pleurocerids were distributed across Western North America from Washington to Texas. With progressive aridity since the Miocene, only peripheral species remain in the Pacific Northwest and Texas (Morrison, 1954). He stated that Elimia (Oxytrema) comalensis (Pilsbry) is the easternmost living representative of the Rocky Mountain group, and that this Texas species possesses the same female reproductive characters as does O. plicifera (Lea), from Oregon and Washington.

Elimia comalensis has been periodically compared with the Mexican Pacycheilus pleuristriata (Say) of Mexico

(Wetherby, 1878, Singley, 1893). *Pachycheilus* is much larger and the shell is glossy smooth; otherwise, the groups are similar. Unfortunately, *Elimia comalensis* is being crowded out in Comal Creek (type locality) by the introduced thiarid, *Thiara tuberculata*.

Summary of Texas Pleuroceridae

Elimia (*Goniobasis*) is the only pleurocerid representative in Texas. It appears to be more closely related to western United States species, than to the nearest northeastern species, *Goniobasis potosiensis plebius* (*Mudalia plebius* of Branson), which occurs south to Oklahoma (Branson, 1961). *Elimia comalensis* is distributed from Somervell County, sporadically southward along the margin of the Edwards Plateau to Del Rio, Texas.

As there are no fossil records of pleurocerids in Texas, it is not presently possible to determine the exact migration path of this species into Texas.

Family Thiaridae

The family Thiaridae is world-wide in distribution, with the majority of the species occurring in warm tropical, subtropical and temperate regions. The family is large, and many species are important as intermediate hosts for several human-infecting lung and liver trematodes such as *Paragonimus westermani* and *Metagonimus yokogawai*. In Formosa and the Phillippines, the medium-sized animals are considered a delicacy.

Thiarid shells closely resemble those of pleurocerids, and some authors include the North American Pleuroceridae as a subfamily of Thiaridae (Pleurocerina ?). However, the reproductive organs in the two families are quite different, as are several other internal features (Dundee, 1960). The time of thiarid establishment in the United States is unknown. *Thiara granifera* was discovered at Lithia Springs, Hillsborough County, Florida, in 1940 (Clench, 1947, in Ward and Whipple, 1918). The range in North America should be limited to areas where water temperature remains over 21.11 degrees Centigrade.

Morrison (1954) cited two western hemisphere thiarid genera, *Cubaedomus thiele* from Cuba, and *Aylacostoma* from Cuba southward to Ecuador and Peru. The generic taxonomy of this family is confused, and both *T. granifera* and *T. tuberculata* are included in literature under *Melanoides* and *Tarebia*.

FAMILY CHARACTERS: Shells are high and turreted, measuring up to 51 mm; whorls rounded with moderate or impressed sutures, usually including conspicuous sculpture, spiral and axial intersections to form ridges, ribs, knobs or tubercles; spines sometimes present, although a few species exhibit smooth surfaces. Operculum dark brown and corneous, with a multispiral growth and a central or subcentral nucleus. Mantle edge smooth or with digitiform processes; snout is as long as the foot, and the tentacles are round and slightly tapered. The radula contains seven teeth per row; central tooth small, with five to seven denticles on the anterior edge, but with no basal denticles; lateral tooth (1) and marginal teeth (2) have few cusps in some species and numerous cusps in others (modified from Malek and Cheng, 1974).

ECOLOGY/BIOLOGY: Generally, thiarid species prefer warm, slow-moving water. A few species are oviparous, and many are ovoviviparous with "brood pouches" located on the dorsal side of the mother snail. As with the viviparids, relatively few males occur, and many females are parthenogenic (Emerson and Jacobson, 1976).

However, according to Morrison (1954), all members of the family Thiaridae are parthenogenic and ovoviviparous, and no males are known for any species.

MAJOR REFERENCES: See Malek and Cheng (1974), Dundee (1960), and Murray (1964, 1971, 1975).

Key to Texas Thiaridae

a. Shell with distinct spiral rows of beads; body whorl wide and aperture slightly rounded . . . . . T. granifera

b. Shell without spiral rows of beads; body whorl slender; shell surface reticulated or slightly nodular . . . . T. tuberculata

Genus Thiara Roding

Thiara tuberculata (Muller), (Fig. 6a).

Melanoides tuberculata (Muller), Murray, 1964-65, Amer. Mala. Un. Ann. Rpt., 1964, p. 15, Rpt. 1965, p. 25.

GENERAL DISTRIBUTION: Africa, Asia, Formosa, Phillipines, and East Indies.

TEXAS DISTRIBUTION: Introduced County Records: Landa Park, New Braunfels, COMAL; Brackenridge Park, San Antonio, BEXAR; Las Moras Creek, Bracketville; KINNEY (Murray 1964, 1975); Christoval, TOM GREEN; Balmorhea State Park, REEVES (McClure - DMNH Coll.).

DESCRIPTION: Shell imperforate, height 30 to 50 mm, uniformly turreted and bears eight to eleven whorls separated by deep sutures; sculpture reticulate or nodular, varying from heavy to light; mantle edge bears finger-shaped fringes (Malek and Cheng, 1974); lower aperture rounded; conspicuous spiral lirae and, often, transverse ribs on the spire whorls. Shell marked with transverse reddish-brown streaks; whorls slightly rounded (Dundee, 1960).

ECOLOGY/BIOLOGY: T. tuberculata is the intermediate host for Paragonimus westermanni, the lung fluke, and for the heterophylid Stellantchasmus formosanum and many other trematodes such as Clonorchis sinensis.

Murray and Stewart (1968) discovered the cercariae of Philophthalmus sp., an ocular parasite of birds and occasionally mammals including man (Penner and Fried, 1963), from T. tuberculata at Brackenridge Park, San Antonio.

Murray (1971) and Abbott (1952) believed that this species and T. granifera are being established in the United States by the dumping of aquaria contents into streams, particularly around large cities. Both species are widely sold in pet shops. The aquaria in the Dallas City Aquarium contain both species.

Thiara granifera (Lamarck), (Fig. 6b).

Tarebia granifera (Lamarck), Murray 1964-65, Amer. Mala. Un. Ann. Rpt., 1964, p. 14, Rpt. 1965, p. 25.

GENERAL DISTRIBUTION: Taiwan, the Phillippines, and the island of Southeast Asia (Malek and Cheng, 1974).

TEXAS DISTRIBUTION: Same localities as for T. tuberculata, except not at Bracketville locality.

DESCRIPTION: The body whorl is wide with distinct spiral rows of beads; mantle bears finger-shaped fringes (Malek and Cheng, 1974); whorls flat sided with impressed sutures. They are also sculptured with many spiral rows of beads rather than lirae. The aperture is large; color is chestnut to olive brown; whorls 9 to 12; height 30 to 50 mm (Dundee, 1960). Spire acute and lower part of the body with several strong spiral ridges; aperture sharply angled above and below; lip entire and thin (Emerson and Jacobson, 1976).

ECOLOGY/BIOLOGY: Specimens in the colony established at Lithia Springs, Florida died in large numbers when the water temperature fell below 21.11 degree Celsius (Emerson and Jacobson, 1976). This warm-water requirement may help limit its spread in the United States. Although T. granifera is the first intermediate host for the human lung fluke, Paragonimus westermanni, a second intermediate crab host, is required. It is not known if any North American freshwater crustaceans fulfill this requirement.

Generally, *T. granifera* may be separated easily from *T. tuberculata* by its smaller size, the rows of beads and the more solid, brownish color. In the springs at Landa Park, New Braunfels, both species are crowding out the indigenous molluscan fauna, including *Elimia comalensis* for which this is the type locality.

Family Valvatidae Gray, 1840

Members of the family Valvatidae differ from the majority of the operculate freshwater snails by being hermaphroditic, and having a concentric, multispiraled operculum. *Valvata* is the only recent genus containing about fifteen species distributed in North America, Europe, Asia and Africa. Binder (1966) has placed several of the very small species (*Valvata minuta*, etc.) from France in the family Hydrobiidae, based on differences in the embryonic shell. One species (*Valvata granosa*) described by a prominent conchologist, was actually the snail-like sand-grain case of *Helicopsyche*, a caddisfly.

Nearly all valvatid species are confined to the colder, temperate regions of the Northern Hemisphere. In North America, the family consists of three currently recognized species. *V. sincera*, with several subspecies, occurs from New York northward to the subarctic tree-line. *V. bicarinata*, which may be a variant of *V. tricarinata*, is distributed along the Atlantic Coastal Plain to Georgia. *V. tricarinata* is found from Nebraska to Alaska.

Although Cheatum and Allen (1965) listed *V. tricarinata* as recent for "Texas and Oklahoma," my collections and those of others have not located them. I consider them to occur only in Pleistocene deposits across North Central Texas and the Panhandle.

FAMILY CHARACTERS: The valvatids are small, 6 mm in diameter or less, dextral, umbilicate, with a complete aperture (lip forms a continuous circle). The shell may be conispiral or planispiral, where the shell is almost uncoiled (*V. sincera ontariensis*). There is one feathery gill, and the eyes are sessil, located at the inner base of the long tentacles. The foot is short, wide, rounded posteriorly and bilobed anteriorly, and the lobes form fringe-like processes. The penis is external, slender and long. The female opening lies on the right side between the gill and rectum. Clarke (1973) stated that the long penis implies that cross-fertilization is usual. Also, the single duct from the hermaphroditic organ leads to both the vas deferens and the oviduct. The radula is taenioglossate (formula 3-1-3), and the jaw is single and covered with small scales (Clarke, 1973).

Reproduction in North American species occurs from late spring to late summer (Heard, 1963). The egg capsules are spherical and contain varying numbers of eggs (1 to 60), depending on the species. Developing embryos are green in most populations, but after hatching the color persists only in the digestive gland.

Valvatids may be found in a variety of lentic and lotic habitats, but primarily in large lakes and rivers with ample vegetation (Clench, in Ward and Whipple, 1918). They occur in areas of fine silt and sand grains.

MAJOR REFERENCES: See Clarke (1973), Wenz (1939), Fretter and Graham (1962), Baker (1928), Heard (1963).

GEOLOGICAL DISTRIBUTION: Carboniferous (?) or Jurassic to Recent (Wenz, 1939). He also placed Orygoceras as an extinct genus in this family which is known to be otherwise (see Orygoceras, this paper).

Genus Valvata Muller, 1774

Valvata tricarinata (Say), (Fig. 6c).

Cyclostoma tricarinata Say, 1817, J. Acad. Natur. Sci. Phil., 1:13 (Binney reprint 1858:59).

Valvata tricarinata (Say), Haldeman, 1844, Mon. p. 3.

GENERAL DISTRIBUTION: New Brunswick to Virginia, west in the St. Lawrence and Upper Mississippi River drainage areas to Iowa and Nebraska, north in the Canadian Interior Basin to James Bay and Hudson Bay, northwest within tree-line to the mouth of the Mackenzie River, and west to Alberta (Clarke, 1973).

TEXAS DISTRIBUTION: Fossil County Records - Subfossil in Tule Canyon, SWISHER (Cummins in Singley, 1893); Strecker (1935) cites Singley's records; MOTLEY, DENTON, and DELTA deposits (Cheatum and Allen, 1965); HARDEMAN (DMNH Coll.); RANDALL and ARMSTRONG (Frye and Leonard, 1963); BROOKS (Hubricht Coll.).

DESCRIPTION: Shell up to 5 mm high, (most Texas specimens are smaller), wider than high, solid, spirally angled or carinate, and brownish to green; nuclear whorl planorbid and with microscopic spiral striae; whorls about 4, with three strong, evenly spaced spiral cords, one at the shoulder, one at the periphery, and one bounding the umbilicus; one or more of the cords may be reduced in varying degrees, locus of each missing cord is discernible at least as a spiral angulation; lowest (and often the middle) cord of angulation on spiral whorls covered by the following whorl; whorls flattened between carinae and sloping upward from upper carina to suture; sutures distinct and impressed; aperture round internally and angled externally by the carinations or angulations; lip continuous and adnate to the body whorl for only a short distance; umbilicus round, funnel shaped, and deep; fine sculpture consisting of distinct, crowded growth lines and poorly defined spiral lines; color brownish, pea green, or emerald green; operculum round, horny, multispiral and with about 10 turns (modified from Clarke, 1973).

ECOLOGY/BIOLOGY: *V. tricarinata* is generally considered a species of perennial, large-bodied cool lakes, containing abundant aquatic vegetation. Its spotted occurrence on the Great Plains is limited to pools fed by cold water springs, such as in Woodward County, Oklahoma (Branson, 1961). In Canada, Clarke (1973) did not find it in small, permanent or vernal ponds or roadside ditches, but did find it in subarctic muskeg pools.

Taylor (1960) stated that in Northern Nebraska, V. tricarinata was found in a spring-fed pond with a constant temperature of 15 degree Centigrade, crawling on aquatic plants, including large Ceratophyllum, Elodea, and on algae near the pond. He added that its occurrence here was due to the insulating effect of the cool spring water (i.e., relict habitat). It presumably feeds on aufwuchs communities.

Furrow (1936) showed that V. tricarinata is protandrously hermaphroditic, functioning first as a male and later as a female after a brief transformation period. The germinal tissue consists of a single ovotestis (Furrow, 1937). Heard (1963) found that the egg capsules contained from one to eighteen eggs which hatched in seven to fifteen days. The capsules were mostly attached to aquatic vegetation.

Many Valvata species and subspecies have been erroneously described on the basis of the number of carinae on the shell, especially by Baker (1928). LaRocque (1956) suggested a numerical method for reporting members of this polymorphic species. Clarke (1973) employed this method in his study of the valvatids of the Canadian Interior Basin. He found that the geographical distribution of populations, in which many specimens exhibited loss of one carina or more, was largely random. The body is pinkish-white with brown splotches in the mantle which show through the shell. The radula has numerous cusps on the central and lateral teeth which number approximately 15-1-15 (central tooth), 12-1-16, 12-1-20, and 9-1-25 (laterals) (Baker 1928, Clarke 1973).

DISCUSSION: The most recent fossil occurrence of *V. tricarinata* during the Texas Pleistocene according to Cheatum and Allen (1965) was in Delta County, northeastern Texas. Carbon-14 dated shells determined that the age of the site near Ben Franklin, Texas was between 9,500 and 11,135 B.P. The assemblage is known as the Ben Franklin Local Fauna (Sulphur River Formation). These dates would place the site in the Late Wisconsin glacial age.

However, Frye and Leonard (1963), in their analysis of the Pleistocene Geology of the Red River Basin in Texas, stated that *V. tricarinata* did not persist beyond the Kansan Age in Texas, where it appears in several Kansan faunal assemblages. At any rate, the presence of *V. tricarinata* in Texas Pleistocene deposits indicates that during periods of glacial advance, Texas had temporary large bodies of clear water lakes, or at least large back river areas with abundant aquatic vegetation, and that the water temperature was considerably cooler than at present.

If relict populations still exist in Texas, which is extremely doubtful, they would probably occur in spring-fed pools in the Panhandle or North Central Texas areas. Branson (1967) reported one shell of *V. tricarinata* from drift near the mouth of the "Rio Colorado," Matagorda, Texas, The specimen was probably a fossil.

Family Viviparidae Gray

The Viviparidae are world wide in distribution except in Central or South America, and are most numerous in tropical and warm-temperate regions. They occur in rivers, streams and lakes where they generally prefer a silty or debris-laden substrate. All viviparid species are ovoviviparous with some species being dioecious and others monoecious. The tentacles are long, slender, and in males the right one is shorter than the left, forming a sheath for the verge.

Among the North American freshwater snail families, the Viviparidae and Pleuroceridae contain the most species. The viviparids are distributed only eastward of the Rocky Mountains. Four genera of Viviparidae occur in North America, with three, Tulotoma, Lioplax and Campeloma being restricted to the continental United States.

Tulotoma, with only one species, magnifica, is a unique large-shelled genus limited to the Coosa-Alabama River system in Alabama, and is generally considered extinct due to river siltation and damming. The genus Lioplax contains about four species (Clench, 1962), and is distributed along the Atlantic States from New York to Florida and Georgia. The shell is quite similar to Viviparus except that the operculum in Lioplax has a subspiral nucleus.

Although the genus Campeloma is limited to North America, it contains the largest number of species (approximately 17) and has the widest distribution, from the Mississippi River system, east to the Atlantic coast and northward to Ontario and Quebec, Canada. Species in Canada and the northern United

States lack males and reproduce parthenogenetically, but in at least some more southern species, males are present and reproduction is sexual (van der Schalie, 1965).

Viviparus is represented on all continents except Central and South America. In North America, it is distributed in drainages of the Gulf States northward up the Mississippi River systems to Minnesota, including Ohio and Indiana (Malek and Cheng, 1974). One species, V. bermondiana d'Orbigny, occurs in Cuba. Two oriental species, Cipangopaludina (Viviparus) chinensis malleatus, the so-called "Japanese Mystery Snail" and C. japonica were introduced into California prior to 1900, and have now become widespread in the United States, particularly in the north central and northeastern states (Clench, 1962). The North American viviparid species distributions are characteristically more restricted than are Campeloma species, by drainage area boundaries.

FAMILY CHARACTERS: Shells moderately large to large, orthostrophic, conispiral, holostomatous, non-umbilicate or with a small umbilicus, thin to thickened, subinflated to inflated, and smooth or highly sculptured (Tulotoma). Operculum large, corneous and paucispiral. Some species are known to be omnivorous (Campeloma), and to feed on dead animals and plant material, but the feeding habits of others are unknown (Clarke, 1973).

"Animal with a long snout, not divided into tentacular lobes; eyes on peduncles on the exterior base of the tentacles;

mantle with two cervical lobes, of which the right is the larger, forming with the mantle distinct tubular conduits for the ingress and egress of water (and air when at the surface) for respiration: jaws two; radula with (usually seven) teeth simple or denticulate, central tooth large, broad, without basal denticles, laterals large, subtrigonal, marginals narrow, elongated. . ." (Walker, 1918, in Clarke, 1973).

GEOLOGIC DISTRIBUTION: Carboniferous (possibly), or Jurrassic to Recent (Wenz, 1939). Two fossil species, Paludina araucaria Phillippi from the Tertiary of Chili and Viviparus wichmanni Duello-Juardo from the Upper Cretaceous of the Rio Negro area of Argentina, have been described, although no Recent species of Viviparidae occur there now. With few exceptions, in North America the fossil record centers in the region of the Rocky Mountains and western Plains, from New Mexico north into Northern Alberta (Clench, 1962).

Apparently, the periodic glacial advances obliterated most of the viviparids in the western and northern United States. Some genera, Viviparus and Lioplax, have begun to reinvade these only during the last Century (Clench and Fuller, 1965).

ECOLOGY/BIOLOGY: Viviparids have a wide, Recent distribution in North America. Clench and Fuller (1965) contended that the basis for this expanding range is ecological. Viviparids exhibit a tremendous tolerance of, and adaptability to, "new and demanding environments," with Campeloma being the most tolerant, and Viviparus closely following. V. georgianus and other species of the genus (V. intertextus) may exist in silted and otherwise polluted environments. Viviparus prefers a mud and detritus substrate, in nearly stagnant to slowly flowing water, usually in areas with some protective littoral vegetation (Clench and Fuller, 1965).

Key to Texas Viviparidae

Key to Genera

1\. a. Shell appearing inflated (ovate-conic): whorls rounded, suture lines impressed; shell thin 2

b. Shell more elongate, whorls not rounded; aperture more ovate; shell thick . . . . Campeloma

2\. a. Shell height less than 45 mm . . . . Viviparus

b. Shell height greater than 45 mm . . . Cipangopaludina

Viviparus

1\. a. Shell usually with 4 brown bands; imperforate or narrowly umbilicate; suture deeply impressed; body whorl inflated, spire somewhat depressed . . . . V. georgianus

b. Shell without bands, (if banded, less than 4) 2

2\. a. Shell thin, whorls convex; spire short; base umbilicate; color greenish horn to brownish; fine, equidistant brown spiral lines; shell usually very dark, outer lip with a blackened margin . . . . V. intertextus

b. Shell thick; whorls flatly rounded; shouldered; spire long; imperforate; shell usually with a purplish tinge (especially in aperture); nucleus pinkish . . . . *V. subpurpureus*

c. Shell similar to above, except more compact, thicker and the protoconch is very conspicuous in side view . . . . *V. subpurpureus tamaulipanensis*

Cipangopaludina

Shell large, to 65 mm; blackish periostracum. . . . . *C. chinensis malleatus*

Campeloma

Aperture elongate, sides of whorls flattened, whorls, especially the uppermost ones shouldered . . . . *Campeloma crassulum*

Genus *Viviparus* Montfort, 1810

Viviparus georgianus (Lea), (Fig. 6h-i).

Paludina georgiana Lea, 1834, Trans. Amer. Phil. Soc. (n.s.), 5:116, pl. 19, fig. 85.

Vivipara georgiana (Lea), Binney, 1865, Land and freshwater shells of North America, III, p. 34.

TYPE LOCALITY: Hopetown, near Darien, Georgia.

Holotype - USNM106252.

GENERAL DISTRIBUTION: Quebec south to central Florida and westward to the Mississippi Valley, Texas. Fossil Record unknown.

TEXAS DISTRIBUTION: New State Report: SHELBY County.

DESCRIPTION: Shell subglobose in outline and varying in size, large specimens reaching about 44 mm in length; imperforate or with a narrow slit-like umbilicus; usually rather thin in structure, but strong and smooth; color yellowish or olivaceous green to dark brownish green, banded or uniform in color. Banded specimens usually have four dark reddish-brown bands about evenly spaced. Whorls 4 to 5, strongly convex and generally with a slight shoulder; spire somewhat extended and produced at an angle of from 50° to 65°; aperture ovate to subcircular; outer lip thin; parietal lip consisting of a thickened glaze; columella narrow and arched; suture deeply indented; sculpture consisting only of fine growth lines; young specimens with a few spiral threads which eventually disappear as they grow older; operculum corneous, thin, with concentric growth lines and a submarginal nucleus (Clench, 1962). The operculum is also usually a reddish amber.

BIOLOGY/ECOLOGY: The animals are sluggish and seem to prefer quiet water with a bottom of silt or muddy sand. The distribution is spotty, and it is generally not found in larger rivers, but in the sloughs that may margin them or in smaller creeks, lakes, ponds and springs. Colonies can exist where there is a great deal of soft mud and vegetation in quiet water, but may also be found in sandy areas (Clench and Turner, 1956).

This species is exceedingly variable in shell shape. Size, shape and color patterns of the shells are uniform within the spotty colonies. However, according to Clench and Turner (1956), there are extremes in shell features over the species range, with many intergrading forms between these extremes. These differences appear to have no pattern.

Clench (1962) noted that *V. georgianus* has, since 1867, spread northward from its presumed origin in the southern states. In 1916 it appeared in the Boston Public Gardens, and was first noticed in New York's Central Park in the 1950's. Emerson and Jacobson (1976) observed that shells from Quebec, in the extreme north of the range and in Florida, were much smaller than those from around the Great Lakes region.

V. georgianus apparently is a favorite aquarium snail, which probably accounts for much of its spotty distribution. Specimens have been observed in several pet shop aquaria across Texas, and the timing of establishment of the Shelby County Colony is unknown.

DISCUSSION: A series of young, banded viviparids were sent to me for identification by Mr. Gerard Sala of the Sabine River Authority. Specimens were collected in the Sabine River at the headwaters of Toledo Bend Reservoir, 3 September, 1975. It had previously been reported from the Red River drainage in DeSoto and Rapides Parishes, Louisiana (Clench, 1962) Although immature shells of *V. intertextus* and *V. subpurpureus* may often be banded, these specimens fit the description of *V. georgianus*.

The fossil record of _V_. _georgianus_ extends from the Lower Cretaceous in Alberta, Canada to the Upper Cretaceous of Utah. It also occurs in Pliocene deposits from Utah and Washington. Fossil records are also known from the central and eastern states, these being within the current range of the species (Henderson, 1935, Clench and Fuller, 1965). However, no fossil records of this species exist for Texas.

Viviparus intertextus (Say), (Fig. 7a).

Paludina intertextus, Say, 1829, New Harmony Disseminator of Useful Knowledge, 2:244.

Vivipara intertexta (Say), Binney, 1865, Land and Fresh-water Shells of North America, III, p. 17.

TYPE LOCALITY: Marshes near New Orleans and on bank of Carondelet Canal, Louisiana. Lectotype: ANSP 124545.

GENERAL DISTRIBUTION: The Mississippi Valley from Louisiana, Texas and Mississippi to Minnesota (Clench and Fuller, 1965).

TEXAS DISTRIBUTION: Recent County Records: SHELBY (as _Cochliopina texana_, Harrel, 1973), LIBERTY, HAYS, MARION (DMNH Collection); Houston Ship Channel system, 13 mi. W. of Houston, both HARRIS (Addicks Collection); San Jacinto River system: Cleveland, LIBERTY (Clench and Fuller, 1965); Liberty River system: Dayton, LIBERTY (Clench and Fuller, 1965); Neches River system: Neches River, Town Bluff, TYLER (Clench and Fuller, 1965).

DESCRIPTION: Shell ranging from globose to depressed-globose and varying somewhat in size; large specimens reaching about 32 mm in length. Imperforate, or with a narrow, slit-like circular umbilicus; shell rather thin in structure and smooth; color dark yellowish green to dark olivaceous green. All examined mature Texas specimens totally lacked bands; occasional immature individuals with three reddish bands, possibly a fourth indistinct band; whorls usually 4.5, strongly convex and with a slight shoulder; spire moderately extended and produced at an angle of about 55^{0} to 80^{0}; aperture subovate; outer lip (thin) and inner lip margined with black, and with the parietal area somewhat thickened; columella narrow and arched; suture deeply indented; sculpture consisting of fine axial growth lines and minutely beaded spiral threads; operculum corneous, thin, with concentric growth lines and a depressed submarginal nucleus; height 23.0 to 32.0 mm (Clench and Fuller, 1965).

ECOLOGY/BIOLOGY: The ecology of V. intertextus is poorly known. It is assumed that it requires clear, quiet backwater areas of lakes or rivers where abundant aquatic vegetation exists. Baker (1928) stated that the subspecies V. i. illinoisensis lives in the bayous of the Mississippi River. The Liberty County, Texas, specimens were taken from a slough near the Trinity River, in a dense palmetto stand. The slough water was low, and no live specimens were taken.

Clench and Fuller (1965) stated that V. intertextus is usually found around and among roots and stems of underwater vegetation, in cool and comparatively swift water. The substrate was generally of a coarser nature than that preferred by other North American species in this genus, and found specimens in streams no more than a yard or two wide, and in areas subject to thorough scouring during flooding.

DISCUSSION: A single specimen of *V. intertextus* labeled "San Marcos Area," with no date, represents the material from Hays County. It was collected by Dr. E. P. Cheatum. Since no other specimens have been collected there, its occurrence in Hays County is doubtful. The specimen could be "*Melania rufa*," cited by Roemer (1849) (see *Elimia comalensis*). The Marion County report is from Caddo Lake, in clear water about 25 cm deep.

Viviparus subpurpureus (Say), (Fig. 6j).

Paludina subpurpurea, Say, 1829, New Harmony Disseminator of Useful Knowledge, 2:245.

Vivipara subpurpurea, (Say), Binney, 1865, Land and Fresh-water Snails of North America, 3:19, figs. 32-36.

Viviparus texana, Tryon, 1862, Clench, 1962, Occ. Pap. on Moll., Mus. Comp. Zool., 2(27):285. Holotype - ANSP 27714a, "Texas."

TYPE LOCALITY: Fox River, an arm of the Wabash (White County, Illinois).

GENERAL DISTRIBUTION: Southern Minnesota to Illinois, Iowa, Indiana, southward from Missouri to Texas, Louisiana and Mississippi; also in eastern Georgia and South Carolina (Clench and Fuller, 1965).

TEXAS DISTRIBUTION: Recent County Records: Caddo Lake, HARRISON (Vaughn), HOUSTON, HARRIS (Kennedy), Subfossil from Artesian well in Galveston, GALVESTON (Gwyn in Singley, 1893 and repeated in Strecker, 1935), Sulphur River, BOWIE (Strecker and Williams); Neches River System - Neches, 0.5 mi. below dam, Town Bluff, TYLER; Evadale, JASPER, Sabine River system - Sabine River, Smith's Fish Cabin, 1 mi. N. of Deweyville; confluence of Sabine River and Cypress Creek, 5 mi. N. of Deweyville, both NEWTON; Caddo Lake, HARRISON (Clench and Fuller, 1965).

DESCRIPTION: Shell thick, whorls flatly rounded; shouldered; spire long; base imperforate; shell elongate-ovate or subovate; olive green or yellowish-green with a tinge of purple, especially in the aperture; spire conic and longer than the aperture; whorls 6 and flatly rounded; shouldered at the upper part near the deeply impressed sutures; surface shiny; nucleus pinkish; penultimate whorl very large and high (from behind); sculpture of fine, raised, epidermal laminae; lines of growth diagonal; very heavy; very fine spiral lines (sometimes); operculum smaller than _V. intertextus_ or _V. georgianus_ with a roundly ovate nucleus of granular texture; (shell) narrower than _V. intertextus_ or _V. georgianus_, thicker and heavier (Baker, 1928). Color bands, when present, are typically of brownish color, three in number and generally evenly spaced. Length ranges from 23.0 to 33.0 mm. Spire is produced at an angle of about 45^{o} to 55^{o} (Clench and Fuller, 1965).

The animal is generally light bluish or lead colored, flecked with yellow spots, principally on head, rostrum and tentacles; cervical lappets as in _V. intertextus_, but longer.

The radula formula is 8-1-8: 1-6-1-6: 8-1-4: 10-4 (3-1-3). The center tooth is slightly longer than wide, the base rounded. The female is slightly more rotund than the male (Baker, 1928).

ECOLOGY/BIOLOGY: Apparently, this species requires much the same habitat type as does V. intertextus and V. georgianus, small bodies of water such as sloughs, bayous and ox-bows of rivers and small lakes or ponds with clear water, rooted aquatic vegetation and a muddy bottom. The feeding habits of all viviparids are poorly known; they have been reported to consume algae and detritus. The life cycle and reproductive habits are also relatively unknown. V. subpurpureus, like V. intertextus often occurs in swift waters on rocks (Clench and Fuller, 1965). No specimens were obtained from this type of habitat in Texas.

DISCUSSION: The type locality of the species, V. texana Tryon (1862) is listed as "Texas." Its only other listing appeared in Baker (1928), where he cited it as a variety occurring from Missouri to Texas. He attributed it with a much narrower shell. North to south variation in shell size is a known but unstudied feature in many genera of freshwater gastropods (Lymnaea, Helisoma, Physa, etc.).

I did not find this species in any of the shell material examined during this study. During the literature search, I observed that aberrant forms of several freshwater snails (Helisoma trivolvis intertextum, V. texana) have been described from southeastern Texas.

A word of caution should be made at this point in regard to identifying *V. subpurpureus*. The shell in several respects greatly resembles shells of *Campeloma*, found in northeastern Texas.

Viviparus subpurpureus tamaulipanensis, New subspecies (Fig. 6g).

In 1976, a series of fossil freshwater gastropods, collected by a former student, Mr. John Kieschnick, was sent to me for identification. The shells were taken from a terrace of unconsolidated sand below Falcon Dam, Starr County, Texas. Among the collection was a series of fossil viviparids, the first records in Texas.

TYPE LOCALITY: Campground below Falcon Dam, STARR County, Texas. Unconsolidated sand of T_1 Terrace of the Rio Grande River. Probable age is Pleistocene. Holotype - DMNH 1200, Paratypes - USNM.

DESCRIPTION: Holotype: Shell thick-walled, compact, imperforate; height 24.7 mm, diameter 18.5 mm; aperture subcircular, holostomous lip unreflected; aperture width 11.4 mm, height 12.8 mm; thickened parietal callus; whorls 5.5, sutures deeply impressed; whorls strongly shouldered and attenuate; protoconch wall elevated above first whorl and smooth; a slight ridge occurs on the basal portion of each whorl, and three very faint bands present; surface dull with regularly spaced, oblique growth lines and several irregularly spaced, deep collabral lines on body whorl (not present in 3 paratypes).

DISCUSSION: *V. s. tamaulipanensis* generally resembles *V.*

subpurpureus. However, it differs enough in the following respects to merit subspecific rank: (1) the shell is much thicker, more compact and smaller; (2) whorls are more rounded; (3) protoconch is much more elevated; and (4) there is a consistent basal ridge on each whorl.

This first fossil viviparid discovery in deep South Texas was totally unexpected. I propose that at some time during the Pleistocene, conditions in the coastal region of Texas were more favorable for eastern American freshwater snail expansion than was previously thought. The faint presence of the color bands in the shells indicate that these specimens most likely occurred in the area after the Wisconsin Age.

Genus *Cipangopaludina* Hannibal, 1912

Cipangopaludina (*Viviparus*) *chinensis* *malleatus* (Reeve), (Fig. 7c).

Paludina *malleata*, Reeve, 1863, Conchologia Iconica 14: *Paludina*, pl. 5, fig. 25 (Japan).

Cipangopaludina *malleatus* (Reeve), Hannibal, 1912, Proc. Malac. Soc. London 10, p. 194.

TYPE LOCALITY: Japan.

GENERAL DISTRIBUTION: Orient. Introduced into the United States (California) prior to 1900, now widespread particularly in the north central and northeastern states, Texas and Oklahoma.

TEXAS DISTRIBUTION: Recent County Records: Kidd Springs, (spring-fed city park pond), Dallas, DALLAS (DMNH Coll.); Pond, Waco, McLENNAN (Clench and Fuller, 1965).

DESCRIPTION: Shell large, 65 mm in height; globose with a greenish-black periostracum with one to four rows of tiny scar pits.

DISCUSSION: In addition to its well-established colonies in Dallas and Waco, the species will probably appear around other Texas urban areas. This is the so-called "Oriental or Japanese Mystery Snail" and is widely sold in pet shops. It occurs in Arizona (Bequaert and Miller, 1973) and Oklahoma (Branson, 1959).

Another oriental species, _Cipangopaludina japonica_ Martens (Fig. 7b), has become established in North America, though not reported in Texas as yet. It has a narrower, higher and less globose shell than _C. c. malleatus_. Also, the rows of scar pits found in _C. c. malleatus_ are replaced by a few incised spiral lines in _C. japonica_. In Japan, _C. malleatus_ is the intermediate host for two echinostomes, _Echinochasmus elongatus_ and _E. rugosus_ (Malek and Cheng, 1974).

Genus _Campeloma_ Rafinesque, 1819

The taxonomy of the genus _Campeloma_ is confused, and the shell is practically valueless in species determination, as are several other separation characters commonly used, such as the operculum, species distributions, and radula.

Several specific names have been applied to the very few known collections from Texas. To avoid further confusion, Campeloma will be treated rather conservatively, with generic recognition characters emphasized rather than specific characters in this report. The specific name, C. crassula, for Texas specimens, is selected only for categorical purposes.

Campeloma Crassula Rafinesque, (Fig. 6f).

Campeloma crassula Rafinesque, 1819, J. de Physique de Chemi d' Historie Natwrelle, Paris, 88:423.

Campeloma ponderosa Say, 1821, Clench, 1962, Occ. Pap. on Moll., Mus. Comp. Zool. Har., 2(27):279.

Campeloma rufa (Haldeman, 1871), Clench, 1962, Occ. Pap. on Moll., Mus. Comp. Zool. Harv., 2(27):279.

Campeloma subsolida (Anthony, 1844), Clench, 1962, Occ. Pap. on Moll., Mus. Comp. Zool. Harv., 2(27):279.

Campeloma lewissi Walker, Strecker, 1935, Trans. Tex. Acad. Sci., p. 17.

Campeloma decisa Say, Singley, 1893, Geol. Surv. Tex., Fourth Ann. Rept., pt. 1:313.

TYPE LOCALITY: Ohio River.

GENERAL DISTRIBUTION: Exact limits unknown. Ohio, Illinois and southward.

TEXAS DISTRIBUTION: Recent County Records: Sabine River, SHELBY; Village Creek, HARDIN (Askew); Caddo Lake, HARRISON (Vaughn), as C. decisa in Singley, 1893; Sulphur River, (as C. lewisii in Strecker, 1935); MARION, HARDIN, TYLER (DMNH Coll.); Baker (1902) lists C. ponderosum as, "south to Alabama and Texas." No Fossil Records.

DESCRIPTION: (Genus Campeloma); shell rather large, occasionally reaching 61.5 mm (nearly 2.5 inches) in length, subglobuse to subovate, imperforate and usually rather solid; color light green to dark olivaceous green; whorls smooth, usually rounded or slightly shouldered; aperture oval with a simple lip; columella and parietal wall generally thickened; operculum with a sub-marginal nucleus (parietal margin) and concentric growth lines (Clench and Turner, 1956). Shell dextral (rarely sinistral), orthostrophic, conispiral, almost smooth except for lines of growth and with impressed sutures and rather rounded whorls; aperture ovate, inner lip more or less sinous; operculum horny.

The foot of the animal is large, truncated anteriorly and rounded posteriorly; eyes on peduncles at outer base of tentacles; two horny jaws present, one on either side of the mouth; radula taenioglossate, formula normally 2-1-1-1-2; omniverous and ovoviviparous (Clarke, 1973).

ECOLOGY/BIOLOGY: Species in Canada and Northern United States lack males and reproduce parthenogenetically, but in at least some more southern species males are present and reproduction is sexual (van der Schalie, 1965). In the southern region, males are smaller than females, and have the right tentacle enlarged and modified to form a functional penis (Clarke, 1973). Anderson (1966) stated that the apparent boundary between maleless colonies and colonies with males present lies near Kentucky and Tennessee.

Generally, Campeloma inhabits streams, rivers and back-water areas of lakes where there is abundant sand or mud with detritus present. It burrows, and will congregate in quiet pools just below a stream obstruction such as a dam or fallen tree. The aggregating at such places may also be due to its positively rheotrophic habit of moving upstream until stopped by an obstruction (Bovbjerg, 1952). Branson (1961, 1963) cited Campeloma from southeastern Oklahoma, Louisiana and far east Texas as C. decisa, and stated that he always found it associated with roots of Water Willow (Dianthera americana).

Because Campeloma burrows and forages principally at night, many colonies are undoubtedly overlooked. Allison (1942) developed a workable collecting technique by burying a dead chicken in the sand or mud for twenty-four hours or less and then screening the adjacent sand. Apparently, the snails are readily attracted to decomposing flesh.

Malek and Cheng (1974) cited several Campeloma species as being intermediate hosts for trematodes. C. decisa is first and second intermediate host for the brachylaimid trematode Leucochloridiomorpha constantia, a bird parasite and also for several species of the trematode family Aporocotylidae. C. rufum (Fig. 6d), (= crassula) is an intermediate host for Troglotrema mustelae, a parasite of dogs, cats and mink.

DISCUSSION: The long list of North American names has been narrowed to about 17 species by recent authors. Campeloma decisum is the common northern species (Clarke, 1973) and C. geniculum is recognized from the eastern seaboard to Georgia (Clench and Turner, 1956). Dr. W. J. Clench has contended for many years that all Campeloma west of the

Mississippi are referable to C. integrum (Type Locality - Missouri River), but refrained from placing a southern limit on its distribution. Clarke (1973) suggested reasons why C. integrum should be synonomized under C. decisa. The shell of C. decisa is thin, and the extreme northeastern Texas populations partially resemble this species in being relatively thin shelled. They also resemble C. integrum. However, naming the northeastern Texas shells C. decisa or integrum makes no sense, distributionally. If. C. integrum is conspecific with C. decisa, or with C. crassula (whose distribution is very similar with that of C. integrum on the east side of the Mississippi River), then the northeastern Texas material should be referred to as C. decisa, which has priority.

Another "southern" species, C. exilis, described in 1860, occurs in Mississippi and probably will prove to be a variant of C. crassula (1819). Several malacologists think that Campeloma originated in the lower Mississippi Basin, and the genus spread northward. Routes of eastward expansion have not been hypothesized. If the center of origin is correct, then the entire Mississippi drainage Campeloma are closely related, and C. crassula will be the correct name applied to species from this region, including the name integrum. However, if C. integrum and C. decisa prove to be conspecific, then C. decisa will be the valid name.

A population from Hardin County in southeastern Texas closely resembles C. crassula by the thick shell and deep green color. Otherwise, the shell features conform to C. integrum.

The question of which specific name (or even several names) should be applied to Texas Campeloma must await extensive study of the entire North American Campeloma series.

Summary of Texas Viviparidae

Viviparus and Campeloma are the only North American genera occurring in Texas as Recent or fossil. The family is, furthermore, almost exclusively restricted to the Austroriparian Province of East Texas. The only known exception is the occurrence of V. intertextus in Hays County, and this report is doubtful.

The taxonomy, distribution, and ecology of viviparids are probably the poorest known of any family of freshwater snails in Texas. This paper represents the first attempt to clarify the status of the family in the State.

In general, Viviparus is represented by four fairly well-definable species, all occurring in clear water lakes or streams with adequate littoral vegetation. The overall distribution appears extremely spotty, but will undoubtedly be extended with further collection. Unfortunately, the situation is not as clear for Campeloma. Clench and Turner (1956) considered the genus perhaps the most taxonomically confused of all the North American freshwater gastropods. Many species have been described, and the distributions of the better-established species are very poorly understood. The problem is further compounded by the fact that several members of this group reproduce either wholly or partially through parthenogenesis, which complicates species definition. Although various *Campeloma* species have been investigated in the Northern and Southeastern United States, almost no studies have been conducted on southern, Central States species.

I list 6 viviparid species as valid for Texas; fourteen specific names were found in the literature. Also, the first fossil viviparid (*V. subpurpureus tamaulipanensis*) is recorded and described here.

Family Ancylidae Rafinesque

The freshwater limpets are easily recognized by the patelliform (cup-shaped), uncoiled shell. Although they bear a superficial resemblance to the primitive marine *Neopilina* (Monoplacophora), the freshwater limpets actually are a highly evolved group, thought to have secondarily moved into freshwater habitats from a terrestrial existence (Basch, 1963). In fact, they have reduced the lung, a highly advanced and characteristically land molluscan organ, and replaced it with a secondary gill-like structure, the pseudo-branch. The ancylids are most closely related to the Planorbidae, also possessing a pseudo-branch, and are thought to have evolved from this group (Clarke, 1973).

FAMILY CHARACTERS: Shells patelliform, small- to medium-sized and thin to somewhat thickened; with rounded to elongate-ovate aperture; with radial and concentric sculpturing variously developed; and with an apex which may be low or elevated and which is located centrally or posteriorly, and on the mid-line or to the right. Radulae formulae vary from about 8-1-8 (some Rhodacmea) to about 37-1-37 (Ancylus). The central tooth has 2 or 4 cusps, and the laterals and marginals have 2 to many cusps (Hubendick, 1967).

As in the other higher Basommatophora, the soft parts are sinistrally organized with the mantle opening, genital pore, anus and pseudobranch located on the left side. Even though the shell is roughly bilaterally symmetrical, the arrangement of the soft parts clearly indicates that they had a coiled ancestor.

DISTRIBUTION: The Ancylidae are distributed world wide and are composed of several well-characterized genera, occurring in fairly well-definable regions, according to Hubendick (1964). Amphigyra and Neoplanorbis (Coosa River, Alabama, probably now extinct); Ancylastrum (Tasmania); Ancylus (Palearctic, Northern Africa); Burnupia (Africa); Ferrissia (Nearctic, West Indies, Africa, Southern Asia, Australia); Gundlachia (Neotropical); Laevapex (Nearctic); Rhodacmea (Southeastern North America). Two other patelliform basommatophers Lanx and Acrolox (restricted to Northwestern North America) are not related to the Ancylidae. Three genera, Ferrissia, Laevapex and Gundlachia occur in Texas, comprising a total of seven species.

ECOLOGY/BIOLOGY: Limpets occur in lotic and lentic freshwater habitats, except in torrential mountain streams and in lakes or rivers with bare sandy bottoms. In ponds, permanent ditches and lake backwaters with rooted vegetation, limpets may be found on the lower portions of plant stems. Lentic ancylids have been collected on *Sagittaria*, *Nymphaea*, *Nuphar*, *Scirpus*, *Potamogeton*, *Typha*, *Sparaganium*, *Cyperus*, *Carex*, twigs and leaves of various trees (Basch, 1963). Some species appear to be restricted to certain plant species, but more conclusive work is needed. Lotic ancylids usually never occur on plants but rather on stones, anchored debris, and old mussel shells.

Environmental factors appear to not only restrict species occurrence, but also influence shell shape of the limpets even to the size and shape of substrate objects. Basch (1963) noted that lentic forms have lower shell contours than do the lotic forms.

Most life-cycle studies have been conducted on temperate North American and European species (Hunter 1953, 1961; Basch, 1959; Geldiay, 1956). These species largely undergo univoltine life cyles, with bimodal size distributions and peaks corresponding to the previous years' and the present year's crop (Basch, 1963). In Texas, McMahon (1976) found that at least two species, *Gundlachia radiata* (his *Hebetancylus excentricus*) and *Laevapex fuscus* undergo a bivoltine life cycle with *G. radiata* even having a third generation per year.

Kozloff (1954) found a number of protozoan parasites in ancylids. Basch (1963) found a protozoan closely resembling *Entamoeba coli* in the digestive glands of *Laevapex fuscus* from Michigan. Ancylids are also intermediate hosts for several trematodes.

Wurtz (1955) found that ancylids will live in organically polluted waters, but appear intolerant of inorganic pollutants such as insecticides, detergents, and industrial wastes. Damming lotic environments also is detrimental to the stream forms (Basch, 1963).

PALEONTOLOGY: Ancylids are known from the Middle Oligocene to the Recent. In Texas, several more northern species (*Ferrissia parallela* and *Ferrissia rivularis*) are known only as fossils from Pleistocene deposits. Leonard and Frye (1962) recorded fossil specimens of *Ferrissia californica* (*Ferrissia shimeki*) from the Trans-Pecos region. Cheatum and Allen (1965) listed this species (as *Ferrissia meekiana*) from Hardeman County.

For definitive works on the family Ancylidae, the reader is referred to Basch (1963); Hubendick (1963, 1964, 1967, 1970); McMahon (1975, 1976); McMahon and Hopkins (1977).

Key to Texas Ancylidae

Key to Genera

1. a. Apex of shell with fine radial striae . . . . *Ferrissia*
   b. Apex of shell without fine radial striae 2
2. a. Apex very obtuse, almost in midline of the shell . . . . *Laevapex*
   b. Apex subacute, distinctly eccentric to the right of midline . . . . *Gundlachia*

Gunclachia Species

Apex of shell distinctly subacute (depressed), distinctly eccentric, to the right of midline and slightly posterior. No radial striae on apex. Post embryonic shell with visible linear striae that continue to the edge of the shell; with or without a posterior septum . . . . *Gundlachia radiata*

Laevapex Species

(Modified from Basch, 1963)

1. a. Shell ovate, smooth or with fine radiating raised riblets on the anterior slope. Apex usually just posterior to the center of the shell. Principally lentic (lakes or ponds) or in backwaters of rivers on vegetation or submerged debris. . . . . *Laevapex fuscus*

   b. Shell subcircular, smooth, apex usually medial to the shell; on submerged objects in slowly flowing streams . . . . *Laevapex diaphanus*

Ferrissia Species

1. a. Shell large, (length to 9 mm); elevated; sides very narrow and parallel; Fossil Only . . . . . *F. parallela*

   b. Shell smaller and sides not narrow or parallel . . . 2

2. a. Shell length to 7 mm, elevated; aperture elliptical; anterior slope convex, posterior slope gently concave, lateral slopes fairly straight; apex central; strictly lotic; Fossil Only . . . . *F. rivularis*

   b. Shell length to 6 mm; depressed or moderately elevated; primarily lentic .3

3. a. Shell length less than 4 mm (rarely beyond 3.5 mm); depressed or moderately elevated; with or without a posterior septum; aperture variable; ditches or small bodies of standing water, often temporary and stagnant. . . . . *F. californica*

   b. Shell length to 6 mm; usually depressed; septum never present; apex subacute, often in the far right posterior quadrant; clear water ponds (on vegetation or debris). . . . . *F. walkeri*

Genus *Ferrissia* Walker, 1903

Ferrissia californica (Rowell), (Fig. 7g).

Gundlachia californica Rowell, May, 1863, Proc. Calif. Acad. Sci., 3:21.

Ferrissia californica (Rowell), Taylor, 1975, unpublished.

Ferrissia fragilis (Tryon June-July, 1863); Bequaert and Miller, 1973. The Mollusks of the Arid Southwest, Tucson Univ. Press, p. 212.

Ferrissia shimekii (Pilsbry, 1890), Basch, 1963, Bull. Mus. Comp. Zool., 129(8):435 as *F. fragilis*.

Ferrissia meekiana (Stimpson, Dec., 1863), Basch, 1963, Bull. Mus. Comp. Zool., 129(8):435 as *F. fragilis*.

TYPE LOCALITY: "Feather River at Marysville," Yuma County, California. Holotype - UMMZ 102011.

GENERAL DISTRIBUTION: North America, but sporadic.

TEXAS DISTRIBUTION: Fossil County Records: WARD, PECOS (Leonard and Frye, 1962 as *F. shimekii*); HARDEMAN (Cheatum and Allen, 1965) as F. meekiana): DELTA, DONLEY and DALLAS (DMNH Coll.). KNOX-BAYLOR (as F. meekiana, Hibbard and Dalquest, 1966); KAUFMAN (?) (Thurmond), DELTA (Cheatum and Allen), HARDEMAN (Dalquest), DALLAS (as G. meekiana, Willimon, 1972). Recent County Records: DALLAS (McMahon, 1976 as F. fragilis), "Rio Grande" (Clapp, 1913), BOWIE (DMNH Coll.).

DESCRIPTION: "Shell very small and fragile, sides nearly parallel or slightly incurved in the middle, but diverging anteriorly; ends rounded; apex elevated, acute, curved backward, with about two-thirds of the shell anterior to it." - (Tryon, 1863, F. fragilis, Holotype ANSP 22011).

"Size of the largest specimens, length 4 mm, breadth 1.15 mm, height 1 mm. Most of the specimens do not exceed two-thirds of these dimensions. . . . this species is smaller, thinner, and wants the convex lateral margins of our Anc. rivularis, Say. It agrees with that shell, however, in the greater width of its anterior end, while in the shape of its lateral margins it resembles Anc. parallelus, Hald. It is much the smallest of our species," (Tryon, 1863 F. fragilis). Apex with fine radial striae. Septate forms are known from California (Rowell, 1863), Texas (Clapp, 1913), and New York (Smith and Prime, 1870, Cooke, 1882, Basch, 1963).

BIOLOGY/ECOLOGY: F. californica occurs in mud-bottomed ditches and ponds, often temporary and usually stagnant (Basch, 1963). They are found on stems and submerged leaves of rooted aquatic plants (Typha), or on submerged objects such as sticks, bottles or cans. Basch (1963) found septate forms in seasonal bodies of water which were dry sometime during the year. McMahon (1976) found a colony on bullrushes (Scirpus sp.) and limestone rocks in a backwater inlet of White Rock Lake, Dallas County (Jackson's Branch).

DISCUSSION: Ferrissia californica is the smallest North American limpet, and also perhaps the most variable in shell size and shape. It has been cited under many names, and Basch (1963) retains three variant names. None of these occur near Texas.

The original description of F. californica is extremely vague, and the shell description given here is from Tryon's (1863) brief description of F. fragilis which, although the most currently used name, is now considered a synonym of F. californica by several authors. The type localities of F. fragilis and F. californica are less than 90 miles apart in California. Bequaert and Miller (1973) cited it as Laevapex (Ferrissia) californica, based upon the earlier (May, 1863) published description by Rowell than Tryon's (June-July, 1863) publication of F. fragilis. This information was supplied to them by Allyn G. Smith. Rowell's type specimen was separate, and at that time all septate forms were placed in the genus Gundlachia. Septation is now believed to be environmentally induced, and has been discarded as a taxonomic character.
J. G. Cooper (1890) and Pilsbry and Ferriss (1919) suggested that A. fragilis was a non-septate form of G. californica.

Pilsbry and Ferriss (1919) commented that some Arizona specimens in the Gundlachia (septate) stage did not appear specifically separable from G. californica.

I always found F. californica in lentic habitats, usually attached to Typha stems, on old cans and other submerged debris.

Ferrissia parallela (Haldeman), (Fig. 7f).

Ancylus parallelus Haldeman, 1841. Monograph of the freshwater univalve Mollusca of the United States, no. 3, description on the cover.

Ferrissia parallela (Haldeman), Walker, 1918. Misc. Publ. Mus. Zool. Univ. Mich., 6:119.

TYPE LOCALITY: "inhabits New England" (Haldeman, 1841). Holotype - ANSP 21996H.

GENERAL DISTRIBUTION: In the Northern United States and Canada, from the Atlantic Coast westward.

TEXAS DISTRIBUTION: Pleistocene County Records: WARD, CRANE and PECOS (Leonard and Frye, 1962); Pecos River in WARD (Askew, in Singley, 1893 and repeated in Strecker, 1935); HARDEMAN and KNOX (DMNH Coll.).

DESCRIPTION: "Shell pale, thin and delicate, lengthened, sides subrectilinear, diverging slightly forwards; apex rather sharp, conspicuous, with two-fifths of the shell posterior to it. Dimensions: length 0.25, height 0.15, elevation 0.08 inch," Haldeman (1841).

"Narrow, elongated, the lateral margins nearly straight, widening more or less anteriorly, ends well rounded; anterior slope rather long, slightly convex; posterior slope shorter than anterior, straight but slightly concave; right lateral slope nearly straight, left lateral slope slightly convex; apex sub-acute, slightly turned toward the right and slightly anterior of the center of the shell; radially striate; lines of growth fine, irregular, but well marked; the peritreme of the shell may be even or it may be concave at both ends, when the habitat has been upon *Scirpus*. Color of the shell pale corneous" (Baker, 1928).

ECOLOGY/BIOLOGY: Basch (1963) found *F. parallela* primarily on vegetation, particularly *Scirpus*, *Typha*, etc., in clean shallow lakes. However, some were collected from muddy, turbid water in shallow swamps. It occurs principally on smooth plant stems near the surface, but also on cans or other submerged metal objects.

F. parallela is another lake or pond species that probably spread across the High Plains and the Southwest during pluvial periods of the Pleistocene. I think this concept particularly applies to Texas since this region has had no natural lentic systems except during those wetter Pleistocene periods. Basch (1963) stated that this species appeared able to withstand much higher summer temperatures than *F. rivularis*. This could be a post-Pleistocene adaptation of populations that established during the wetter periods.

Ferrissia rivularis (Say), (Fig. 8a).

Ancylus rivularis Say, 1817, J. Acad. Natur. Sci. Phil., 1:125.

Ferrissia rivularis (Say) Walker, 1918, Misc. Publ. Mus. Zool. Univ. Mich., 6:119.

Ferrissia tardus (Say) Basch, 1963, Bull. Mus. Comp. Zool., 129(8):429.

TYPE LOCALITY: Delaware and Susquehanna Rivers, Pennsylvania. Holotype - ANSP 2182.

GENERAL DISTRIBUTION: Throughout most of North America; exact limits are unknown (Clarke, 1973). The complete distributional pattern is difficult to determine due to the variety of names periodically applied to this species. La Rocque (1953) recorded it from New Mexico.

TEXAS DISTRIBUTION: Fossil County Records: (subfossil) Tule Canyon, SWISHER (Cummins, in Singley, 1893 as *Ferrissia tarda* and repeated in Strecker, 1935); CRANE, WARD, PECOS and TERRELL (Leonard and Frye, 1962); MOTLEY (Cheatum and Allen, 1965); DONLEY, BRISCOE and DELTA (DMNH Coll.); COOKE (as *F. tarda* in Willimon, 1972).

DESCRIPTION: "Shell corneus, opaque, conic-depressed; apex, obtuse, nearer to and leaning towards, one side and one end; aperture oval, rather narrower at one end, entire; within milk-white. Length 1/4 inch" (Say, 1817). "Ovate, the margins regularly curving, the ends rounded, anterior slope convex, posterior slope concave below the apex but more or less straight near the peritreme; right slope slightly convex or straight; left slope usually straight but sometimes slightly convex; shell rather well elevated, with a subacute apex, inclining somewhat toward the right side; the apex is situated about a third of the distance from the posterior end;

apex radially striate; growth lines somewhat irregular, well marked, with more or less of radial sculpture on the anterior slope, the peritreme of the shell is usually quite flat; the greatest width of the shell is in front of the apex, the shell narrowing somewhat posteriorly; color pale corneous" (Baker, 1928).

ECOLOGY/BIOLOGY: Ferrissia rivularis is characteristically lotic. According to Basch (1963), "the usual habitat of F. rivularis is a stream with a gravelly bottom, containing a large proportion of stones at least two inches in diameter. Occasional good collections have been made from earth silt-laden streams with muddy bottoms. . . , but where the silt is finely divided clay that remains in suspension, limpets are invariably absent. F. rivularis is tolerant of organic pollutions." Clarke (1973) did not specifically note the presence or absence of stones for limpet attachment, but clearly remembered some F. rivularis localities without a stony substrate, and added that it also occurred on or in empty freshwater mussel shells.

The anatomy of F. rivularis has been described by several authors, Baker (1928), Hoff (1940) and Hubendick (1963). The radula formula is quite similar to those of all the North American Ferrissia species, as well as those species of Laevapex and Gundlachia, 19-1-19 to 21-1-21, with two large cusps on the central tooth and one minute cusp basally on each side. The first laterals have three large cusps (on the outer edge) which are gradually replaced by two large cusps and several small cusps on others nearer the ends of the transverse rows (Clarke, 1973).

Basch (1963) noted while discussing the distribution of _F. rivularis_ that "typical specimens are known from the east coast to the Rockies, but apparently in the southern and western states the specimens are characteristically smaller."

DISCUSSION: I hesitate to list _F. rivularis_ as only a fossil in Texas, due to insufficient collecting, and because of the possibility that it may exist in the smaller form noted by Basch. Thus, a series of small specimens might be first identified as _F. californica_ or, more likely, as _F. walkeri_. Although the general adult shell length of _F. rivularis_ is 7 mm, Basch (1963) graphed 5 populations and each had individuals within the maximum size of _F. californica_ (4 mm) and _F. walkeri_ (6 mm). However, in all of the fossil and recent shell material examined during this study, no specimens were observed that would conform to _F. rivularis_.

Ferrissia walkeri (Pilsbry and Ferriss), (Fig. 8c).

Ancylus walkeri Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil., 1906:564.

Ferrissia walkeri (Pilsbry and Ferriss), Walker, 1918, Misc. Publ. Mus. Zool. Univ. Mich., 6:120.

TYPE LOCALITY: Rogers, Benton County, Arkansas: Type lots - ANSP 87479H, UMMZ 101987.

GENERAL DISTRIBUTION: Arkansas, Michigan, southern California, southern Oklahoma (McMahon et. al. 1976): The actual range of *F. walkeri* is unknown. This species is limited to ponds and lakes and is dependent more upon suitable habitats than upon geographical areas for its distribution (Basch, 1963).

TEXAS DISTRIBUTION: Recent in TARRANT County (McMahon, 1977).

DESCRIPTION: "Shell pale corneous, thin, oval, the right and left sides equally curved; moderately elevated, the apex depressed, radially striate. Situated behind the posterior third, and much nearer the right than the left margin. Surface densely and minutely striate concentrically, and showing faint traces of radial striae. Anterior and left slopes convex; right and posterior slopes concave. Length 4.3 mm, width 2.75 mm, height 1.4 mm" (Pilsbry and Ferriss, 1906).

ECOLOGY/BIOLOGY: *F. walkeri* occurs on the undersides of water lilies (*Nymphea*) and other large flat surfaces in clean standing water (Basch, 1963). However, McMahon (1977) found it occurring on the stems of southern bullrushes (*Scirpus acutus* Muhl.), and on the underside of leaves of arrowhead (*Sagittaria graminea Michaux*) that extended above the substrate, in a small pond resulting from a dammed tributary of the West Fork of the Trinity River. He also found *Laevapex fuscus* on the basal leaf portions of *S. graminea* where it emerged from the substrate. Thus, as he pointed out, the two species were spatially separated even though they occurred on the same plant. He also found that adult *F. walkeri* were infected with cercariae of an unidentified trematode, but specimens of *F. fuscus* collected at the same site were not infected.

The validity of *F. walkeri* as a species is open to question (Basch, 1963). "Of the standing-water *Ferrissia* (*fragilis*, *walkeri* but excluding *parallela*) there are innumerable intergrading forms, the larger of which I have specified as *F. walkeri* (6.0 mm). Between this species and *F. fragilis* (*californica*) we find a continuous gradient, but the ends of the series are so different that I find it inconsistent to apply the same specific name. . . ." He also observed that the larger specimens (i.e., *walkeri*) are characteristic of larger bodies of standing water, while the *californica* type occur in smaller ponds and ditches with more organically turbid water.

F. walkeri may be externally differentiated from the similar-sized *Laevapex fuscus* by the apical striations. With the discovery of *F. walkeri* and *F. californica* in North Central Texas, an excellent opportunity is present to better define their exact taxonomic relationships through such techniques as gel electrophoresis.

DISCUSSION: I had hoped to find large populations of *Ferrissia* for statistical analysis of shell length. However, no such populations were discovered, nor did I find any shells that could definitely be considered as *F. walkeri*.

Genus *Gundlachia* Pfeiffer, 1849

Gundlachia radiata (Guilding), (Fig. 8b).

Ancylus radiatus Guilding, 1828, The Zoological Journal, 3:536.

Gundlachia hjalmarsoni (Pfeiffer, 1858), Nall. Blatt., 5:197.

Hebetancylus excentricus (Morelet, 1851), Basch, 1963, Bull. Mus. Comp. Zool., 129:422.

Ferrissia excentricus (Morelet, 1851), Walker, 1918, Misc. Publ. Mus. Zool. Univ. Mich., 6:120.

Ancylus excentricus (Morelet, 1851), Text. Noviss. Insul. Cuba et Amer. Centr., Pars II:17, Lake Pecten, Guatemala.

Gundlachia excentrica (Morelet, 1851), Taylor, 1966, the Veliger, 9(2):209.

TYPE LOCALITY: West Indies, Saint Vincent's Island?

GENERAL DISTRIBUTION: Circum-Caribbean: from southeastern Georgia, Florida, southern Texas and Mexico in the north to Columbia, Venezuela, and Trinidad in the south. Many West Indian Islands from Grand Bahama to Saint Vincent and Guadelupe to Old Providence (Hubendick, 1967). The fossil distribution is unknown.

TEXAS DISTRIBUTION: Recent County Records: COMAL, TRAVIS (as *F. excentrica*, Walker, Pilsbry and Ferriss, 1906 and Singley, 1893); CAMERON as *G. hjalmarsoni* (Clapp), in Singley (1893) and repeated in Strecker (1935); HAYS, KERR, JACKSON, VICTORIA, and MASON (as *H. excentricus*, Basch, 1963); TARRANT, DALLAS, BASTROP, HOOD, SOMERVELL and PALO PINTO (as *H. excentricus*, McMahon, 1976).

DESCRIPTION: The shell is usually elliptical. Sometimes the left side is more projecting than the right one. The anterior end is usually slightly blunter than the posterior end. Sometimes, particularly in septate forms, the shell is rather elongate. The apex is rarely central; it is usually located well behind the middle of the shell and well to the right of the median. In the West Indian non-septate forms, the apex is never located near the right margin of the shell. In the Central American forms, it is often further to the right, sometimes above the margin. The apex is normally pointing dorso-posterior and somewhat to the right. It is blunt and never really hooked. The anterior slope of the shell is normally slightly convex, the posterior slope concave. The shape of the lateral slopes vary; the left one has a tendency of being convex, the right one being concave and steeper. Septation occurs frequently.

The apex has no characteristic sculpture, but is sometimes irregularly punctate. Below the apical region is a radial sculpture of usually distinct ridges running down to the lower part of the shell, or down to the edge. The interspaces have from two to six times the width of the more or less slender ridges. The radial sculpture is often incomplete, but there are mostly at least some ridges on the anterior part of the shell. Sometimes the radial sculpture is completely missing (the excentrica type).

The color of the shell varies from almost colorless or light tan to brownish. The soft body has normally a rich, irregular pigmentation dorsally on the mantle. There is no pigment of the abductor muscle. The head usually has fine grayish dots, dorsally.

"The form-group has a wide range of variation even within one population. The shell length is 2.7 - 10 mm, width 2 - 5.5 and height 0.8 - 2.1 mm." (Hubendick, 1967).

ECOLOGY/BIOLOGY: Gundlachia radiata, in Texas, was found on rocks in swift streams and rocks and rooted vegetation in lakes and river backwaters. Thus, it appears to have a lesser habitat specificity than Ferrissia or Laevapex. Generally, though, it occurs more frequently in streams, and replaces Ferrissia rivularis as the "common" stream limpet south of the Red River (McMahon, 1976). In the only life cycle study conducted on this species, McMahon (1976) found that G. radiata had a bi-voltine life cycle, with only the second generation surviving over winter to reproduce in the spring. The first generation spawns from late August through mid-November. Some individuals of the first generation survive until just before spring breeding, which begins in February and lasts through May. None of the second (winter) generation survives beyond May (McMahon, 1976). McMahon's life cycle study of Laevapex fuscus and Gundlachia radiata in North Central Texas is an excellent model to follow in other such studies on Texas freshwater gastropods.

DISCUSSION: Hubendick (1964, 1967) reviewed the neotropical ancylid fauna and placed the multitude of species into "form-groups." The shell characteristics I have given here follow his description of the G. radiata form-group. Guilding's (1828) description of the nominal species Ancylus radiatus was too vague for adequate use, but the name has priority.

Apparently, *G. radiata* is the most common limpet in Texas. Although once considered strictly a subtropical species, and reported in Texas only along the Rio Grande River (Clapp, 1913), McMahon (1976) reported it from southeastern Oklahoma. Whether or not this indicates an increasing range and replacement of the lotic *Ferrissia* species awaits further study of north central Texas ancylid fossil material. The fact that it has not been reported as a fossil in Texas may be due to incorrect identifications. However, in examining all fossil ancylid material available to me, I did not find *G. radiata*.

I also have some reservations concerning McMahon's statement that *G. radiata* replaces other lotic dwelling limpets in this area for several reasons. It was never found during this study in abundance at any one locality, thus disallowing the possibility of inter-specific competition for space or for available food. Where I found *G. radiata* and other ancylids such as *L. fuscus* occurring together, both species appeared to be fairly equal in the number of individuals present.

Genus *Laevapex* Pfeiffer, 1849

Laevapex fuscus (C. B. Adams), (Fig. 7e).

Ancylus fuscus Adams, Bos. J. Natur. Hist., 3:329.

Laevapex fuscus (Adams), Basch, 1959, Misc. Publ. Mus. Zool. Univ. Mich., 108:1-56.

Ferrissia kirklandi (Walker), Basch, 1963, Bull. Mus. Comp. Zool., 129:419.

TYPE LOCALITY: Andover, Massachusetts.

GENERAL DISTRIBUTION: United States and Canada, generally east of the Great Plains; Great Lakes area; Florida and southeastern states. Generally absent from mountainous areas; Kansas (Shimek, 1935); Kansas (Leonard, 1959); Oklahoma (Branson, 1959); Texas (McMahon, 1976, 1977).

TEXAS DISTRIBUTION: Recent County Records: DALLAS, TARRANT, SAN PATRICIO (McMahon, 1976); COMAL and VICTORIA (Clapp, in Singley, 1893 and repeated in Strecker, 1935 as F. kirklandi); POLK, DALLAS, SAN PATRICIO, DENTON, HAYS and KIMBLE (DMNH Coll.).

DESCRIPTION: "Shell thin, transparent without the epidermis, not much elevated, elliptical, moderately curved at the sides, epidermis brown, visible through the shell, giving it the appearance of having the same color, thick, rough, slightly extending beyond the margin of the shell; apex obtuse, moderately prominent, scarcely behind the middle, inclining to the right, so as to have only two-fifths of the width on that side. Length 0.31 inch, width 0.22 inch, and height 0.05 inch" (Adams, 1841). Basch (1963) listed the average dimensions of 25 specimens from Michigan as: length 5.34 mm, diameter 3.75 mm, height 1.72 mm. Apex smooth as is the shell, occasional, fine raised riblets on anterior slope; apex behind the center of the shell. Below apex, shell with a fine concentric growth sculpture and an extremely fine radial sculpture.

ECOLOGY/BIOLOGY: Laevapex fuscus, the common "pond" limpet is generally found in swamps, ponds, slow rivers and lakes (Basch, 1963, Clarke, 1973). It prefers dense emergent rooted vegetation where it inhabits the lower stems. Basch (1963) found it on the undersides of *Nymphea*, on *Typha*, *Scirpus* and other rooted vegetation. He also found it in assocation with *Ferrissia californica* (*fragilis*) in stagnant waters and with *Gundlachia radiata* (his *Hebetancylus excentricus*) in streams. In North Central Texas, McMahon (1976, 1977) collected *L. fuscus* on *Scirpus californicus*, and on the lower leaves of *Sagittaria graminea*.

McMahon (1976) determined that, in Texas, *Laevapex fuscus* undergoes a bivoltine life cycle as does *Gundlachia radiata* with several notable exceptions. The second generation that hatched in June to mid-July did not completely replace the first generation which hatched in mid-April. Both generations overwintered and laid in late March. Egg laying continued until early June when the overwintering individuals died off. One population from Mountain Creek Lake, Dallas County had three generations per year. He also determined that egg laying was correlated with a rise in the ambient water temperature. *G. radiata* oviposition began at 15.0^{o} C while *L. fuscus* began at 15.8^{o} C.

DISCUSSION: *Laevapex* may also be differentiated from *Ferrissia* by its tentacles which have a black core while those of *Ferrissia* do not. Although McMahon (1976) stated that the southern distributional limit might be in the North Central Texas region, I have collected it southward to the coastline. It was also found to occur in streams almost as frequently as in ponds. I consider *L. fuscus* to be rather common for the State.

Laevapex diaphanus (Haldeman), (Fig. 7d).

Ancylus diaphanus Haldeman,1841, Monograph of the Limnaides or freshwater univalves of North America, no. 3, description on the cover.

Ferrissia diaphana (Haldeman), Walker, 1918, Misc. Pub. Mus. Zool. Univ. Mich., 6:120.

Laevapex diaphanus (Haldeman), Basch, 1963, Bull. Mus. Comp. Zool., 129:421.

TYPE LOCALITY: "Ohio" (Haldeman, 1841). Holotype - ANSP 21978.

GENERAL DISTRIBUTION: Delaware, Ohio, Illinois, Georgia, Alabama, and Arkansas.

TEXAS DISTRIBUTION: New State Report: Lake Fork Creek, WOOD and RAINS Counties (collected by Gerard Sala).

DESCRIPTION: "Shell thin in texture, diaphanous, very wide, nearly circular, depressed; apex obtuse, almost central; slope scarcely convex. Color very pale olivaceous, translucent, aperture white. Dimensions: length 5.5 mm, width 4.5 mm, height 2 mm." (Haldeman, 1841). The shell is distinguished by the circular aperture, flattened shape and by the central, inconspicuous apex.

ECOLOGY/BIOLOGY: Basch (1963) consistently found *L. diaphanus* in slowly flowing streams and rivers and usually on smooth rocks two or more inches in diameter. Otherwise, no ecological or biological information is available for this species.

DISCUSSION: Mr. Gerard Sala of the Sabine River Authority collected ancylids along Lake Fork Creek during September, 1975 and sent them to me for identification. Two lots were readily recognizable as L. diaphanus.

The creek, according to Mr. Sala, is slow flowing and shallow with a sandy substrate. He could not recall if the specimens were on rocks or vegetation. The stream, due to be impounded, drains into the Sabine River.

Summary of Texas Ancylidae

This report includes three ancylid genera and seven species as fossil or Recent for Texas. Literature records included four genera and 14 species for the State. Locality records cited reflect only the material actually observed by the author or from those literature citations by competent authors. In reviewing lots from other collections made available to me, I found the vast majority were found to be misidentified.

Two fossil species (F. rivularis, F. parallela) occur in the state. I determined that G. radiata and L. fuscus are much more widely distributed in the State than previously thought. L. diaphanus is reported for the first time in Texas. With the exception of Gundlachia radiata, all Texas ancylid species were found in habitats described in the literature. G. radiata was cited by Basch (1963) as being principally a lake form. I found it primarily in clear streams. The Texas species can be grouped by hapitat as follows: (1) Streams, on rocks or cans: F. rivularis, G. radiata, L. diaphanus, L. fuscus; (2) Lakes or ponds on vegetation: F. californica, F. parallela, F. walkeri, G. radiata (not on vegetation).

Family Lymnaeidae Rafinesque

The Lymnaeidae is another world-wide and taxonomically confused group of freshwater snails. The most comprehensive studies on this family since 1900 have been by Baker (1911, 1928), Hubendick (1951), and Clarke (1973). Baker divided the Lymnaeidae into many formal subgroups, particularly at the generic and specific levels. Contrastingly, Hubendick advocated the abandonment of most of the subgroups above the generic level and reduced the world number of genera to one, Lymnaea. Recently, Walter (1968, 1969) considered both viewpoints vastly incorrect in that they were too artificial based upon his anatomical findings. Clarke (1973) agreed with Walter, and in his The Freshwater Mollusca of the Canadian Interior Basin (1973) presented his own taxonomic lymnaeid scheme somewhat following Walter's view. The Lymnaeidae systematic format adopted for this study retains much of Baker's system for North America while attempting to bring the generic and specific taxonomy more into line with current knowledge of these levels. Walter's recommendations may eventually prove to be the most valid, but because his investigations to date encompass a relatively small number of North American lymnaeids, I have chosen to follow Baker.

FAMILY CHARACTERS: Shells small to large, thin or of moderate thickness, orthostrophic and conispiral (and elongate in most species) or patelliform (Lanx), and non-operculate. Conispiral species holostomatous, with aperture typically angled above and rounded below; umbilicate or non-umbilicate, and sculptured with collabral lines and with or without periostracal ridges, surface malleations, and additional microsculpture; monoecious (with facultative cross- and self-fertilization) and phytophagous; condensed from Clarke (1973).

"Animal dextral. Head with broad short muzzle dilated at the end. Foot rounded behind. Tentacles flattened. Jaw composed of three plates, a large onein the centre, and two small, narrow laterals. Radula broad; central tooth small, simple or bicuspid, the laterals bi- or tricuspid. The marginals bi-, tri- or multicuspid or serriform." (Walker, 1918).

DISTRIBUTION: Lymnaeidae is one of the most abundant fresh-water gastropod families in the cool Holarctic climate. However, lymnaeid species are also represented in every other zoogeographical region of the world.

ECOLOGY/BIOLOGY: The largest sized lymnaeids are found in northern cold-water lakes and rivers. Southward (particularly in North America), the shell becomes small and the species fewer in number. In the south, lymnaeids occur in shallow lakes, temporary ponds, sloughs, even on the wet mud adjacent to the water. They particularly seem fond of crenon areas with abundant moss or algae.

PALEONTOLOGY: Upper Jurassic to Recent (Zilch, 1959). Recent species number about one hundred in addition to almost that many strictly fossil forms.

Key to the Lymnaeidae of Texas

1. a. Shell succineiform; spire usually not more than one-third the length of the shell aperture; cross-hatching effect on body whorl . . . *Pseudosuccinea columella*

   b. Shell not succineiform; spire more than one-third the length of the shell aperture 2

2. a. Shell large, usually over 40 mm in length; axis gyrate . . . . *Lymnaea stagnalis appressa*

   b. Shell smaller, less than 38 mm in length 3

3. a. Shell usually ranging from 8-20 mm in length . . . 4

   b. Shell usually ranging from 20-38 mm in length . . 6

   c. Shell usually less than 7 mm in length, spire turreted; axis straight . . . . *Fossaria dalli*

4. a. Shell elongated; spire usually acutely conic; whorls 6 - 6.5 5

   b. Shell globose, with a short broad spire; whorls 4.5 . . . . *Stagnicola cockerelli*

5. a. Recent shells with heavily incised spiral lines and these lines evident in fossil shells under oblique light; axis thickened but not twisted; whorls 6 - 6.5 . . . . *Stagnicola caperata*

   b. Only faint indications of spiral lines in recent shells and these lines absent in fossil shells; body whorl greatly inflated; axis consists of a series of smooth, hour-glass-shaped columns; whorls 6 . . . . *Stagnicola bulimoides techella*

c. Recent shells with coarse growth lines and fine spiral lines; axis with a slight twist; whorls 5.5 . . . . *Fossaria obrussa*

6. a. Axis with a pronounced twist 7

b. Axis with a slight twist and frequently gyrate; whorls flat-sided; shallow sutures; steeple-shaped spire . . . . *Stagnicola exilis*

7. a. Whorls rounded and much wider than high; columellar plait heavy . . . . *Stagnicola elodes*

b. Whorls flatly rounded; whorls not much wider than high; usually a heavy plait across center of columella . . . . *Stagnicola reflexa*

Genus *Fossaria* Westerlund, 1885

Fossaria obrussa (Say), (Fig. 10d).

Lymneus obrussus Say, 1825, J. Phil. Acad. Natur. Sci., V:123.

Fossaria obrussa (Say), Baker, 1928, Wisc. Geol. Natur. Hist. Surv. Bull., 70, Pt. 1:293.

Lymnaea desidiosa (Authors, non Say), Baker, 1911, Chi. Acad. Sci., Spec. Publ., 3:271.

Lymnaea humilis rustica Lea, Hibbard and Taylor, 1960, Univ. Mich. Mus. Zool. Contrib., XVI(1):94.

Lymnaea modicellus Say, 1825, J. Phil. Acad. Natur. Sci., 5:122.

TYPE LOCALITY: "Harrow gate, Philadelphia County, Pennsylvania" (Say, 1820). Holotype - ANSP 58700.

GENERAL DISTRIBUTION: "From the Atlantic to the Pacific oceans, and from Mackenzie Territory, Canada, south to Arizona and northern Mexico" (Baker, 1928). Geological Range: "Early Pleistocene (Nebraskan) to Recent. The earliest-known occurrences in the southern Great Plains are in the Illinoian Berends and Butler Springs local faunas" (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages; Wisconsin: DONLEY, KNOX, BAYLOR, HALL, DALLAS, HARDEMAN and WICHITA (DMNH Coll.); DALLAS (Clarke, 1939); HARDEMAN (Cummings, 1893, as _L. humilis_); HALE (Sellards, Evans and Meade, 1947, as _L. humilis_); HARDEMAN (Baker, 1911, as _L. modicella_); HOWARD (Singley, 1893, as _L. modicella_). Sangamonian: DALLAS (Slaughter, et. al., 1961, as _L. obrussa_ and _L. modicella_); FOARD (Dalquest, 1961, as _L. modicella_). Recent County Distribution: COMAL; Pilsbry (1906, as _Lymnaea humilis_) AUSTIN; (Branson, 1961, as _Lymnaea humilis_); LLANO, GILLESPIE, FAYETTE, SOMERVELL, IRION, BOSQUE, BEXAR, UVALDE and DALLAS (DMNH Coll.);

DESCRIPTION: Baker (1928) stated that the typical shell of "_obrussa_ may be known by its pointed spire, compressed body whorl; elongated and shouldered aperture; inner lip appressed to the body whorl about the middle of the aperture; shell sculpture of many coarse growth lines and fine spiral lines; whorls 5.5, rounded; last whorl about one-half the length of the shell;" aperture elongated and shouldered at its junction with body whorl which is usually compressed; axis with a slight twist; shell not turreted, and whorls only somewhat shouldered; 8 - 20 mm in length.

ECOLOGY/BIOLOGY: Habitat similar to S. bulimoides techella, although from field observations in Texas, it was found more in shallow water and marshy habitats than S. b. techella.

DISCUSSION: Many specimens of both fossil and recent shells from Texas over 8 mm in length approach F. humilis. However, where collections were large enough for a quantitative study, all Texas specimens seemed to be within the variation ranges of F. obrussa. Although Cummings (1892) listed fossil F. humilis from Hardeman County, judging from specimens which have been examined from that area I must conclude that Cummings' specimens were probably F. obrussa. Branson (1961) followed the work of Hubendick (1951) by incorporating obrussa, modicella, parva, and dalli under the species humilis. Van der Schalie (personal communication) shared with me the opinion that although Hubendick's work is very useful, much more needs to be done before one could submerge all of these species under humilis. Baker (1911) gave the following Recent distribution of F. humilis: "Southeastern United States, so far as presently known, humilis is confined to the upper and lower austral life zones, east of the Appalachian Mountains."

Fossaria dalli (Baker), (Fig. 9f).

Lymnaea dalli Baker, 1907, Nautilus, 20(11):125.

Fossaria dalli (Baker), Baker, 1928, Wisc. Geol. Natur. Hist. Surv., Bull., 70, Pt. 1:288.

Lymnaea _parva_ Lea, Hibbard and Taylor, 1960, Univ. Mich. Mus. Zool. Contrib., XVI, No. 1:93.

TYPE LOCALITY: "Lake James, Steuben County, Indiana" (Baker, 1907).

GENERAL DISTRIBUTION: "Ohio to northern Michigan and Montana, south to Kansas" (Baker, 1911). _Geologic_ _Range_ - Early Pliocene to Recent. The oldest known occurrence is in the Laverne local fauna, Beaver County, Oklahoma (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages; Kansan: GARZA (Frye and Leonard, 1957); KNOX (Strickland, 1961, as _F_. _parva_); BRISCOE, CROSBY, GARZA, and LUBBOCK (Frye and Leonard, 1957, as _F_. _parva_). Illinoian: BORDEN (Frye and Leonard, 1957, as _F_. _parva_). Sangamonian: DALLAS (Slaughter, et. al. 1959); FOARD (Dalquest, 1961). Wisconsin: DENTON and DELTA (Cheatum and Allen, 1962); CRANE, GAINES, RANDALL, and LUBBOCK (Frye and Leonard, 1957, as _F_. _parva_); ECTOR, CRANE and WINKLER (Wendorf, 1961, as _F_. _parva_); PECOS (Leonard and Frye, 1962, as _F_. _parva_); Undetermined Ages: DONLEY, KNOX, BAYLOR, HALL, WICHITA, and HARDEMAN (DMNH Coll.). Recent County Records: GILLESPIE, JEFF DAVIS, COMAL and BREWSTER (DMNH Coll.); BRAZOS, UVALDE and HOUSTON (Mather Coll.).

DESCRIPTION: "Very small, thin, ovate-conic, turreted; marked by heavy crowded growth lines which are elevated into indistinct edges in some specimens; whorls 4.5 - 5.5, rounded and distinctly shouldered" (Baker, 1911). Baker (1911) also stated that _F. dalli_ "differs from _parva_ in its smaller size, rounder and more turreted whorls, slenderer outline, longer and narrower aperture and smaller and less conspicuouos umbilicus;" axis straight; shell length varies from slightly over 3 mm to 4.5 mm; spire turreted; straight axis; aperture narrowly eliptical; maximum size range 3 - 8 mm. This species is the smallest of all American lymnaeids.

ECOLOGY/BIOLOGY: Amphibious in habit; the favorite habitat observed during this study seemed to be on moist vegetation in seepage areas. Baker (1911) stated that this species "is more prone to leave the water than (any) other of the Lymnaeas."

DISCUSSION: Baker (1930), in describing _Fossaria dalli grandis_, stated that "_Fossaria dalli_ of the Pleistocene is uniformly larger, with 5 to 5.5 full whorls, the sutures deeper and the whorls rounder, the whole shell wider, the aperture larger and narrower. All are uniformly larger than the recent form, which only rarely attains any such proportions in length, and never in width and general size. The recent _dalli_ is undoubtedly the descendent of the larger Pleistocene variety." Based upon shell measurements of Pleistocene _F. dalli_ from Texas deposits, several specimens conformed to Baker's _F. dalli grandis_. However, lack of consistency did not warrant its inclusion as a valid Texas species.

Genus _Lymnaea_ Lamarck, 1799

Lymnaea stagnalis appressa (Say), (Fig. 9b).

Lymnaeus appressus Say, 1818, J. Phil. Acad. Natur. Sci., 2:168.

Helix stagnalis Linneaus, 1758, Systema Natura, Ed. 10:774.

Lymnaea stagnalis appressa (Say), Baker, 1905, Amer. Natur., 39:667.

Lymnaea stagnalis jugularis (Say), authors.

TYPE LOCALITY: Lake Superior. Holotype - 2 unnumbered specimens, ANSP.

GENERAL DISTRIBUTION: North America from about the 37th (Colorado) and 41st (Illinois) parallels of north latitude to the Arctic Ocean (Baker, 1928). Geologic Range: Pleistocene to Recent. The oldest definite occurrence is in the Illinoian Butler Spring local fauna, southwestern Kansas, but the subspecies may occur in the late Kansan Cudahy fauna, in Lincoln County, Kansas (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages; Illinoian: HARDEMAN (DMNH Coll.).

DESCRIPTION: Baker (1928) described the shell of this species as follows: "Large, elongated, somewhat fusiform, thin; lines of growth rather coarse, crossed by distinct impressed spiral lines; all spire whorls very flat sided; spire long, acutely pointed, usually more than one-half as long as the entire shell; aperture ovate, sometimes somewhat dilated above, rounded below; outer lip thin, acute; pillar of the columellar gyrate, forming a heavy, oblique, ascending plait; umbilical chink closed or slightly open."

ECOLOGY/BIOLOGY: Baker (1928) stated that "the natural habitat of jugularis (appressa) is more or less stagnant parts of both lakes and rivers." This species can over-winter by migrating to deeper water in the fall, and remain until the following spring, breathing cutaneously during this period (Cheatum, 1934).

Genus Pseudosuccinea Baker, 1908

Pseudosuccinea columella (Say), (Fig. 9a).

Lymnaea columella Say, 1817, J. Phil. Acad. Natur. Sci., 1:14 (Binney reprint, 1858:60).

Pseudosuccinea columella (Say), Baker, 1908, Science, 82:943.

TYPE LOCALITY: Not specified, but presumably near Philadelphia (Clarke, 1973). Holotype - ANSP 58791.

GENERAL DISTRIBUTION: "Nova Scotia west to Minnesota, eastern Kansas and central Texas; Manitoba and Quebec south to Texas and Florida" (Baker, 1928).

TEXAS DISTRIBUTION: Recent County Records: COMAL (Pilsbry and Ferriss, 1906); COMAL, DALLAS, JEFFERSON, POLK, FAYETTE, MARION and HARRISON (DMNH Coll.); BASTROP (Mather Coll.).

DESCRIPTION: Shell thin, transparent with a greenish or yellowish sheen; somewhat pointed spire which is usually not more than one-third the length of the aperture; whorls 4, body whorl large, approximately three times the size of all the other whorls and appears cross-hatched from interlacing of faint spiral lines with normal growth lines. Range of shell measurements made during this study: diameter 5-12 mm, height 12-21.5 mm.

ECOLOGY/BIOLOGY: Seems to prefer quiet bodies of water with abundant vegetation, but this species can tolerate, and apparently thrive in stagnant water. At every Texas locality investigated, *P. columella* occurred in small numbers. The most characteristic habitat is almost swampy, stagnant backwaters of lakes. The snails were always collected from submerged sticks and logs.

DISCUSSION: Baker (1911) listed *P. columella chalybea* (Gould) from along the Rio Grande in Texas. Although a large population of *P. columella* may contain a few shells with characteristics of *chalybea*, I am not including this subspecies as valid for Texas. Hubendick (1951) also considered *P. columella chalybea* as *P. columella*.

Genus *Stagnicola* Leach, 1830

Stagnicola caperata (Say), (Fig. 9d).

Lymnaeus caperatus Say, 1829, New Harmony Disseminator of useful knowledge, 2:238 (Binney Reprint, 1858).

Stagnicola caperata (Say), Baker, 1928, Wisc. Geol. Natur. Hist. Surv. Bull., 70, pt. 1.

TYPE LOCALITY: "Indiana" (Say, 1829).

GENERAL DISTRIBUTION: "From Quebec and Massachusetts west to California; Yukon Territory and James Bay south to Maryland, Indiana, Colorado and California" (Baker, 1928). Hibbard and Taylor (1960) stated that the known geological range of this species is from "Middle Pliocene to Recent," and that it is "common in Pleistocene deposits of the High Plains."

TEXAS DISTRIBUTION: Undated Fossil County Records:- COTTLE and HARDEMAN (Singley, 1893); HALL, HARDEMAN, FOARD and WICHITA (DMNH Coll.). County Records by Pleistocene Ages; Kansan: SWISHER, GARZA, CROSBY and BRISCOE (Frye and Leonard, 1957); KNOX (Strickland, 1961); ROBERTS and HARTLEY (Leonard, 1950). Illinoian: BRISCOE (Frye and Leonard, 1957); CLAY (Allen and Cheatum, 1961). Sangamon: FOARD (Dalquest, 1962); DALLAS (Slaughter, et. al., 1961). Wisconsin: FLOYD, GAINES, BORDEN, CROSBY and GLASSCOCK (Frye and Leonard, 1957); WINKLER, ECTOR and CRANE (Wendorf, 1961); DELTA (Cheatum and Allen, 1962); WARD, PECOS and CRANE (Leonard and Frye, 1962).

DESCRIPTION: Baker (1928) stated that this species "is one of the most distinct and uniform of American Lymnaeas. The striking manner in which the epidermis stands erect in the impressed spiral lines is peculiar to this species and will always distinguish it when the specimens are fresh." If the epidermis is worn or scraped off, the spiral lines are then similar to the spiral lines in other lymnaeids but still are clearly incised, even in fossil shells when viewed under oblique light. The whorls, which number from 6 to 6.5, very convex; spire acutely conic and usually longer than the ovate-aperture; inner lip reflected over the umbilicus forming a wide triangular expansion; columellar plait absent and umbilical chink open; axis thickened but not twisted; shell surface usually marked by several ridges indicating growth periods; growth lines fine and crowded. Baker (1911) listed shell length varying from 9 to 17 mm, and shell width from 5 to 8.25 mm, from a series of northern specimens. Measurements of Texas Pleistocene shells averaged slightly less than Baker's.

ECOLOGY/BIOLOGY: *Lymnaea caperata*, generally occupies intermittent silty-bottomed streams or small pools, ponds and ditches and sloughs which are dry during part of the year. It also may occur in ditches entirely free from vegetation, with *F. obrussa*; and often in sloughs containing much swamp grass, filled by spring overflow of streams according to Baker (1911). *Stagnicola caperata* apparently was an abundant lymnaeid throughout the Pleistocene in Texas, particularly during the Wisconsin.

Stagnicola bulimoides techella (Haldeman), (Fig. 10c).

Lymnaea bulimoides Lea, 1841, (no title) Proc. Amer. Phil. Soc., 2:33.

Lymnaea techella Haldeman, 1867, Amer. J. Conchol., 3:194, pl. 6:4. Type locality; "Texas."

Galba bulimoides techella (Haldeman), Baker, 1911, Chicago Acad. Sci. Spec. Publ., 3:214.

Stagnicola bulimoides techella (Haldeman), Taylor, 1960, U. S. Geol. Surv. Prof. Pap., 337:54.

TYPE LOCALITY: "Oregon." Holotype - ANSP 330131.

GENERAL DISTRIBUTION: United States west of the Mississippi River, Rocky Mountain foothill regions and Canada (Clarke, 1973); in the south, Alabama west to southern California and northern Mexico (Baker, 1911). Geological range Late Pliocene to Recent (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records: Pliocene:- OLDHAM (Hibbard and Taylor, 1960). Pleistocene:- KNOX (Salt Fork of the Brazos River near Rhineland; collected by E. L. Lundelius, Univ. of Texas). Sangamon: DENTON (Cheatum and Allen, 1962). Recent County Records: DALLAS (Baker, 1911, as Lymnaea techella); DALLAS, C. HALL (Hemphill); HUNT (Hannah, Singley); HARRIS (Hemphill, Pilsbry), ROCKWALL (Ferriss, C. G. Ragsdale); BEXAR (Pilsbry); TARRANT (Sampson, Walker); FORT BEND, NUECES, TRAVIS, EL PASO, COMAL, THROCKMORTON, JACKSON (Smith Coll.); McLENNAN (Strecker); DENTON, DALLAS, TARRANT, CROCKETT, UPTON, MENARD, PECOS, SOMERVELL, COOKE, KENDALL and GRIMES (DMNH Coll.); TARRANT, ROCKWALL, DALLAS, HOUSTON and HAYS, Pilsbry and Ferriss (1906 as Lymnaea bulimoides techella).

DESCRIPTION: Baker (1911) stated that "techella may be known by its acutely conic spire, obese body whorl, broadly dilated and flattened inner lip and wide and deep umbilical chink." Shell of six convex slightly shouldered whorls, body whorl often malleated; growth lines coarse and spiral lines faint; the roundly ovate aperture ranges in length from one-half to three-fifths the length of the shell; axis a series of hour-glass-shaped columns; average size ranges from 8 to 14 mm. Leonard (1959) listed shell lengths varying from 9 to 11.3 mm; whorls 6; body whorl inflated; spire acutely conic with a deep umbilical chink; spiral lines faint or absent. Maximum shell size from specimens I measured were diameter 9.0 mm and height 14.0 mm. Hubendick (1951) placed S. techella and S. cockerelli in synonymy with S. bulimoides.

ECOLOGY/BIOLOGY: S. b. techella is an inhabitant of temporary pools and roadside ditches. Live specimens from Dallas County were found buried six inches deep in moist, caked mud in roadside ditches in 1973.

Stagnicola cockerelli (Pilsbry and Ferriss), (Fig. 9c).

Lymnaea bulimoides cockerelli Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil., 58:162.

Lymnaea cockerelli Pilsbry and Ferriss, Pilsbry and Ferriss, 1910, Proc. Acad. Natur. Sci. Phil., 62:44.

Stagnicola cockerelli (Pilsbry and Ferriss), Hibbard and Taylor, 1960, Univ. Mich. Mus. Paleon. Contrib., 16(1):90.

TYPE LOCALITY: "New Mexico: Las Vegas" (Pilsbry and Ferriss, 1906).

GENERAL DISTRIBUTION: "Sporadic over most of the United States west of the Mississippi River" (Hibbard and Taylor, 1960). Geologic Range: Early Pleistocene to Recent.

TEXAS DISTRIBUTION: Fossil County Records: Wisconsin CASTRO and GLASSCOCK (Frye and Leonard, 1957); WARD (Leonard and Frye, 1962). Recent County Records: HUNT and FAYETTE (Baker, 1911 as Lymnaea b. cockerelli); HUNT (Smith Coll.); LAFAYETTE (DMNH Coll.).

DESCRIPTION: Baker (1911) gave the following distinguishing characteristics for S. cockerelli, which he considered as a subspecies of S. bulimoides: "The shell displays a very globose form, short and very broad spire, wide expansion of the inner lip, which is not folded but broadly expanded, producing a deep umbilical chink." Whorls 4.5, convex, and rapidly enlarge; spire shorter than the aperture; average size ranging from 8-14 mm; axis similar to techella in form.

ECOLOGY/BIOLOGY: Habitat similar to S. bulimoides techella. Mr. George H. Clapp in correspondence with F. C. Baker (Baker, 1911) told of an incident in which S. bulimoides cockerelli "had been out of water 45 days" and were still alive. In their natural habitat, or in an aquarium, they seem to spend as much time out of water as in it.

DISCUSSION: Among the thousands of shells examined from the fossil lymnaeid group from Texas (DMNH Collections), S. cockerelli was not present. Since its geographical range covers some of the areas from which the fossil shells were taken, one would expect it to be present judging from the conclusions reached by Hibbard and Taylor (1960). After reviewing previous literature, and examination of specimens of S. bulimoides techella and S. bulimoides cockerelli, they concluded that the two subspecies were specifically distinct. This conclusion was based upon (1) morphologic distinction, (2) occurrence of S. cockerelli in the same areas as S. bulimoides and S. bulimoides techella without evident intergradation, and (3) distinct geographic distribution. Hibbard and Taylor (1960) also pointed out that an apparent lack of intergradation of cockerelli and techella in the same habitat "might possibly be explained by hypothesizing that S. cockerelli is a phenotype controlled by its habitat in temporary ponds." If cockerelli and techella always maintain their distinct phenotypic appearance in the same habitat then it would seem logical to assume that they are also genotypic.

Stagnicola elodes (Say), (Fig. 10a, b).

Lymnaeus elodes Say, 1821, J. Acad. Natur. Sci. Phil., 2:169, (Binney Reprint, 1858:66).

Stagnicola elodes (Say), Baker, 1928, Wisc. Geol. Natur. Hist. Surv., Bull. 70, pt. 1:212.

Galba palustris (Muller), of authors but not Muller, 1774. Original citation of Muller's species is: Buccinum palustre O. F. Muller, 1774; Vermium terrestrium et fluviatilum . . . (etc.), 2:131.

Lymnaea desidiosa (Say), Clarke, 1973, Malacologia, 3(1-2):351.

TYPE LOCALITY: "In paludosis frequens" (no locality mentioned but Europe implied) (Clarke, 1973).

GENERAL DISTRIBUTION: Circumboreal, New England west to the Rocky Mountains and from Canada south to New Mexico, northern Asia and Europe. North America from the Atlantic to the Pacific Ocean, and from Alaska south to New Mexico. Pleistocene to Recent, very common in certain sand, gravel and lacustrine deposits (Baker, 1911).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages: Kansan: KNOX (Strickland, 1961); GARZA and LUBBOCK (Frye and Leonard, 1957). Sangamon: FOARD (Dalquest, 1962). Wisconsin: HARDEMAN (Cheatum and Allen, 1962); REEVES (Leonard and Frye, 1962). Note: Almost all records were as S. palustris.

Undetermined Ages: STONEWALL, HARDEMAN and SWISHER (Singley, 1892, Baker, 1911); HALE (Sellards, Evans and Meade, 1947); KNOX (E. L. Lundelius, Univ. of Texas); TARRANT (B. A. Branson, Univ. of Kansas); HALL (DMNH Coll.).

DESCRIPTION: Baker (1911) described the shell of S. palustris (S. elodes) as "varying from elongate to elongate-ovate, surface covered with numerous crowded growth lines crossed by several elevated spiral lines and by numerous impressed spiral lines; whorls seven, rounded, the last varying in its rotundity but usually quite obese; spire varies from over one-half to three-fifths the shell length; aperture length approximately one-half the length of the shell; shell is frequently malleated; a heavy callus is formed by the inner lip which is tightly appressed to the parietal wall; the umbilical chink closed or narrowly open; axis with a pronounced twist; columellar plait heavy." Recent, and frequently, fossil shells showed malleated sculpture; many fine growth lines broken by conspicuous spiral lines which gave the shell a latticed effect under low power magnification. Hibbard and Taylor (1960) reported "one adult and one nearly adult specimen" of this species which conform to Baker's (1911) Stagnicola palustris blatchleyi (Baker). Their specimens differed from typical S. elodes in being smaller, having more convex whorls and a relatively smaller aperture. Maximum size of measured Texas fossil shells: diameter 10.0 mm, height 29.0 mm. My study of these measurements indicated that the most obvious difference between the description of the typical S. elodes shell and most Texas fossil shells was a difference of spire length as compared with total shell length. The spire height was less than one-half of the total length; this is not true in shells from more northern localities.

ECOLOGY/BIOLOGY: Baker (1928) stated that this species hibernates more than any of the other lymnaeas, and that it usually occupies intermittent streams and ponds.

Stagnicola reflexa (Say), (Fig. 9g).

Lymneus reflexa Say, 1821, J. Acad. Natur. Sci. Phil., 2:167; Amer. Conchol. (etc.), 31:2.

Stagnicola reflexa (Say), Baker, 1928, Wisc. Geol. Natur. Hist. Surv., Bull. 70, pt. 1:221.

TYPE LOCALITY: "Inhabits Lakes Erie and Superior" (Binney, 1858).

GENERAL DISTRIBUTION: Ohio-Mississippi drainage area north of about the 37th parallel. Great Lakes-St. Lawrence River system throughout, including artificially connected waterways in New York. Canadian Interior Basin in several disjunct areas. Recorded from Nebraskan deposits in Kansas (Taylor, 1960) and in later Pleistocene deposits there (LaRocque, 1963).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages; Kansan: KNOX (Strickland, 1961); GARZA (Frye and Leonard, 1957). Wisconsin: DELTA (Allen and Cheatum, 1962); DONLEY (DMNH Coll).

DESCRIPTION: Surface covered with crowded growth lines and minute impressed spiral lines that give a latticed effect to the shell; growth lines usually wavy and frequently so elevated as to produce distinct ridges; whorls 7, flatly rounded, and not much wider than high; sutures distinctly impressed; aperture ovate; spire long and sharp, occupying about two-thirds length of shell; axis twisted. Maximum shell measurements from Texas locality specimens: diameter 16.0 mm, height 47.0 mm.

ECOLOGY/BIOLOGY: Occurs in sluggish waters associated with floating objects or submerged vegetation. Baker (1911) commented that it was "more often found in summer-dry ponds than in larger bodies of water."

Stagnicola exilis (Lea), (Fig. 9e).

Lymnaea exilis Lea, 1834, Trans. Amer. Phil. Soc., 5 (N. S.):114, pl. 19:82.

Stagnicola exilis (Lea), Baker, 1928, Wisc. Geol. Natur. Hist. Surv. Bull., 70, pt. 1:226.

TYPE LOCALITY: "Ohio."

GENERAL DISTRIBUTION: Ohio to Kansas, northward to northern Minnesota and northern Michigan (Baker, 1911). Geologic Range Late Pliocene to Recent (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records by Pleistocene Ages; Illinoian: CLAY (Allen and Cheatum, 1961). Wisconsin: DELTA (Cheatum and Allen, 1962).

DESCRIPTION: Shell "elongated, attenuated, thin. . . . growth lines distinct, crowded, crossed by numerous very fine incremental striae:. . . whorls six to seven, very flat-sided, the last a little over one-third the length of the entire shell; spire long and very acutely attenuated; . . . aperture elongate-ovate, narrow. . . rounded at the lower part; . . . inner lip very narrow, erect, reflected over the umbilicus, completely closing it; the callus on the parietal wall is well marked" (Baker, 1911). Axis slightly twisted or gyrate; no collumelar plait; last whorl longer than wide; axis with a slight twist or gyrate; maximum shell measurements from Texas localities: diameter 11.5 mm, height 39.0 mm.

ECOLOGY/BIOLOGY: "*S. exilis* is an inhabitant of sloughs, ponds and rivers which dry up more or less during a portion of the year" (Baker, 1911). *S. exilis* is an excellent example of the confused taxonomy, and current rate of aquatic gastropod name changing. *S. exilis*, as retained in this report, probably does not represent a valid species. Hubendick (1951) placed *S. exilis* under *S. palustris*, and Clarke (1973) placed it in synonomy with *S. reflexa*, while noting that *S. reflexa* and *S. elodes* were extremely similar.

Summary of Texas Lymnaeidae

Like the Physidae and Planorbidae, a large number of lymnaeid genera, species, and subspecies have been cited for Texas. At least 9 genera, and 30 species and subspecies appear in the literature. In this report, 4 genera, 9 species and subspecies are considered valid for the state. Of the 9 species and subspecies, 5 occur only as fossils (*L. stagnalis appressa*, *S. caperata*, *S. reflexa*, *S. exilis* and *S. elodes*). The taxonomic scheme utilized in this report is arbitrary, and will quite likely require adjustment as further investigations in Texas on this problematic family furnish new information. Several species listed in the literature were not considered valid records: *Lymnaea megasoma* (Say), Leonard and Frye (1957); *Lymnaea catascopium* (Say), Hanna (1923); *Lymnaea cubensis* (Pfeiffer), Baker (1911); *Lymnaea tryonii* Lea, Singley (1893).

The key I constructed posed problems, particularly with regard to the *F. parva-dalli-humilis* complex. Baker (1911) recognized this difficulty when he placed the above complex under the subgenus *Simpsonia* but stated that the "Shell offers no definite characters of group value by which to separate *Simpsonia* from *Galba*." Subsequently Baker (1928) included *F. parva*, *dalli*, *humilis*, and their subspecies under the genus *Fossaria*. All of these species and varieties are recorded in literature for Texas. Baker is followed here in using *Fossaria* for this group and *Stagnicola* for the species *caperata*, *cockerelli* and *bulimoides techella*, all of which are recorded for Texas. In separating certain species, the axis was used as a distinct taxonomic character which, it is believed, is more revealing and distinctive in separating certain species than by using some of the more standardized external shell characteristics. It is also realized that the use of the axis as a separating character is more tedious and time-consuming since it requires shell dissection, but, one hopes, the use of this structural shell feature in a key can help eliminate confusion encountered in those species whose shells show externally most all conditions of intergradation. A case in point to emphasize this taxonomic confusion is that given by Baker (1911) in his discussion of *obrussa*. *F. obrussa*, said Baker, "is one of the most widely distributed, as it is one of the most variable of the American lymnaeas, not even excepting the circumboreal *palustris*. The spire may be long or short, pointed or wide, and strongly shouldered. The whorls may be slender, scalar or wide and corpulent, while the aperture varies from almost round to long and narrow. The umbilicus may be rather widely open or it may be reduced to a minute chink, depending upon whether the inner lip is closely appressed to the axis or is raised over the umbilical region." I feel that some of this taxonomic confusion can be eliminated by the use of the axis as an aid in separating species of the *Stagnicola* and *Fossaria* genera.

The greatest difficulty in composing the key was in recognizing species and subspecies within the *Fossaria* group. Arbitrarily, only *obrussa* and *dalli* are recognized here under *Fossaria*. It is also fully realized that this decision is controversial, since many conchologists consider *F. modicella humilis rustica*, *parva*, *dalli* and *obrussa* as distinct species, and all of these have been listed for Texas. Taylor (1960) did not recognize *F. modicella*, *F. humilis rustica* or *F. parva* from the High Plains, but he did recognize *F. obrussa* and *F. dalli* from this region. Since *F. modicella*, *humilis* and *humilis rustica* fall within the size range of *obrussa* and appear to intergrade, one within another, these species are synonomized under *obrussa*. The separation of *dalli* and *obrussa* in the key is based upon shell size and appearance of the axis. Any key using shell characteristics exclusively must be based upon those shell features which are typical of the species, and it cannot in any sense cover intergrades.

The preparation of the key became even more difficult when fossil shells were included, because in many cases the epidermis of the fossil shell has been destroyed, thus removing features of the shell sculpture which are more obvious and significant in Recent shells. Perhaps the best example of shell sculpture markings that are lost with the removal of the epidermis are the spiral lines of certain species which may either be delicate as in Stagnicola bulimoides techella or incised as in Stagnicola caperata. In caperata the incising is so deep that even after the epidermis has been removed the lines are usually distinct under an oblique light. As a matter of fact, a strong oblique light and a binocular microscope with magnification of 20-30X were necessary for identification of the smaller shell.

However, there are shell features which, if applicable at all, would apply equally well to fossil and Recent shells, such as the size and shape of the nuclear whorls, the shape and length of the spire as compared to total shell or aperture length; number, size and shape of the whorls; sutures impressed or not impressed; presence or absence of columellar plait; description of axis; aperture shape; and size range for each species. All of these characteristics are used in compiling keys, but one using the key must bear in mind that the characteristics and size ranges apply only to mature shells.

Juvenile forms of many species are at this time difficult if not impossible to classify with certainty. This difficulty can only be overcome by much needed research on complete life-histories for all species which includes descriptions and figures of the shell at various growth stages. It must also be pointed out how important it is to correctly identify species, since fossil shells are used not only as indicators of past environments but the fossil locations of certain species may ultimately be used to designate specific geological ages. Since environmental needs vary with the species, an incorrect identification can easily lead to an incorrect interpretation of the environment or the geological age.

One notable example of shell character and environmental interpretation was observed during this study. In many instances the shells of *S. caperata*, *S. reflexa* and *S. palustris* are malleated, which indicate certain ecological situations. Baker (1911) noted that the "more distinctly malleated forms inhabit stagnant pools where the bottom is muddy with more or less decaying vegetation present." He also attributed shell malleations to the environment and closely followed Stearn's (1901) interpretation of the cause of malleations which is summarized as follows: the character of the bottom, even in a pond of limited size, often exhibits very considerable differences in the matter of compactness or density; alluvial mud, clayey mud, clay or sand, with fine or coarse gravel intermixed with fragments of aquatic plants and plant stems in varying proportions. The habits of these mollusks include, non-technically speaking, burrowing, wallowing or submersion, and moving as they do with somewhat of a rotating motion; this combined with the moderate impact of the surrounding matter, contributes to produce the malleated or dented surface, which frequently exhibits a somewhat spiral arrangement. Baker (1911) believed that this theory was well borne out by an ecological study of S. elodes, S. bulimoides techella, and S. reflexa which live in bodies of water that frequently dry up so that the snails are forced to burrow. The impact of objects upon newly formed shell would result in the hammered-silver effect. Dr. E. P. Cheatum (personal communication) observed malleations among lymnaeid shells that lived in the littoral areas of lakes in Michigan and Indiana, where the snails were subjected to frequent wave buffeting and turbulence.

Among the species of snails listed in this report, it is interesting to note that most species, with the exception of such large forms as L. stagnalis appressa, inhabit small ponds, roadside ditches and other shallow bodies of water which may frequently dry up during dry seasons, thus forcing the snails to burrow down to moisture if they are to survive. S. elodes, however, seems to be more intimately associated with permanent sluggish water than are the other species. Although the large L. stagnalis appressa is found living in stagnant pools and in quiet areas of rivers, it is usually associated with larger lakes and permanent water. The shell is so large and cumbersome that it would be exceedingly difficult for this species to burrow like the smaller lymnaeid species. Therefore, the presence of *L. stagnalis appressa* would seem to indicate the presence of larger and more permanent bodies of water in the general area studied.

Family Physidae Dall, 1870

Many genera and species have been described for the family Physidae. Only three genera (*Physa*, *Aplexa* and *Stenophysa*) are now recognized which occur world wide, while a few physid genera are recognized from smaller geographic areas such as *Pterophysa* in western North America. *Physa* drapanaud is world-wide in distribution and contains many species. The genus is distinguished by the mantle margin being reflected over the shell and with digitiform projections on its margin. *Aplexa* Fleming, characterized by the absence of the digitiform projections along the reflected mantle and an elongate, smooth shell is circumboreal in distribution. Only one species, *Aplexa hypnorum*, is represented in northern North America. The genus *Stenophysa* von Martins encompasses Central and South America in distribution and, periodically, has been placed as a subgenus of *Aplexa*. The aperture in *Stenophysa* is more than one-half the total shell length and the apex is simple and acute. Taylor (1966) cited *Stenophysa* as ranging into North America from Mexico with one species, *S. microstriata*, occurring in southern Utah.

The pulmonate Physidae perhaps shares the dubious honor with the prosobranch Pleuroceridae of being a taxonomic catastrophe. The physid shell is extremely plastic and innumerable species have been described. The family is important in North American fossil studies, and, world-wide, numerous species are important intermediate hosts for several parasites, including trematodes. In fact, one North American trematode parasite in waterfowl is named after its intermediate host, Physa (Physella) parkeri DeCamp. The parasite, Trichobilharizia physellae, is well known in Michigan and elsewhere as "Swimmer's Itch" caused by dermal migration of the cercariae.

PALEONTOLOGY: Upper Carboniferous (?) or Jurrasic to Recent (Zilch, 1939).

FAMILY CHARACTERS: Shells small to rather large, thin or slightly thickened, hyperstrophic (sinistral), conispiral and nonumbilicate; aperture large, angled above and rounded below; spire short to moderately produced; surface smooth or with well-marked microsculpture. Monoecious (with facultative self- and cross-fertilization) and phytophagous.

"Animal sinistal, having the pulmonary, genital and excretory orifices on the left side; tentacles slender, cylindrical; foot narrow, pointed behind; jaw single, arcuate, with a vertical fibrous accessory process on the superior margin; radula with the teeth arranged in oblique (chevron-shaped) rows. Central tooth wide, base with projecting processes before and behind, multicuspid; laterals obliquely comb-like, multicuspid, with a peculiar process at their external angle" (Walker, 1918).

The sinistral (left-handed) aperture opening is a trademark of the Physidae and separates them from the closely related and dextral Lymnaeidae. In Africa and the Middle East, a planorbid genus, Bulinus, is somewhat physid-shaped and also sinistral.

ECOLOGY/BIOLOGY: On a world-wide scale, Physidae occupy almost every conceivable type of habitat from cold, rushing rivers to aquatic environments so organically polluted that few other organisms can exist. Clarke (1973) felt that perhaps one reason for colonies of Physa appearing in tremendous numbers in mildly polluted water was the absence of predators such as fish and leeches. Lack of inter-specific competition on the same trophic level is probably another reason for these tremendous populations. Along certain stretches of the polluted Trinity River in Dallas, Texas only great colonies of Physa and the chironomid blood-worm were found present, particularly in the summer.

Physids are also not particular as to the type of substrate or vegetation present in their habitats. It must be stated, however, that some species do exhibit some habitat preference such as the cold-water Aplexa hypnorum. Unfortunately, though, many Physa species in North America have been considered distinct species, based principally upon the habitat-type where they were found, without further investigation on this observation. Baker (1928) stated the physid taxonomic problem quite succinctly; "the study of the genus Physa (in North America) is attended with great difficulty; the species are very variable in form and structure; and as well, often in sculpture. . .the early authors, Say, Lea and Tryon, frequently described a species from one or two examples and several names have been given to the extremes in variations of a single species for this reason." Call (1887), in regard to the species of Physa, stated "In every pond and pool in which undoubted specimens of one (species) occurs, there also may be found typical examples of the other."

The life cycle of some physid species such as Physa gyrina have been determined, particularly in the northern United States. The reader is referred to Clampitt (1970), DeWitt (1954 a, b, c, 1955 a, b).

Physids are rapid gliders on a solid object or even on the underside of the neuston. Leonard (1959) observed an interesting behavior of Physa hawnii Lea. The animal ascended from the benthos to the surface by raising the anterior end of the foot and rising, leaving a mucous thread attached to the bottom, and "spun" it to the surface. At the surface, the animal inverted, and crawled along the neuston upside down, taking in air through the pneumostome. To return to the bottom, the animal located the same mucous thread or one of another physid and crawled down the thread rapidly at a tilt.

Key to Texas Physidae

1. a. Shell and aperture elongate, slim and polished; spire elevated and acute; up to 18 mm. Fossil Only. . . . . *Aplexa hypnorum*

   b. Shell, aperture and spire height variable but not glossy or narrow. 2

2. a. Shell symmetrically elongate-ovate; upper lip of aperture grades smoothly into the body whorl and not shouldered; spire whorls flattened and slightly elevated; shell smooth (Fossil Only?). . . . .*Physa gyrina*

   b. Upper aperture lip (peristome) shouldered, meeting the body whorl at a larger angle; size very variable, slim or obese; spire depressed or acute, surface usually slightly sculptured but never glossy. . . *Physa virgata*

Genus *Aplexa* Fleming, 1820

Aplexa hypnorum (Linnaeus), (Fig. 8f).

Bulla hypnorum Linnaeus, 1758, Systema Natura, 10th ed., p. 727.

Aplexa hypnorum (Linneaus), Fleming, 1820, (in) Brewster's Edinburgh Encyclopedia, 14:617.

TYPE LOCALITY: "in Europe Muscis humentibus" (Linneaus, 1758).

GENERAL DISTRIBUTION: Circumboreal and Holarctic; Europe, northern Asia, northern North America from Alaska to Hudson Bay and south to the vicinity of the Ohio River (Baker, 1928), northern Nebraska,

TEXAS DISTRIBUTION: Fossil County Records: Moore Pit local fauna, DALLAS 37,000 B. P. (Slaughter, et. al., 1962); Quitaque local fauna, MOTLEY, 31, 400 ± 5,600 B. P. (Cheatum and Allen, 1965); DONLEY (DMNH Coll.).

DESCRIPTION: Shell up to about 18 mm long, sinistral, elongated, thin, transparent, non-umbilicate, brownish (but appearing blackish when containing the soft parts), with a long spire and glossy surface; nuclear whorl rounded, finely punctate and amber colored; later whorls flatly rounded, each partly enveloped by the succeeding whorl and (including the nuclear whorl) numbering 6 to 7; spire acute, elongate, and comprising about one-third of the shell length. Sutures impressed and bordered below by a narrow white band; body whorl flatly rounded and subcylindrical; aperture acute above, subtruncate below, and about one-half the length of the shell; outer lip thin, flatly rounded, and only slightly thickened within; columella oblique, narrow, slightly twisted, and with a very thin wash of callus on the parietal wall; sculpturing consists of fine lines of growth and (principally in arctic populations) of fine spiral lines, especially where the periostracum is abraded; periostracum polished, thin, brownish horn-colored, and often with a greenish glint.

ECOLOGY/BIOLOGY: Baker (1928) wrote that "Aplexa hypnorum is a species of swales and intermittent streams or stagnant pools in Wisconsin, as far as present data goes. It is especially abundant in wood and pools which become dry in summer but also occurs in small, clean brooks." Mosley (1938) also usually found it in temporary ponds and occasionally in lakes and small streams. Clarke (1973) reported that the densest populations in Canada were from muskeg, spring-flooded areas adjacent to lakes or streams and from vernal woods pools. See Dan Hartog and DeWolf (1962) for details of the ecology and life history of Aplexa hypnorum (in Holland).

Unlike most species of Physa, small cusps do not occur between the large cusps on the lateral and marginal teeth. The organism is dusky-black in color, has a long, narrow foot and, unlike Physa, has no digitations on the mantle. The radula formula is given as 175-1-175 with the central tooth as wide as it is high and with cusps arranged in a 3-1-1-1-3 pattern (Clarke, 1973).

DISCUSSION: Aplexa hypnorum is a relatively rare fossil species in Texas deposits. I am of the opinion that it existed in this region only during periods of extreme glacial advances. Any warming trends quickly obliterated it in north and north-central Texas. The fossil molluscan record is still very incomplete for Texas, but based upon the available data, it appears that Aplexa hypnorum appeared and disappeared from Texas waters but appeared again during the Wisconsin, the last major glacial period.

Genus Physa Drapanaud, 1801

Physa gyrina Say, (Fig. 8d).

Physa gyrina Say, 1821, J. Acad. Natur. Sci. Phil., p. 2171.

TYPE LOCALITY: "Bowyer Creek, near Council Bluff, Council Bluffs, Iowa (Say, 1821).

GENERAL DISTRIBUTION: Canadian Interior Basin northwestward (south of tree-line) to the Mackenzie River Delta; Great Lakes-St. Lawrence drainage area (Clarke, 1973); Gulf of Mexico drainage area from Alabama to Texas (Baker, 1928); probably found in most of North America north of Mexico (Taylor, 1966).

TEXAS DISTRIBUTION: Fossil County Records: POTTER (Walker, 1915); KAUFMAN (Thurmond, 1967); FOARD, DALLAS, MOTLEY, DENTON, CLAY, DELTA, HALL and BRISCOE (Cheatum and Allen, 1965). Recent (?): Singley, 1893, Strecker, 1935, Wurtz, 1949 and others have cited living Physa gyrina for Texas. The specimens examined by the author from these localities were forms of P. virgata. It is remotely possible that P. gyrina may occur in relict colonies, but for the present, must be considered only as a fossil.

DESCRIPTION: Shell up to about 24 mm long, sinistral, variable, of moderate elongation, thin to slightly thickened transparent to sub-opaque, narrowly umbilicate or non-umbilicate, pale yellowish-brown to greyish-brown, with a short spire and a dull surface; nuclear whorl small, rounded, finely punctate and generally red to reddish-brown; whorls gently rounded, each partly enveloping the preceding whorl and numbering 5 to 6; spire acute, rather short and comprising about one-eighth of the shell length; sutures impressed and bordered below by a narrow, pale band; body whorl large and well rounded but not inflated; aperture "loop-shaped," mainly basal, acute above, flatly rounded laterally, rounded basally, and occupying about 6/10 to 8/10 of the shell length; outer lip thin to slightly thickened and bordered inside by a prominent red or reddish collabral band; columella oblique, thin to slightly thickened, and with a thin to moderately thick and extensive wash of callus on the parietal wall; in some specimens, the lower part of the inner lip is raised, exposing a narrow umbilicus; sculpture of numerous coarse lines of growth and in some specimens, one or more internal varices visible externally as whitish collabral bands, and in many populations crowded, impressed spiral lines crossing the growth lines; these spiral lines may be strong and conspicuous, moderately strong, faint, or absent.

ECOLOGY/BIOLOGY: Clarke (1973) found _Physa gyrina_ in all sizes of perennial water habitats and in many temporary overflow swamps and pools which are marginal to permanent streams and lakes in the Canadian Interior Basin.

These habitats are in contrast to the statements of Baker (1928), Taylor (1960), and DeWitt (1955) that _P. gyrina_ and its form (_hildrethiana_) occur in swales, summer-dry ponds and drainage ditches as well as perennial-water habitats. Taylor (1975, in litt.) stated that the habitat of _P. gyrina_ was more usually ponds in the southern part of its range where it overlaps the range of _P. virgata_. Clarke (1973) also reported that, in Canada, submerged aquatic vascular plants were present in nearly all P. gyrina localities and that the substrates were varied, but usually were of mud. Current was slow in the lotic habitats.

The life history, ecology, fecundity and growth of P. gyrina were described in a series of papers by DeWitt (1954 a, b, c; 1955) and Clampitt (1970). McMahon (1975, 1976) studied the life cycle of P. virgata in North-Central Texas and compared the differences that he found in the ecology and life histories of the two species. The environmental parameters that apparently limit the southern distributional limits of this species remain unstudied.

Physa virgata Gould, (Fig. 8e, g).

Physa virgata Gould 1855, Proc. Boston Soc. Natur. Hist., 5:128.

Physa anatina Lea, 1864, Taylor, 1966, the Veliger, 9(2):214.

TYPE LOCALITY: Not selected but described from Gila River (Arizona) and near San Diego (California). Type, 17244a (H. B. Baker, 1964). Lectotype - MCZ 72995 (Johnson, 1964).

GENERAL DISTRIBUTION: "Physa virgata is common over most of southcentral and southwestern America; southern California, southernmost Nevada, Utah and Colorado, but northward is replaced by P. gyrina. In southern Kansas, and southward perhaps throughout Texas, P. virgata is the only living species. Its range extends eastward an unknown extent; and southward over most of the Mexican Plateau" (Taylor, 1966).

TEXAS DISTRIBUTION: Fossil County Records: Common in Pleistocene deposits from DELTA County (East Texas), across the Panhandle and south through the Pecos Valley; Recent County Records: General over the state, probably in every county (see Fullington, 1969).

DESCRIPTION: The shell is extremely variable and description of one shell such as the type or lectotype are not of much taxonomic value. Hibbard and Taylor (1960) separated the subgenus Physella into two categories: (a) shells usually larger, with a conspicuous and usually thicker apertural callus, and shorter spire with shallower sutures; more northern in distribution (Physa gyrina); (b) shells usually smaller, with a less conspicuous, thinner apertural callus, and longer spire with deeper sutures; more southern in distribution, (Physa virgata, P. anatina their report). Thus, the characterization of P. virgata as presently recognized is based upon geographic parameters and upon group features. This approach is similar to the method used by Clench (1962) on the Viviparidae and by Hubendick (1964, 1967, 1970) for the Ancylidae. Taylor (1966) also cited the characters mentioned above with the shell length usually only 8 to 10 mm long. With increasing size of a water body, the shells may grow larger, and especially in slow-moving streams or ponds they become more swollen. Physa humerosa (listed for Texas) falls into another large group (Physa lordi of H. B. Baker, 1928) characterized by - shell larger; spire short and the body whorl is characteristically shouldered.

ECOLOGY/BIOLOGY: As stated previously, Physa virgata may be found virtually in almost any type of aquatic habitat. The only locality where I have failed to find Physa was Ferndale Lake in Camp County, where the pH was 3.75. Few other life forms occurred in the lake. Shell size and variability are most pronounced through the limestone regions of central Texas.

McMahon (1975) conducted the first life-cycle studies ever attempted for southwestern Physa. Similar studies have been done on several more northern species: Physa acuta Draparnaud (Duncan, 1959); Physa gyrina Say (DeWitt, 1954a, 1954b, 1955, Clampitt, 1970); Physa fontinalis (Linnaeus) (DeWitt, 1955, Duncan, 1959, Russell-Hunter, 1961, Girod, 1969); and Physa integra Haldeman (Clampitt, 1970, Eckbald, 1973). Generally, the typical life-cycle for these northern and European species (P. fontinalis) is one to two generations per year. The summer generation hatches in the spring and spawns in late summer. The fall generation over-winters, then dies after spring egg laying. Some of the summer generation may or may not survive the winter and oviposit in the spring.

McMahon (1975) discovered that Physa virgata colonies in Lake Arlington, Texas had a three generation per year life cycle. Such a life cycle is known in only two other pulmonate freshwater species, Lymnaea truncatula and Laevapex fuscus (see L. fuscus, this paper).

Egg production was initiated when the water temperature rose above 13° C., which occurs in North-Central Texas from mid-February or early March to late December. The second and third egg-laying periods were almost continuous during the summer with the last laying occurring into the fall.

DISCUSSION: Nineteen species of Physa have been recorded from the state. Texas is the type locality for several species (P. forsheyi, Fayette County; Physa amygdalus, "Texas, North America"), and most names appear less than three times in the literature (P. anatina, P. humerosa, P. mexicana, P. skinneri, P. heterostropha, P. crandalli, P. elliptica, P. halei, P. bottimeri, P. sayii, P. integra, Bulimus berlanderiana and Stenophysa nitens). I have given less attention to this family in this paper because of my earlier study, Fullington (1969).

Summary of Texas Physidae

Two physid genera are found in Texas, representing three species and one subspecies. Aplexa hypnorum occurs only as a Pleistocene fossil as apparently does Physa gyrina. Clarke (1973) listed its occurrence as from Canada to the Gulf of Mexico drainage from Alabama to Texas. I have never collected P. gyrina alive in Texas. Berry (1949) reported Stenophysa nitens from Brownsville but the specimens cannot be located and it was not collected during this study. Its occurrence is doubtful. Also, Drake (1975) reported Physa skinneri from a deposit in Lubbock County but I was unable to verify the specimen.

All the living Physa in Texas have been grouped under Physa virgata Gould by Fullington (1969). Taylor (1966) and Bequaert and Miller (1973) reported a subspecies, P. virgata *bottimeri* from one locality in West Texas. The validity of this form is open to question. The type locality (a spring near Fort Stockton, Texas) has been dry for several years and the colony has disappeared.

Physids have been collected from acidic bayous in East Texas to ephemeral pools in high canyons of the Guadalupe Mountains. *Physa*, like other pulmonate freshwater snails has the ability to aestivate during periods of drought. Because they can tolerate aquatic environmental extremes and due to their apparent genetic plasticity, shell form is extremely variable and, in Texas at least, reflects Texas edaphic features. In acidic, sandy-bottomed east Texas water, physid colonies are dwarfed. In the Central Texas limestone region, shell size and variability within populations is pronounced. Westward, even though most of the surface rocks and soils are basic pH, colonies are again dwarfed. In the igneous Davis Mountains, I found depauperate colonies approaching tiny hydrobiids in size.

Goodrich (1939) gave an excellent definition of depauperization as applied to mollusks. He stated, "Depauperization as it is understood by malacologists is the outward manifestation of disease, accident or malnutrition or a reaction of inimical environment." Leonard (1959) observed this last effect also among Kansas physid populations and observed dwarfing in colonies living in sandy areas and in habitats subject to dry periods. Long periods of hibernation or aestivation certainly bring about a reduction in size. Physids, like the planorbids, are easily transported in egg or adult form by waterfowl, particularly ducks.

Family Planorbidae Rafinesque

The Planorbidae is a world-wide family consisting of approximately 25 genera and hundreds of nominate species and subspecies, although the current trend is toward a reduction in these numbers. The family is also important as intermediate host for many animal parasites, including man. In the Caribbean Islands and South America, *Biomphalaria glabrata* is the intermediate host for the human blood fluke, *Schistosoma mansoni*.

Even a brief description of the major planorbid genera would require another volume the size of this total paper. The Planorbidae belong to a larger group, the Limnophila which includes all the freshwater gastropods. They are most closely allied to the limpets (Ancylidae), both families possessing a secondary gill, the pseudobranch (except the *Pleisophysae*). The planorbids are also related to the pulmonate families Lymnaeidae, Acroloxidae and Physidae.

FAMILY CHARACTERS: Shells small to moderately large, thin or slightly thickened, orthostrophic or hyperstrophic, and depressed or planispiral in most species or low conispiral in a few species. Aperture oblique, with lip thickened and reflected in some species and with internal lamellae in a few others. The species are monoecious (with facultative cross- and self-fertilization) and are phytophagous.

"Animal sinistral, having the pulmonary, genital, and excretory orifices on the left side. Tentacles long, slender and cylindrical. Jaw in three (or many) segments. Radula with the numerous teeth arranged in nearly horizontal rows, central small and bicuspid, (also tri- and tetra-cuspid) marginals (sic, laterals) tricuspid, laterals (sic, marginals) multicuspid" (Walker, 1918).

Baker (1945) published the most important monograph on the family but unfortunately, because of his death, it was not completed at the species level. Baker's results have been extended, reevaluated, and partly corrected by Hubendick (1955). Based on comparative anatomy, Hubendick recognized 3 subfamilies within the Planorbidae, Plesiophysinae, Bulininae, and Planorbinae. The separation of the subfamilies was based principally upon variations in the reproductive system. The reader is referred to the works of Baker (1945), Hubendick (1955) and Harry and Hubendick (1964) for detailed analysis of the subfamilies.

ECOLOGY/BIOLOGY: Planorbids occupy a wide range of habitats from swiftly flowing streams to stagnant swamps. Most species, however, prefer relatively still water where vegetation is abundant.

Key to Texas Planorbidae

1. a. Axial height 4 mm or more (sinistral or dextral). . 2

   b. Axial height less than 4 mm 6

2. a. (Ultrasinistral) both sides deeply sunken; keel on body whorl to aperture; upper carina not close to shoulder, diameter 11-15 mm . . . . *H. anceps*

   b. Both sides not deeply sunken, body whorl keel not to aperture, angle, if present, on shoulder; diameter usually greater than 13 mm 3

3. a. Shell glossy, smooth, diameter 13 mm . . . . *H. duryi*

   b. Shell with obvious raised growth lines; diameter 12 mm .4

4. a. Shell striations more delicate and close; no grooves between raised striae; diameter 12-22 mm. *H. foveale*

   b. Shell striations more coarse and irregular; grooves between regular striae 5

5. a. Shell more robust; axial height greater than 5 mm; diameter usually greater than 17 mm; no spiral striae on early whorls . . . . *H. trivolvis lenta*

   b. Shell flatter, axial height less than 5 mm; diameter usually less than 17 mm; spiral striae on early whorls sometimes persisting to last whorl (east to east-central Texas). . . . . *H. t. intertextum*

6. a. Growth lines in raised, separated ridges along periphery (costate); diameter 2-3 mm; peristome

complete (lip edge continuous); Fossil Only. . . . .*Armiger crista*

b. Shell not as above; peristome incomplete; shell usually larger than 3 mm 7

7. a. Shell diameter 6-8 mm (or more); shell greatly flattened; whorls tightly coiled; peripheral strong ridge continuing from embryonic whorl to aperture; umbilicus wide and deep; body whorl below ridge extremely flattened and angled toward umbilicus; aperture greatly flattened; apical and umbilical pits, (Coastal Plains) . . . . *Drepanotrema kermatoides*

b. Shell not as above 8

8. a. Whorls also tightly coiled, but periphery not strongly carinated (slightly shouldered); aperture angulated; diameter up to 6.6 mm; no surface pits; body whorl slightly concave . . . . *Drepanotrema cimex*

b. Shell not as above 9

9. a. Whorls more rapidly expanding; aperture slightly flared and rounded; deep internal lamellae may be present; no surface pits; overall shell not as flattened and whorls not as sunken as is *Drepanotrema* spp.; diameter up to 18 mm . . . . . *Biomphalaria obstructa*

b. Shell not as above 10

10. a. Aperture with internal denticles (not lamellae) close to aperture; diameter less than 8 mm; whorls rounded; last of body whorl and aperture deflected

slightly below periphery; Fossil Only . . . . *Planorbula armigera*

b. Aperture without denticles or lamellae; shell variable 11

11. a. Shell flattened with a prominent keel on body whorl; diameter 6 mm or less 12

b. Shell whorls rounded; or slightly shouldered . . . 15

12. a. Shell periphery acutely keeled; shell appears lens-shaped (lenticular) 13

b. Shell periphery angular, but not acute; aperture slightly flared 14

13. a. Shell sculpture with strong spiral lines; diameter 4-6 mm; (Fossil Only) . . . . . . *Promenetus exacuous*

b. Shell sculpture with more or less regularly spaced low ribs in addition to the spiral striae; diameter 3-5 mm (Fossil Only) . . . . . *Promenetus kansasensis*

14. a. Spiral lines (especially on base); umbilicus wider than deep; keel below summit of body whorl . . . . *Micromenetus sampsoni*

b. Spiral lines indistinct or lacking keel on summit of whorl . . . . *Micromenetus dilatatus*

15. a. Aperture slightly flattened; body whorl slightly shouldered; umbilicus deep and wide, exposing all whorls; Fossil Only; diameter 4-5 mm . . . . *Promenetus umbilicatellus*

b. Shell very similar to above, but with very close-spaced radially rounded striae separated by narrow deep grooves . . . . *Promenetus* *carus*

c. Body whorl more evenly rounded; diamter 3-5 mm . . 16

16. a. Shell nearly planospiral (appearing almost the same from both sides); whorls not rapidly enlarging; whorls more nearly even, last whorl not expanded, diameter 2-5 mm; faint keel on body whorl; (Fossil Only) . . . . *Gyraulus* *circumstriatus*

b. Whorls rapidly enlarging; last whorl greatly expanded 17

17. a. Spiral lines indistinct or none; no keel present; shell appearing smooth, with only growth lines apparent . . . . *Gyraulus* *parvus*

b. Spiral lines distinct on whorls; growth lines fine and crowded . . . . *Antillorbis* *aeruginosus*

Genus *Antillorbis* Harry and Hubendick, 1964

Antillorbis *aeruginosus* (Morelet), (Fig. 12 f-g).

Planorbis *aeruginosum* Morelet, 1851, *Test*. *Noviss* *Ins.* *Cubanae* Amer. Centr., 2:15.

Planorbis *filocinctus* Pilsbry and Ferriss, 1906, Proc. Acad. Natur. Sci. Phil., 58:123-175. T. L. Cochise Co., Ariz.

Planorbis *arizonensis* Pilsbry and Ferriss, 1915, Proc. Acad. Natur. Sci. Phil., 1915:363-418 (replacement name for *P*. *filocinctus*).

Gyraulus arizonensis (Pilsbry and Ferriss, 1915), Branson, 1960, 1963, Sou. West. Nat. 5 and 8; 1960 Nautilus 74.

Taphius decipiens (C. B. Adams), Branson, 1964, Sou. West. Nat., 9(2):103.

Promentus aeruginosus (Morelet, 1851), Taylor, 1960; U. S. Geol. Sur. Prof. Paper 337:45.

Antillorbis sonorensis (J. G. Cooper, 1893), Taylor, 1975 (in litt.).

Antillorbis aeruginosus (Morelet), Harry and Hubendick, 1964, Gote. Musei. Zolog. Avd., Ser. b, Band 9, No. 5:29.

Drepanotrema (*Antillorbis*) *aeruginosum* (Morelet), Bequaert and Miller, 1973, Univ. Ariz. Press, p. 209.

TYPE LOCALITY: Lake Yzabal, Guatemala.

GENERAL DISTRIBUTION: Antilles, Guatemala, Mexico (including Sonora), southern Texas and southern Arizona (Bequaert and Miller, 1973). Bahamas and Cuba (Harry and Hubendick, 1964).

TEXAS DISTRIBUTION: Recent County Records: SAN PATRICIO (Branson, 1960); "Big Bend Region of Texas" (Branson, 1963); "South Texas" (Bequaert and Miller, 1973). No fossil record.

DESCRIPTION: Shell planispiral, dextral, aperture extending farther on the right, or clockwise aspect, than on the left; right side (spire) broadly concave, almost flat; apex not countersunken; umbilicus broadly and deeply concave, with all whorls easily visible; sutures on both sides sharply incised; whorls subcircular in section, slightly flattened on right side, rarely so in the body whorl of mature shells on the left side; aperture not deflected, and without teeth or lamellae.

Initial whorls are smooth; later whorls with indistinct numerous, growth striae, and numerous closely spaced, spiral linear ridges, resembling the spiral sculpture of Helicodiscus. These are evenly spaced from right to left side, and of equal prominence on both sides. Maximum number of whorls is 3.25 (greater diameter 4.81 mm, aperture height 1.56 mm), but most specimens in populations have only 2 or 3 suture whorls. Texture of shell silky, not polished. Color uniformly light tan. The shells are frequently heavily encrusted with black (iron?) deposit.

The egg masses are typically planorbid, being flattened, firm gelatinous masses with usually one to four ova, but sometimes as many as twelve.

The penis sac is about as long as the preputium, and of the same diameter. Their junction is swollen, and internally at this point there is a well-developed sarcovelum and velum, with a narrow circular cavity between them. The columellar retractor muscle of the penis inserts on the penis sac about midway along its length. There seem to be no accessory retractor muscles, originating on the body wall. The penis is narrow and elongate, with terminal opening and without cuticular tip. The region just above the tip was uniformly swollen in all specimens examined, thus simulating a glans penis. There are two prominent finger-shaped glands attached to the apex of the penis sac. These retracted preputium contains two pilasters, but no preputial organ.

The spermatheca is spherical, with a short duct, about as long as the diameter of the sac. The prostate follicles are digitiform, not branched, but appear to arise in pairs in linear series along the vas deferens. Slightly above the region of the prostate, there is a small pocket on the vas deferens, which was invariably present in all specimens examined. Its finer structure was not determined.

The jaw consists of multiple plates arranged in a horseshoe pattern, as in _Drepanotrema_ and _Planorbinae_, senso stricto. The radula also bears a striking resemblance to the radula of _Drepanotrema_. The bicuspid central tooth has a small swelling on each shoulder, which might be interpreted as additional cusps. The first laterals are tricuspid, and the marginals are of the oblique type with cusps along the lateral edge. The cusps of the marginals and particularly the laterals are very slender and tapering, as in _Drepanotrema_ (Harry and Hubendick, 1964).

ECOLOGY/BIOLOGY: Harry and Hubendick (1964) recorded two types of habitat in Puerto Rico where _Antillorbis aeruginosus_ occurs: (1) temporary puddles, a few inches deep in roadside ditches, quarries, deep ruts in roads, etc.; (2) marginal pools of Lake Cartagena but not in the main body of the lake. It appeared to require standing water under arid conditions.

Branson (1960) collected empty shells in drift and on a small island in the Aransas River on the Welder Wildlife Refuge, San Patricio County. Apparently no live specimens have ever been collected in Arizona either, but the shells were recovered from habitats similar to those described by Harry and Hubendick from Puerto Rico.

DISCUSSION: The synonomies listed in this paper represent only the names under which this species has been listed for Texas. Harry and Hubendick (1964) and Bequaert and Miller (1973) provide for a more complete list of names ascribed to this gastropod.

Antillorbis differs from Drepanotrema, in addition to being much smaller (diameter 4.81 mm), by the shell sculpturing. The animal is also different in the shape of the foot, the pigment pattern of the cephalopedal mass and roof of the pulmonary cavity, the presence of a pulmonary lamella and pseudobranch with this lamella extending into it (Harry and Hubendick, 1964).

At first, it was tempting to disregard A. aeruginosa as a valid taxon occurring in Texas based upon the limited number of reports. I was not able to obtain specimens from Branson and failed to collect specimens in the field. Dr. D. W. Taylor (personal communication) has observed Texas specimens, and agreed that this species is valid for Texas. The shells that I examined from Arizona closely resemble Gyraulus circumstriatus and could easily be misidentified. Old drift shells also resemble the terrestrial snail, Helicodiscus.

Genus *Armiger* Hartmann, 1840

Armiger crista (Linnaeus), (Fig. 13b).

Nautilus crista Linnaeus, 1758, *Systema Natura*, 10th ed., p. 709.

Armiger crista (Linne), Baker, 1945, The Molluscan Family Planorbidae, p. 78.

TYPE LOCALITY: "in Germaniae paludibais" (in German marshes).

GENERAL DISTRIBUTION: The genus is Holarctic in distribution and was first known from the Middle Miocene period (Wenz, 1939). *A. crista* is also Holarctic (Europe, northern Asia, North Africa, and from scattered localities in the northern United States, Maine to Minnesota), Canada and Alaska (Fort Yukon, Dall, 1917), southward to central California, southern Nevada and Utah (Taylor, 1975, in litt.). As a Pleistocene fossil, *A. crista* occurs sporadically in deposits across the High Plains southward into Texas and New Mexico.

TEXAS DISTRIBUTION: Fossil County Records: Good Creek Local Fauna, FOARD, Howard Ranch (Groesbeck local fauna), HARDEMAN, 16,000-19,000 B.P. (Cheatum and Allen, 1965); Forney Dam Local Fauna, KAUFMAN (Thurmond, 1967).

DESCRIPTION: Shell very small (2 to 3 mm), thin, depressed, planorbiform, ultradextral, pale brown, and with numerous narrow costae and very fine, spiral lines. Costae parallel to lines of growth, about 12 to 18 in number on each whorl, inclined forward, and projecting as triangular periostracal lamellae at the periphery of the body whorl. (In fossil specimens the periostracum is absent and the peripheral projections appear nodular). Whorls 2.5 in adults, rapidly increasing in size, flattened above, rounded below, and angularly rounded at the periphery. Umbilicus wide, deep, and showing all previous whorls. Aperture prosocline, sub-elliptical, and wider than high. Lip thin and complete (holostomous).

ECOLOGY/BIOLOGY: In North America, A. crista occurs in seasonal aquatic habitats such as temporary ponds, marshes, and ditches (Taylor, 1975, in litt.). Clarke (1973) found it living at only two localities in the Canadian Interior Basin. Each site was a eutrophic pond (about 2 acres), surrounded by Typha and grass. A. crista was taken from submerged vegetation, such as Potamogeton, etc. The bottom was muddy. Fresh, empty shells were taken from one sluggish creek with similar vegetation found in the ponds.

Moquin-Tandon (1855) described the anatomy and reproduction of A. crista, and Baker (1945) thoroughly discussed the anatomy. The animal is very similar to Gyraulus, except that A. crista lacks a penial stylet.

DISCUSSION: Clarke (1973) stated that A. crista was rare in the Canadian Interior Basin and probably in North America as a whole. LaRocque (1964) listed only 18 eastern North American sites and only three of these included living colonies. Its relative abundance seems to have declined since the last glacial (Wisconsin Age) period.

The presence of _Armiger crista_ in northern Texas along with _Aplexa hypnorum_ clearly indicates humid but quite cold conditions and abundant aquatic vegetation. It also indicates the presence of small lentic systems that fluctuated periodically in water level.

The degree of costation on the shell varies even within one population, and the non-costate forms closely resemble the related _Gyraulus parvus_. Almost all the shells from Texas examined during this study were consistently 1-2 mm smaller than recorded sizes for living northern populations.

Genus _Biomphalaria_ Preston, 1910

Opinion 735, 1965, International Commission on Zoological Nomenclature: _Biomphalaria_ Preston, 1910 (Gastropoda): Grant under the plenary powers of precedence over _Planorbina_ Haldeman, 1842, _Taphius_ J. and A. Adams, 1855, and _Armigerus_ Clessin, 1844. Bulletin Zoological Nomenclature 22(2).

Biomphalaria obstructa (Morelet), (Fig. 14e).

Planorbis obstructus Morelet, 1849, Testacea Novissima Insulae Cubanae et Americae Centralis. Test. Noviss., pt. 2.

Biomphalaria obstructa donbilli (Tristram, 1861), Malek, 1969, Malacologia, 7:2-3.

Biomphalaria (_Planorbis_) _orbicula_ (Morelet, 1859), Malek, 1969, Malacologia, 7:2-3.

Tropicorbis gracilentis (Gould, 1855), Taylor, 1975, (in litt.).

NON-TEXAS SPECIES LITERATURE CITATIONS:

Biomphalaria (Tropicorbis) havanensis (Pfeiffer, 1839) (+ T. Liebmanni Dunker, 1950), Malek, 1969, Malacologia, 7(2-3).

TYPE LOCALITY: Carmen Island, Campeche, Mexico.

GENERAL DISTRIBUTION: Puerto Rico; Gulf Coastal States from Florida to Texas; east coast of Mexico to the Yucatan Peninsula (Malek, 1969).

TEXAS DISTRIBUTION: Recent County Records: BELL, BEXAR, CALLAHAN, CAMERON, CONCHO, FORT BEND, HAYS, HIDALGO, VAL VERDE, MAVERICK, NOLAN, RUNNELS, TRAVIS, WILLIAMSON and ZAPATA (Berry, 1947); ELLIS (Cheatum and Burt, 1931); KINNEY (Mearns); COMAL (Strecker); GILLESPIE (Askew (Singley, 1893); LIVE OAK (Vanatta); STONEWALL (Case (Walker); HAYS, BREWSTER, UVALDE, KIMBLE, McCULLOCH, MASON, HAMILTON, MENARD, KENDALL, KERR, ERATH, BLANCO, SAN PATRICIO, IRION, VICTORIA, FAYETTE, TARRANT, ARANSAS, WHARTON, LIMESTONE, JACKSON, REEVES, LAMPASAS, REAL, DIMMIT, EDWARDS, BANDERA, KAUFMAN, JOHNSON, DALLAS, SAN SABA, FRIO, SCURRY, TOM GREEN, WEBB, BURNET, DeWITTE, BOSQUE, BRAZOS and GARZA, (DMNH Coll.); COMAL, VICTORIA and CAMERON (Baker, 1945). Other recent reports: (Pilsbry and Ferriss, 1906), Fossil County Records: TERRELL and PECOS (Leonard and Frye, 1962), PRESIDIO, HARDEMAN and DICKENS (DMNH Coll.).

DESCRIPTION: Shell length up to 11 mm; whorls narrow, slowly increasing in size; aperture with or without internal lamellae; whorls visible from above and below, periphery of whorls rounded and sutures distinct; aperture heart shaped; spire concave and umbilicus shaped like a shallow depression.

ECOLOGY/BIOLOGY: In the United States, *Biomphalaria obstructa* inhabits a wide variety of aquatic habitats. In Louisiana, Malek (1969) found it in sloughs, bayous, ponds, lakes, etc., where the water was clear or turbid. The bottom was usually mud and humus. Aquatic plants usually associated with the habitat were *Lemna* spp., Coontail, *Ceratophyllum demersum*, Pondweed, *Potamogeton* and water lilies, *Nymphaea odorata*. Berry (1947) found it in similar Texas habitats. I have collected living specimens from mud in a dry stock tank in Brewster County and from clear Hill Country streams. *B. obstructa* appears to be an adventituous species but what parameters determine its northern limit in the State are unknown. Fossil *Biomphalaria* are known northward from Oklahoma to Kansas.

Malek (1969) has described the anatomy of *B. obstructa* and most *Biomphalaria* spp. in North and South America have received considerable attention as potential intermediate hosts for *Schistosoma mansoni*, the human blood fluke.

DISCUSSION: The *Biomphalaria* group is in a chaotic mess, particularly the Central American forms. Two species (both listed for Texas), *B. obstructa* and *B. havanensis*, were considered one species by Harry and Hubendick (1964) and as two separate species by Malek (1969). The claim that the two are valid species is entirely open to question. The type locality of *B. havanensis* is Puerto Rico. Harry and Hubendick (1964) synonomized the two as _B_. _havanensis_ with little justification. Malek's separation of the two were based upon fairly trivial internal reproductive tract differences. He stated that _B_. _havanensis_ had a more well-developed vaginal pouch, longer hermaphroditic duct and a smaller ratio of female tract to penial complex. He also stated that _B_. _havanensis_ was restricted to Puerto Rico.

Biomphalaria _obstructa_ and _B_. _havanensis_ also have been separated by the presence or absence of apertural lamellae. Malek (personal communication) found that non-"toothed" forms, when deprived of water for short periods, developed internal lamellae. I obtained similar results when I stressed a series from a pool in San Marcos, Texas. Lamellae began to appear within 3-5 days after exposure to air. It was also discovered during this study that non-lamellated forms were always associated with permanent water. I was not able to dissect Puerto Rican specimens, and am following Malek in keeping the two species separate, as his investigations have been the most thorough to date.

Genus _Drepanotrema_ Crosse and Fisher, 1880

Drepanotrema _kermatoides_ (d'Orbigny), (Fig. 14d).

Fossulorbis _kermatoides_ d'Orbigny, 1835, Mag. de Zool, 62:27; redescribed and figured by d'Orbigny, 1837, Voy. Amer. Mer. Moll., p. 350, pl. 45, figs. 1-4.

Drepanotrema _kermatoides_ (d'Orbigny), F. C. Baker, 1945, the Molluscan family Planorbidae, p. 184.

Drepanotrema (Planorbis) cultratus (d'Orbigny, 1845), Hubendick, 1961, Medd. Gotes. Musei. Zool. Avdeln., 132:43.

TYPE LOCALITY: Province of Lima, Peru.

GENERAL DISTRIBUTION: Texas, Mexico, Central America, Venezuela, Peru, Brazil, Puerto Rico and the Lesser Antilles (Harry and Hubendick, 1964).

TEXAS DISTRIBUTION: Recent County Records: "Southern Texas" (Baker, 1945); SAN PATRICIO (Branson, 1960); JACKSON (DMNH Coll.). No Fossil Record.

DESCRIPTION: Shell planispiral, dextral (lip advanced more on the right side than on the left); right side broadly and slightly concave, with the apex not additionally sunken; left side almost flat, or sometime broadly and slightly concave, but umbilicus not in a countersunken pit; suture incised, and narrowly margined by the shell attachment; whorls of spire about equally inflated on each side; body whorl similarly inflated on the right side, flattened and sloping obliquely on the periphery. There is a prominent angle on the left shoulder which is sometimes drawn out into a keel.

Texture silky, growth lines numerous, closely spaced, always prominent and regular. Spiral pits have not been observed in the juvenile shell (none available), but such pits are often present and irregularly arranged on the left side of the body whorl in larger shells. Spiral linear grooves, causing a puckering of the growth striae, are prominent and regular, persisting even to the aperture of larger shells.

Inorganic shell substance colorless and transparent. Cuticle almost colorless, never dark golden brown as is sometimes apparent in other species of this genus. Specimens rarely or never encrusted with iron deposit.

Maximum size 5.25 mm, suture whorls (greater diameter 8.0 mm, aperture height 1.62 mm). Shells of some other areas (Peru) may be nearly 15 mm in diameter, with a correspondingly larger number of whorls (Harry and Hubendick, 1964).

ECOLOGY/BIOLOGY: Drepanotrema kermatoides is a neo- and tropical species of standing water of ponds and lake backwaters. Harry and Hubendick (1964) found it in artificial ponds in St. Croix, Puerto Rico. Only drift specimens have been found at the Texas localities, thus no ecological data is available for this species in Texas at present.

DISCUSSION: D. kermatoides may be differentiated from D. cimex by its slightly larger size and by the strong peripheral keel along the upper edge of the body whorl. Also, the spire and umbilicus contain small pits along the whorls, and the entire shell is flatter than in D. cimex.

Possibly, the D. kermatoides colonies are relicts having previously arrived in Texas from Puerto Rico or even Mexico. I re-collected the Branson (San Patricio County) locality but failed to obtain live specimens.

Drepanotrema cimex (Moricand), (Fig. 12h - i).

Planorbis cimex Moricand, 1839, Mem. Soc. Phys. Hist. Natur. Geneve, 8:143, pl. 3, figs. 8-9.

Drepanotrema cimex (Moricand), F. C. Baker, 1945, The Molluscan Family Planorbidae, p. 94.

Drepanotrema cultratum labrosum Pilsbry, 1934, Harry, 1962, Malacologia, 1(1):40. T. L. Brownsville, Texas, Holotype - ANSP 14-3416.

TYPE LOCALITY: Bahia, Brazil?

GENERAL DISTRIBUTION: Greater Antilles, south Texas, Mexico, Central America, Venezuela and Brazil (Harry and Hubendick, 1964).

TEXAS DISTRIBUTION: Recent County Records: (all records cited as D. c. labrosum); CAMERON, HIDALGO, BASTROP, HAYS and VAL VERDE (Pilsbry, 1934). No Fossi Record.

DESCRIPTION: Shell planispiral, dextral, right and left sides flat, neither apex nor umbilicus pitted; whorls of spire evenly rounded on both sides; body whorl rounded on the right side, flat and obliquely sloping on the periphery, with a prominent, rounded angle at the left shoulder, rarely or never drawn out into a keel; left side of body whorl inflated and a prominent labial callus often present; inorganic shell material almost colorless and transparent; cuticle uniformly colored, but may vary from nearly colorless to dark golden brown; dark iron deposit often present.

Texture silky or polished, varying in intensity on the same shell; growth lines variable, almost absent in polished parts of the shell to numerous, close, regular and prominent on the silky parts; spiral sculpture as in D. kermatoides. It was not possible to determine the presence of textural pits. Maximum size range: greater diameter 6.62 mm, aperture height 1.12 mm (Harry and Hubendick, 1964).

ECOLOGY/BIOLOGY: *D. cimex* occupies a habitat similar to that of *D. kermatoides*. In Puerto Rico, Harry and Hubendick (1964) found it in limestone sinks behind sand dunes, swamps, drainage ditches and in the backwaters of the Rio Arecibo River. It appeared to be able to occupy even more turbid water than could *D. kermatoides*. As in the case of *D. kermatoides*, all specimens collected from Texas localities were drift shells and no living specimens have been found.

Genus *Gyraulus* Charpentier, 1837

Gyraulus parvus (Say), (Fig. 13c).

Planorbis parvus Say, 1817, Nicholson's Encyclopedia. 1st American ed., pl. 1, fig. 5 (Binney reprint, 1858:45).

Gyraulus parvus (Say), F. C. Baker, 1928, F. W. Moll. Wisc., 1:364.

Gyraulus vermicularis (Gould, 1847), Taylor 1975:21, (in litt.).

Gyraulus labiatus Leonard, 1948, Nautilus 62(?):41-47.

TYPE LOCALITY: "Very numerous in the Delaware (River near Philadelpha)" (Say, 1817).

GENERAL DISTRIBUTION: "North America, from Alaska and northern Canada to Cuba and from the Atlantic to the Pacific coasts. Perhaps also in northern Eurasia" (Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records: FOARD (Good

Creek Local Fauna), HARDEMAN (Groesbeck fauna), MOTLEY (Quitaque L. F.), KNOX, EDWARDS, COOKE, DONLEY, TERRY, RANDALL, DELTA, DENTON (Clear Creek L. F.), DICKENS, BELL, BRISCOE, HALL and BOSQUE (DMNH Coll.); CRANE, WARD, REEVES and TERRELL (Leonard and Frye, 1962). Recent County Records: CULBERSON, COLEMAN, McCULLOCH, HAMILTON, SCURRY, KIMBLE, MASON, ANDREWS, RANDALL, LAVACA, SOMERVELL, KERR, DALLAS, PRESIDIO, LIMESTONE, GILLESPIE, WICHITA, KNOX, VAL VERDE (fossil ?), WICHITA, DALLAS and POLK: as G. vermicularis, TOM GREEN, DALLAS, FLOYD, MARION, GILLESPIE, RANDALL, MASON, HAYS, SOMERVELL and JEFF DAVIS (DMNH Coll.); ARMSTRONG, McLENNAN (Strecker), POTTER (Henderson), SOMERVELL, COLORADO (Sterki), STONEWALL (Case, Walker, 1918), ELLIS (Cheatum and Burt, 1934), STONEWALL and SWISHER (Cummins, Singley in Strecker, 1935); TAYLOR (Beasley and Fullington, 1978).

DESCRIPTION: Shell small (maximum diameter 5 mm), planorbiform, ultra-dextral, depressed, pale brown to dark brown, variable in shape but without prominent striation, peripheral keel, or hirsute periostracum. Periphery rounded and located close to the center of the body whorl; periostracum in fresh, clean specimens smooth (except for lines of growth) and glossy; spire flat with first 2 whorls depressed; umbilicus wide, shallow, "reamed-out," and exhibiting all the whorls; aperture prosocline, ovate, and in the same plane as the body whorl or somewhat deflected below it; outer lip thin (in most specimens); inner lip with a thin callus (condensed from Clarke, 1973).

ECOLOGY/BIOLOGY: "Usually in quiet bodies of water, often of small size. . . parvus is partial to a habitat which has rather thick vegetation. This species was more often found in vegetation than in any other situation" (Baker, 1928). Taylor (1975, in litt.) stated that it was most common among dense plant growth in lakes and streams, less often in seasonal situations. However, Clarke (1973) found it from large lakes to vernal ponds, swamps, ditches and stream backwaters but always where the aquatic vegetation was dense and the bottom was mud. Current flow was slow to moderate in the lotic systems. Baker (1928, 1945) thoroughly described the anatomy of *G. parvus* and stated that its soft parts closely resembled those of *Gyraulus deflectus*. *G. parvus* is the intermediate host of both the avian schistosome *Gigantobilharzia gyrauli* and the plagiorchid frog parasite *Haematoloechus parviplexus* (Malek and Cheng, 1974).

DISCUSSION: During this study, *G. parvus* in Texas was found more often in ponds and stream backwaters, particularly where *Potamogeton* and *Ceratophyllum* were abundant and was almost on the vegetation. In central and east Texas, it was common where streams were slow flowing and choked with submerged vegetation.

Caution should be exercised when attempting to identify, particularly fossil, specimens of *Gyraulus*. As Clarke (1973) stated, "Much time was spent during this work in an effort to find consistent differences which would validate these taxa (*G. parvus*, *G. circumstriatus*, *G. deflectus*, *G. similaris*, etc).

but without avail. Unfortunately, even positive differentiation of G. parvus from some specimens of G. circumstriatus and G. deflectus is not always easy. Revision of the difficult genus is especially desirable."

Whether Taylor's (1975, in litt.) synonomies of G. similaris and G. vermicularis under G. parvus are correct or not is academic, but is plausible, until the entire genus is thoroughly investigated. The best diagnostic features of the genus Gyraulus are the rounded whorls or subangulated periphery with all whorls visible from above and below.

Gyraulus circumstriatus (Tryon), (Fig. 14a).

Planorbis circumstriatus Tryon, 1866, Amer. J. Conchol., 2:113, pl. 10:6-8.

Gyraulus circumstriatus (Tryon), F. C. Baker, 1928, F. W. Moll. Wisc., 1:378.

TYPE LOCALITY: "Artificial pond at Weatague, Connecticut" (Tryon, 1866).

GENERAL DISTRIBUTION: Widespread in the western United States east of the Rocky Mountains across southern Canada to Connecticut; across the northern United States and south in the Rocky Mountains to New Mexico, southern California and central Arizona (Taylor, 1975, in litt.).

TEXAS DISTRIBUTION: Fossil County Records: MARTIN and HOWARD (Frye and Leonard, 1964); FOARD, KNOX, PRESIDIO, HARDEMAN (Good Creek Formation), COOKE, BELL, BRISCOE, DALLAS, MOTLEY and CLAY (DMNH Coll., includes specimens from Cheatum and Allen, 1965). No Recent Records.

DESCRIPTION: Shells small (maximum diameter 5 mm), low, planorboid (planospiral in many specimens), variable, whitish, transparent to semi-transparent; whorls laterally rounded and increasing in size more slowly than in Gyraulus parvus. Periostracum smooth and glossy; fine spiral striae visible in most specimens, especially on the base; collabral lines and lines of growth well marked to strong; all whorls visible in both apical and umbilical view; umbilical depression wide, shallow, and in many specimens so similar to the apical depressions that except for the configuration of the collabral sculpture and of the aperture the upper and lower views of the shell are essentially mirror images of each other. Aperture prosocline, ovate and in the same plane as the body whorl or slightly below it; outer lip thin in most specimens; inner lip without a perceptible callus (Clarke, 1973).

ECOLOGY/BIOLOGY: "G. circumstriatus is characteristic of small, seasonal water bodies, such as wood pools, marshes, ponds on flood plains or prairie ponds" (Taylor, 1960). Clarke (1973) obtained similar data in Canada. Although Baker (1945) described the anatomy of G. circumstriatus, like most of the other small planorbid species, its life cycle or ecology are largely unknown. In warmer climates (southern portion of its range), G. circumstriatus occurs only in mountainous regions. It also prefers water with dense submerged vegetation and with a muddy bottom.

DISCUSSION: Whether Gyraulus circumstriatus came to Texas from the west or the north during the Pleistocene cannot be determined, as it is a fairly common fossil across the High Plains into New Mexico. However, it can definitely be grouped with the aquatic snails that did inhabit this area during much cooler and wetter times than at present.

Differentiating characters between G. parvus and G. circumstriatus used during this study were: in G. circumstriatus the whorls are more closely coiled, with the last not being rapidly enlarged and usually has fine spiral striae on the smooth shell.

A thickened lip or parietal callus was also used to separate G. circumstriatus, G. parvus and G. vermicularis (a western synonomy of G. parvus). There are definite indications, however, that lip thickening is ecophenotypic and indicative of depauperization, not of generic or of taxonomic significance. The same holds true for apertural denticles in aquatic snails. It is also well known by malacologists that species with a wide range of tolerance for diverse water hardness typically produce thicker shells in hard water than in soft (Goodrich, 1939).

Genus Helisoma Swainson, 1840

Helisoma anceps (Menke), (Fig. 12c).

Planorbis anceps Menke, 1830, Molluscorum . . .in Museo Menkeana (etc.), p. 36. No description but refers to Lister Conch. tab. 139, fig. 44

Helisoma anceps (Menke), F. C. Baker, 1945, the Molluscan Family Planorbidae, p. 128.

Planorbis _bicarinatus_ Say, 1817, _Nicholson's_ _Encyclopedia_, 1st Amer. ed., pl. 1, fig. 4 (Binney reprint, 1858:44).

Helisoma (_Planorbis_) _antrosus_ (Conrad, 1834), Amer. J. Science, 1(25):343.

TYPE LOCALITY: "virgin(ia)." (Lister, 1770) (Menke, 1830).

GENERAL DISTRIBUTION: Throughout North America from southern James Bay and Hudson Bay south to North Carolina, Alabama, Texas and northwestern Mexico and west to Oregon, Alberta and the Canadian Interior Basin (Clarke, 1973); introduced in Italy.

TEXAS DISTRIBUTION: Recent County Records: Nueces River (Ferriss), SOMERVELL (Sterki), FORT CLARK, KINNEY (Mearns), McLENNAN (Strecker), GILLESPIE (Askew-Singley, 1893), WILLIAMSON (Walker-Singley, 1893), COMAL, HAYS, TRAVIS, BEXAR, WASHINGTON, STONEWALL, HOWARD and HARDEMAN (Cummins-Singley, 1893). Pleistocene: (in Strecker, 1935); KIMBLE, UVALDE, HOWARD, PRESIDIO and TERRELL (Cheatum, et. al., 1972); UVALDE, KIMBLE, DALLAS, GILLESPIE, FAYETTE, VICTORIA, BLANCO, WILLIAMSON, SOMERVELL, TOM GREEN, DENTON, PALO PINTO, IRION, SAN SABA, TRAVIS, BEXAR, TARRANT, HAYS, KERR, ERATH, MENARD, BELL, GUADALUPE, BOSQUE, VAL VERDE and KAUFMAN (DMNH Coll.). Fossil County Records: HOWARD, FOARD, HARDEMAN, MOTLEY, KNOX, DELTA, DALLAS, WICHITA, VICTORIA, COOKE, PRESIDIO, HALL, TERRY and DENTON (DMNH Coll.); REEVES, CROCKETT, PECOS and TERRELL (Leonard and Frye, 1962).

DESCRIPTION: "Shell medium-sized to large (maximum diameter

17 mm), planorbiform, with 4 whorls in the adult, ultra-dextral, variable, relatively high, blackish brown to pale brown, and in most populations with 2 prominent carinae, one on the upper surface of the body whorl and one bounding the umbilicus. Upper and lower carinae (when present) rounded, sharp, or corded, the upper carina of variable position and located at the center of the whorl or close to, but not on, the shoulder. Periphery rounded. Spire immersed to a variable extent but in most populations it is deeply recessed. Umbilicus deep and narrow. Spiral striae absent or present and of prominence varying from barely apparent to strong and obvious. Collabral sculpture present and fine to moderately fine. Aperture ear-shaped, expanded in some populations, commonly thickened internally, and with a moderately thick callus deposit on the parietal wall" (Clarke, 1973).

ECOLOGY/BIOLOGY: H. anceps appears to prefer lentic systems from small streams to large rivers, particularly small creeks. But in the northern United States and Canada, it also occurs in deep lakes (Leonard and Frye, 1962). In the Canadian Interior Basin, Clarke (1973) found it in lakes, rivers and springs but only in habitats with permanent water. The substrate types were varied, and the current varied from rapid to imperceptible.

Baker (1945) described the anatomy of H. anceps as the type for his subgenus Helisoma (senso stricto). Harman and Harman (1975) conducted a population study on H. anceps, from a lake in New York State and showed that H. anceps underwent a typical northern species univoltine reproductive cycle. Spring egg laying began in late May and ceased by late July. Most individuals, after surviving the winter, usually died after the spring egg-laying although some survived and laid eggs the following spring.

Katsigianis and Harman (1973) studied variation in the radular teeth in several population of *H. anceps*. They essentially confirmed a general suspicion that radular teeth variation is not a reliable taxonomic tool at the specific level.

DISCUSSION: In Texas, *H. anceps* occurs principally in streams and along upper river stretches and usually not in large populations per locality. The presence of aquatic vegetation does not appear to be necessary. It seems to especially be prevalent in gravelly, riffle areas.

Analysis of all available Texas *Helisoma anceps* specimens revealed that the distribution of living populations is spotty while the fossil distribution is quite extensive and numerous. This may be an indication that *H. anceps*, actually a more northern, cooler climate species, is being exterpated from this area by current drying trends.

It was also discovered that many specimens in collections were misidentified as *H. t. lenta*. The best recognition characters that I found to be reliable of *Helisoma anceps* were: (1) the sunken spire and deep umbilicus; (2) the carination of both the upper surface of the body and near the umbilicus.

Helisoma foveale (Menke), (Fig. 12d-e).

Planorbis fovealis Menke, 1830, Synop. Method. Mollusc. . . . p. 37 cites "Lister Conch. tab. 140, fig. 47; where the word "I am" appears adjacent to the figures.

Helisoma foveale (Menke), Pilsbry, 1934, Proc. Acad. Natur. Sci. Phil., LXXXVI:45.

Helisoma caribaeus (d'Orbigny, 1845), Harry and Hubendick, 1964, Medd. Gate. Musei Zool. Ardel. 1, 136:40.

Planorbis tumidus Dunker, 1850, Pilsbry, 1934, Proc. Acad. Natur. Sci. Phil., XXXVI:44.

Planorbis sinuous Bonnet, 1864, Pilsbry, 1934, Proc. Acad. Natur. Sci. Phil., XXXVI:44.

NON-SYNONOMOUS (?) TEXAS LITERATURE SPECIES RECORDS:

Helisoma tenue (tenusi) ("Phillippi" Dunker, 1850), Sys. Conch. Cab. Mart. and Chem., Ed. 2, Planorbis, p. 45, pl. 9, figs. 14-16, (17-19) (appeared 1850); pl. 16, fig. 23-25 (appeared 1844, without name). ("Haufig in Graben der Umgegend von Mexico mit Limnaeus subulatus Dkr.").

TYPE LOCALITY: "I am," interpreted by Pilsbry (1934) as Jamaica.

GENERAL DISTRIBUTION: As Helisoma foveale: Puerto Rico, Greater Antilles (Harry and Hubendick, 1964); Neotropical Helisoma: Mexico and Central America, southern part of western North American (?) (see Discussion).

TEXAS DISTRIBUTION: Recent County Records: ARMSTRONG, HAYS and McLENNAN (Strecker), KINNEY, EL PASO (Mearns, Dall), BEXAR (Quillin), "Devil's River" (Stearns), CAMERON (Askew, Singley, 1893), LAMPASAS (Mrs. Sinks, Singley, 1893), TRAVIS (Singley, 1893), as P. tumidus in Strecker (1935); FRIO, ERATH, GILLESPIE, COMAL, KERR, WILLIAMSON, TARRANT, HOWARD CAMERON, TRAVIS, PALO PINTO, CAMERON and SWISHER (DMNH Coll.). No apparent Fossil Record. Taylor (1975, in litt.) cited the distribution of H. (Planorbella) tenue in Texas as, "West trans-Pecos Texas."

DESCRIPTION: The shell is planispiral, dextral, the height of the body whorl large in proportion to the greater diameter. The right (clockwise) side almost flat, but with earlier whorls obscured by being deeply sunken in a narrow, deep pit; intermediate whorls on this side sharply angled as they emerged from the pit, and this angulation gradually becomes less pronounced until it disappears on the final whorl of larger shells; suture very pronounced on the right side; left side gently concave to almost flat; a prominent angle can be seen at the shoulder of each whorl, and this angle is obliterated on the shoulder of the last whorl of larger shells. Growth of the body whorl of larger shells is often slightly irregular, both in the cross section of the whorl and the attachment of the body whorl to the previous whorls; growth striae prominent, close and regular on earlier whorls, becoming weaker and more irregular on the body whorl of larger shells; no spiral sculpture present; shells are uniformly light brown in color, often heavily encrusted with black iron deposit, under which the texture of the body whorl is often silky. This enhances the similarity of the shells to *Taphius glabratus*, which large *H. foveale* often resemble in size and general form.

The rectal moiety of the pulmonary lamella is prominently fluted in *H. foveale*, as in *T. glabratus*, and in both species the dorsal moiety of this lamella is not fluted, but well suspended from the roof of the cavity. There is a well-developed renal ridge in the pulmonary cavity of at least larger specimens (see Paraense and Deslandes, 1959). This begins near the apertural end of the pericardium and extends all the way to the apertural reflection of the ureter. It is not fluted, and its crest is not ciliated, in contrast to the pulmonary lamella (Harry and Hubendick, 1964).

ECOLOGY/BIOLOGY: As stated by Harry and Hubendick (1964), virtually no data is available concerning the anatomy or ecology of the neotropical *Helisoma* from Mexico and Central America (including its range into the western United States). In view of the present taxonomic state of this genus in the Neotropics, a conservative approach is required.

Most of the western United States and northern Mexico *Helisoma* with fine striation have recently been referred to as *H. tenue* without real justifications. Bequaert and Miller (1973) stated that *H. tenue* (*H. foveale*) was one of the most widely distributed snails of Arizona occurring in nearly every county, principally in lakes and ponds. Most of the

Texas records were from ponds and lakes also, but eastward of the trans-Pecos and Panhandle, I found it to occur primarily in the backwaters of streams and rivers. The exact eastward limit was not determined during this study. Harry and Hubendick (1964) felt that H. foveale is an introduced species in Puerto Rico and the Antilles.

DISCUSSION: Baker (1945) included all the North American Helisoma group in the subfamily Helisomatinae, characterized by a compound or multiple-lobed diverticula of the prostate gland. The western North American (and Neotropical) species were placed in the subgenus Pierosoma Dall, 1905. Other planorbid genera were placed in other subfamilies and subgenera based upon intricate, though small differences in the genitalia. Hubendick (1955) included several of Baker's subfamilies into one subfamily, the Planorbinae, characterized by an ordinary penis. In his other two subfamilies, the Plesiophysinae possess no pseudobranch, and the subfamily Bulininae possess an "ultrapenis." Within the subfamily Planorbinae, Hubendick erected the tribe Helisoma (corrected to Helisomatini by Clarke, 1973), again characterized by specialized male copulatory organs and evolved prostate glands. This tribe encompassed the species that Harry (1962) considered the foveale group, all in the genus Helisoma.

Harry (1962) listed over 30 species of Neotropical Helisoma, all characterized by the upper first two or three whorls strongly angled on the shoulder (but not doubly carinated as in H. anceps). The great majority of these species, including

H. tenue and *H. foveale*, have extremely vague descriptions and exact type localities (see Harry, 1962). As Harry and Hubendick (1964) stated, ". . .but it is not possible to state definitely whether there is one or more biological species among the thirty or more species from the area (Mexico and Central America)."

DISCUSSION: Due to the fact that *H. tenue* has been recently the most commonly used name for the western North American and northern Mexico *Helisoma*, my application of *H. foveale* for this group probably will receive some criticism. But, until much more definitive investigations are conducted on this geographic group, the Law of Priority should prevail. *H. foveale* is simply the oldest available name applicable to the neotropical *Helisoma*. Again, resorting to Harry and Hubendick (1964), ". . .it seems likely that there is one widely distributed species in the Antilles, Mexico, Central America and possibly parts of Florida."

H. foveale was not found among the fossil Texas *Helisoma* examined during this study, which raises the question whether or not *H. foveale* is a recent invader of Texas.

Helisoma duryi (Wetherby), (Fig. 12a).

Planorbis duryi Wetherby, 1879, J. Cincinnati Soc. Natur. Hist., 2:99, fig. 4.

Helisoma duryi (Wetherby), Pilsbry, 1934, Proc. Acad. Natur. Sci. Phil., LXXXVI:50.

TYPE LOCALITY: "Everglades of Florida" (Wetherby, 1879).

Pilsbry (1934) interpreted the locality to be somewhere along the coast of Volusia County. Holotype - type Lot. No. 9712, Bryant Walker Collection.

GENERAL DISTRIBUTION: Florida Peninsula.

TEXAS DISTRIBUTION: Introduced County Records: Drainage ditch in Houston, HARRIS (D. W. Taylor, personal communication); lower terrace pond of the Brackenridge Advanced Research Laboratory, Austin, TRAVIS (McGuire); Mill Pond in Palmetto State Park, GONZALES (DMNH Coll.).

DESCRIPTION: "The glossy chamois or faintly greenish shell shows weak waves and minute ripples of growth. The height is about half the diamter. Spire (left side) saucer-shaped, the bottom of the saucer or inner whorls being nearly flat the last whorl with an angular ridge which in its last half turn is high with a steep slope to the suture. The five whorls are united by a seam-like suture which is but slightly impressed except when the penult whorl projects a little above it, as is often the case. The right side is deeply imbilicate in the center and shows two to two and a half whorls. The whorls on this side are very convex, more or less narrowly rounded, sometimes almost subangular, and separated by an extremely deep suture, which at the end runs towards the periphery of the penult whorl, as Wetherby mentioned. The aperture is angular above (left) broadly rounded below (right), and somewhat straightened towards the insertion on that side. Parietal callus is very oblique, as in all of this group. Shell height ranges from 8 to 14.5 mm; diameter from 13 to 26.5 mm" (Pilsbry, 1934).

ECOLOGY/BIOLOGY: In Florida, H. duryi occurs in a variety of habitats from shallow lakes, swamps, rivers to drainage ditches and apparently readily establishes itself in new areas. The colony at Palmetto State Park, disoovered during this study, is quite large but it is not known when the snails were introduced or how.

Many subspecies have been described from Florida as the shell is extremely variable. The only fixed or unchanging characters according to Pilsbry (1934) are the "great height of the last whorl, the very shallow spire, the few rapidly increasing whorls of the base and the high gloss." In a few specimens from Florida populations, there were high extensions of the flat-topped spire making the shell appear almost scallariform.

DISCUSSION: H. duryi becomes introduced through one of several methods. The author has seen it infrequently in pet store aquaria in several cities. However, its most probable source of entry is on aquatic vegetation. Palmetto State Park lies on the San Marcos River which, in turn, flows through the commercial Aquarena Springs, where exotic vegetation has been periodically introduced.

Once seen, H. duryi is easily recognizable by the glossy, brown shell. Taylor (1975, in litt.) recorded its introduction through aquarium trade ("Red Ramshorn") from California, Idaho, Nevada, Arizona and to the north mainly in limmocrenes where the water is slightly warmed.

Helisoma (Pierosoma) trivolvis lenta (Say), (Fig. 12b).

Planorbis lentus Say, 1834, Amer. Conch., 6:6, pl. 4, fig. 1.

Helisoma trivolvis lentum (Say, 1834), F. C. Baker, 1945, Univ. Ill. Press. Urbana, p. 149.

NON-SYNONOMOUS TEXAS LITERATURE SPECIES:

Helisoma trivolvis turgidum (Jeffreys), Murray and Roy, 1968, Sterkiana, No. 30:31 (cited by F. C. Baker, 1945:414 as H. trivolvis intertextum (Sowerby, 1878) at (Leon County?), Texas (see Discussion).

Helisoma trivolvis (Say), authors,

TYPE LOCALITY: "Mexico, Ojo de Agua, and Canal at New Orleans" (Say, 1834).

GENERAL DISTRIBUTON: "South Plains region and Gulf Coast of United States; eastern and north New Mexico and Pecos River Valley, Texas. Replaced westward by P. tenuis (H. foveale), but other range limits and relation to P. trivolvis (trivolvis) need clarification" (Taylor, 1975, in litt.).

TEXAS DISTRIBUTION: Recent County Records: STONEWALL (Cummins, Singley), VICTORIA (Mitchell), KINNEY (Mearns) and McLENNAN (in Strecker, 1935); COMAL and VAL VERDE (Pilsbry and Ferriss, 1906); TRAVIS (Baker, 1945); BREWSTER (?), CAMERON, MITCHELL, COLEMAN, KINNEY, UVALDE, RED RIVER, MASON, COLLIN, LUBBOCK, UVALDE, BANDERA, KAUFMAN, WICHITA, DALLAS, EDWARDS, HIDALGO, REEVES, JEFF DAVIS, McCULLOCH, KIMBLE, CORYELL, JEFFERSON, HILL, BEXAR, FLOYD, MEDINA, TARRANT, COOKE, HAYS, PALO PINTO, SAN SABA, SOMERVELL, MARION, ERATH, McLENNAN, MENARD, HARRIS, BOSQUE, DENTON, GILLESPIE, LIMESTONE, VICTORIA, ARANSAS, TRAVIS, WILLIAMSON, BELL, FAYETTE, SAN PATRICIO, COMAL, MATAGORDA, DeWITTE, JACKSON, LAMPASAS, KERR, LUBBOCK, HILL, WHARTON, BURLESON and CULBERSON (DMNH Coll.). Fossil County Records: BRISCOE, DELTA, EDWARDS, COOKE, CLAY, MOTLEY, DONLEY, HARDEMAN, WICHITA, KNOX and FOARD (DMNH Coll.); WILL-BARGER (Hanna, 1923); REEVES (Leonard and Frye, 1962).

DESCRIPTION: "Shell dull brownish or yellowish-brown, subcarinate above, particularly in the young shell; whorls nearly five, striate across with fine raised, subequidistant lines; forming grooves between them; spire concave; aperture large; embracing a large portion of the penultimate volution; labrum more acutely but not very prominently arcuated above, its basal portion horizontally subrectilinear, in the adult, and not extending below the level of the base" (W. G. Binney, 1865). Shell medium to large in size, with irregularly spaced striae and smaller striae between the large striae; body whorl enlarges rapidly and occasionally, large growth lines near the aperture give it an irregular appearance.

ECOLOGY/BIOLOGY: Despite the rather common occurrence of *H. t. lenta* in the state, little is known of its ecology, reproduction or life history. Baker (1945) thoroughly described the anatomy of *H. trivolvis trivolvis*, and Clarke

(1973) found specimens in lakes, ponds and streams of permanent water. The substrate was usually mud and vegetation, moderate to abundant. He concluded that H. t. trivolvis is a creature of eutrophic, permanent water habitats, and that it occurs most frequently as an element of complex molluscan communities consisting of many species.

H. t. lenta, in Texas, occurs in much the same types of habitats that Clarke found for H. t. trivolvis and was found generally over the state, except for far West Texas, in large but sporadic colonies. It was very common in the shallow backwater areas of streams where green algae was abundant. However, it was also common in the shallow, protected coves of lakes where I found it crawling on mud, old cans, and on stems of emergent vegetation. Physa virgata usually was associated with H. t. lenta at these sites.

Cheatum (1935) found that this species attained a smaller size in West Texas and in isolated but abundant colonies. Branson (1960) noted similar situations in San Patricio County in regards to the isolated occurrence of colonies.

DISCUSSION: Helisoma trivolvis lenta belongs to the same subgenus, Pierosoma, as does H. foveale (Baker, 1945), but the two are easily separated. H. t. lenta is usually quite large (up to 20 mm), the striae are also large and irregularly spaced. It may be carinated on the upper surface, but not on the umbilical side. Typical H. t. trivolvis is slightly larger and the aperture more flared. The entire <u>Helisoma trivolvis</u> complex is complicated with many described subspecies, but without distributional limits. Baker (1928) described the distribution of <u>H. t. trivolvis</u> as "Atlantic coast and Mississippi River drainages, northward to Arctic British America and Alaska and southward to Tennessee and Missouri. The southern distribution is not clear owing to mixing with related species."

Eastward from (or in ?) Texas, <u>H. t. lenta</u> is supposed to be replaced by a smaller, flatter form, <u>H. trivolvis intertextum</u> (Sowerby). Pilsbry (1934) described it as having the inner whorls of the shallowly concave left side flattened with an acute keel, normally concealed in the suture. The right side as carinated and spirally striated inner whorls. Resting periods are occasionally conspicuously marked by buff or whitish and dark brown streaks. Baker (1945) described shells from near Leon (?), Texas as pure <u>H. t. intertextum</u>, and Branson (1960) described specimens from Austin as intergrades.

I did not collect <u>H. t. intertextum</u> during this study, and specimens observed from ANSP did not appear to warrant even subspecific rank. I strongly suspect that specimens previously recorded came from aquatic environments that tend to induce a smaller shell, such as soft water or low pH.

Genus <u>Micromenetus</u> Baker, 1845

<u>Micromenetus dilatatus</u> (Gould), (Fig. 14c).

Planorbis dilatatus Gould, 1841, W. G. Binney, 1865, Smith. Misc. Coll., pt. 2:121 (redescription).

Menetus (*Micromenetus*) *dilatatus* (Gould), F. C. Baker, 1945, Univ. Ill. Press, p. 187-190 (as subgenus of *Menetus*).

Micromenetus dilatatus (Gould), authors.

TYPE LOCALITY: Not described.

GENERAL DISTRIBUTION: "The species belonging to the subgenus *Micromenetus* are distributed over the eastern part of North America from Massachusetts west to Iowa and Missouri, and from Maine and Michigan southward to Alabama, Florida and Texas. It is a group found east of the Rocky Mountains. One species, *Menetus uliginosus* Vanatta, is found in Bermuda" (Baker, 1945).

TEXAS DISTRIBUTION: Recent County Records: DALLAS (Baker, 1945), KAUFMAN, BOWIE, DALLAS, HENDERSON, ANGELINA and HOUSTON (DMNH Coll.); VICTORIA (Mitchell); Nueces River Drift (Ferriss); HARRIS (Westgate, in Singley); COLORADO (Sterki, in Singley); COMAL (Singley, in Strecker, 1934); KAUFMAN (Logsdon); CALLAHAN, MENARD and SOMERVELL (Cheatum et. al., 1972). Fossil County Records: POLK (Slaughter, 1965); DALLAS (Slaughter, 1966).

DESCRIPTION: "Shell small, circumference carinated, flat above, convex below and with a small, deep umbilicus; whorls 3; aperture large, expanded. Shell small, of a yellowish-green color, minutely wrinkled by lines of growth; spire flat, composed of not more than 3 whorls, separated by a well-defined suture; outer whorl has a sharp margin on a level with the spire diminishing near, but still modifying the aperture; below this line the whorl is very convexly rounded so as to encircle a small, deep, abruptly very oblique aperture with the lip expanded so as to make it trumpet-shaped. Longest diameter 3/20 inch, breadth 1/20 inch" (Binney redescription, 1865).

Shell thin, reddish-brown; 3 to nearly 4 whorls, slightly smaller than *M. sampsoni*; periphery with a definite carina; body whorl not so strongly embracing previous whorls as in the latter species; aperture more elongated; lip somewhat thickened; spire slightly raised above general contours of shell; umbilicus straight sided and deep, about as wide as high. Animal about like *M. sampsoni*; teeth in both with bicuspid first laterals and long-former marginals. Although it is often stated that this species lacks spiral sculpture, such may often be seen near the suture and a very faint indication just below (to the right of) the carina according to Branson (1961).

ECOLOGY/BIOLOGY: According to Branson (1961), *Micromentus dilatatus*, in Oklahoma, is a species of quiet waters, where it may be found crawling on sticks and stones in temporary and semi-permanent waters. Emerson and Jacobson (1976) stated that it is an inhabitant of quiet pools and ponds throughout the eastern United States. Otherwise, little ecological or biological information is available for *M. dilatatus* or even *M. sampsoni*. Baker (1945) found cercariae and rediae of an unidentified trematode in a *M. dilatatus* specimen from Connecticut. Baker (1945) also described very critically the anatomy of *M. dilatatus* as the type for his new subgenus, *Micromenetus*. Subsequently, it was elevated to full genus by most later authors.

DISCUSSION: *Menetus* is now considered to contain three Recent species and two Recent subspecies, all confined west of the Rocky Mountains and Central Alberta (Clarke, 1973). *Micromenetus* (the shell is smaller than *Menetus*) is distributed east of the Rocky Mountains to the Atlantic and consists of five species with several subspecies. Apparently, Central Texas and Oklahoma are the southwestern limits for this genus, as there are no records of it in New Mexico or Arizona.

I found the Texas aquatic habitats for this *M. dilatatus* and *M. sampsoni* to be very characteristic and similar. They were all quiet, clear water pools with dense vegetation (*Chara*, *Myriophyllum* and *Polyganum*). *M. dilatatus* was also found to be much more abundant than *M. sampsoni* although I found them occurring sympatrically.

Micromenetus sampsoni (Ancey), (Fig. 15c).

Planorbis sampsoni Ancey, 1885, Bull. Sedalia, New Harmony Soc., no. 1:26.

Menetus sampsoni (Ancey), F. C. Baker, 1945, Univ. Ill. Press, Urbana, p. 190.

Micromenetus sampsoni (Ancey), authors.

TYPE LOCALITY: "Vicinity of Seadlia, Missouri" (Ancey, 1885).

GENERAL DISTRIBUTION: Same as for Micromenetus dilatatus (?).

TEXAS DISTRIBUTION: Recent County Records: "Small lake near Hutchins, DALLAS, Texas" (Baker, 1945); TARRANT (Cheatum, et. al., 1972); DALLAS, HOUSTON and ANGELINA (DMNH Coll.). No fossil records.

DESCRIPTION: Shell slightly compressed, flattened above, widely umbilicated, umbilicus concave, previous whorls showing all the volutions, about one-third of the total width. Whorls 3, rapidly increasing, convex, the last one very large and becoming gradually wider towards the aperture, somewhat depressed above, very convex below and around the umbilicus, not carinated at its periphery; aperture large, slightly oblique, expanded at its base and at its columella portion, nearly round, wide, very slightly angular at its base, lactescent or pale bluish within; texture comparatively solid; surface faintly marked with lines of growth and with delicate and numerous revolving lines, of a pale greenish color, somewhat shining, glabrous; diameter 4.5 to 5 mm; animal dark gray to nearly black. Height (of the last whorl towards the aperture) 2.0 mm, greatest diameter 4.75mm, lesser 3.75 mm.

"This new species which I named after Mr. F. A. Sampson, who discovered several specimens of it in the vicinity of Sedalia, Missouri, is very nearly allied to Planorbis (Micromenetus) dilatatus Gould, which is known to me by the description and figure alone. It seems to differ very much from it by its larger size, and numerous revolving lines (these are apparent under a lens in all the specimens I examined) and last whorl not "sharply" carinated,although on a level with the spire above and very slightly angular at its origin. This angulation does not modify the form of aperture as in *M. dilatatus*. It may be looked upon indeed as a very well-marked species and different from all its North American congeners" (Ancey, 1885).

Several Oklahoma specimens that I examined exceeded by 0.5 mm those collected by A. O. Crandall in Missouri (Sampson, 1885) and are generally larger than Ancey's types. Furthermore, Pilsbry (1916) noted that this species was larger than Sampson (1885) indicated.

ECOLOGY/BIOLOGY: Even less ecological data is known for *M. sampsoni* than for *M. dilatatus*. Branson (1961) did find that, in Oklahoma, *M. sampsoni* preferred quiet, relatively shallow stagnant pools or backwaters occurring primarily on submerged vegetation.

Baker (1945) observed that 50 percent of the specimens from the Dallas County lake were affected by cercariae. In another population from the Merrimac River, Missouri, nearly all specimens examined contained trematode cercariae and many were "badly diseased." It is well known that gastropod shells undergo anomolous development when heavily parasitized.

DISCUSSION: My new localities demonstrate that both *M.*

dilatatus and *M. sampsoni* occur over a fairly large state area. The shells are quite distinctive (less than 3 mm in diameter) with the carination on the body whorl. In *M. dilatatus*, the keel occurs along the summit of the body whorl, whereas in *M. sampsoni* the keel (more often just a slight ridge) is lower on the body. Except for size, both species closely resemble *Gyraulus parvus* with their rapidly expanding body whorl.

I found, unlike Branson (1961), that *M. sampsoni* was always associated with clear water, in ponds with a sandy, or at least, a firm bottom. This is also the first report of finding *M. dilatatus* and *M. sampsoni* sympatrically.

Genus *Planorbula* Haldeman, 1842

Planorbula armigera (Say), (Fig. 13a).

Planorbis armigerus, Say, 1821, 1818, J. Acad. Natur. Sci. Phil., 2:164 (Binney reprint, 1858:63).

Planorbula armigera (Say), F. C. Baker, 1928, Wisc. Acad. Sci., Arts and Letters, pt. 1.

(?) *Planorbula* (*Segmentina*) *crassilabris* (Walker, 1907), Clarke, 1973, Malacologia, 13(1-2):418.

TYPE LOCALITY: "Inhabits Upper Mis. (souri) River" (Say, 1818).

GENERAL DISTRIBUTION: New Brunswick west to southeastern Ontario, northwest to the McKenzie River system (Clarke, 1973, includes *P. jenksii*); "New England west to Nebraska, south to Georgia and Louisiana, north to Great Slave Lake" (Baker, 1928).

TEXAS DISTRIBUTION: Fossil County Records: DELTA, CLAY, WICHITA, DALLAS, POLK and PRESIDIO (DMNH Coll.); WARD and REEVES (Leonard and Frye, 1962 as P. armigera and P. crassilabris); PRESIDIO and SUTTON (as P. crassilabris, Cheatum et. al., 1972); DALLAS, CLAY and DELTA (Cheatum and Allen, 1965); KAUFMAN, DELTA and DALLAS (Willimon, 1972).

Singley (1893) cited several Recent localities under Segmentina armigera. Strecker (1935) apparently listed Singley's localities under Segmentina obstructa. Singley stated that S. armigera was always associated with Planorbis liebmanni (Biomphalaria obstructa). I am of the opinion that he was identifying young B. obstructa (also toothed as P. armigera).

DESCRIPTION: Shell small (about 6.0 mm in diameter), planorbiform, dextral, pale brown to blackish, and with fine lines of growth and partly obscure, microscopic spiral striae; whorls about 5 in adults, rounded, but with an obscure carina above and below; spire markedly concave; umbilicus wide, deep, funnel shaped and exhibiting all whorls; last part of body whorl expanded and abruptly deflected downward; lip thin to slightly thickened; aperture ovate, prosocline and at an angle of about 45° with respect to the umbilical axis. Within the aperture of most specimens, about 0.25 whorls back, are 6 unequal tooth-like processes. One, on the parietal wall, is broad and much larger than the others.

These processes are visible under magnification in apertural view or, if the shell is clean, by light transmitted through the shell wall. Rarely, 2 sets of denticles are present, 1 behind the other (condensed from Miller, 1968 and Clarke, 1973).

ECOLOGY/BIOLOGY: Baker (1928) cited _P. armigera_ as occurring characteristically in "Swales and (in) small and stagnant bodies of water." Clarke (1973) found a few specimens at a large number of localities but it was abundant only in muskeg, in heavily sheltered coves of Seven Lake and in one sluggish stream full of vegetation.

The anatomy of _P. armigera_ was described by Baker (1928). The animal blackish and very active, and the tentacles are long and filiform and the shell is carried at an angle.

Taylor (1966) stated that _P. campestris_ (Dawson, 1875) is the only living _Planorbula_ west of the Rocky Mountains. Much of the northeastern and eastern United States _Planorbula_ are listed as _P. jenksii_ (Carpenter, 1871). Clarke (1973) presented a discussion of the problematic _P. armigera_ - _crassilabris_ - _jenksii_ complex.

DISCUSSION: _Planorbula armigera_ is another of the more northern, cooler-climate freshwater gastropods now extirpated from Texas. It closely resembles _Gyraulus parvus_, thus, the inner aperture of any fossil _Gyraulus_-like series should be examined for the internal lamellae characteristic of _P. armigera_. Quite possibly, Baker's (1928) Louisiana and Georgia identifications were based upon immature *Biomphalaria obstructa* shells as Singley (1893) most assuredly did in recording live *P. armigera* for Texas. Singley's collection is lost, and I was not able to examine his material. Until live material is obtained, I am considering *P. armigera* as an extinct species for the State.

Genus *Promenetus* F. C. Baker, 1935

Promenetus exacuous (Say), (Fig. 15a).

Planorbis exacuous Say, 1821, J. Acad. Natur. Sci. Phil., 2:168 (Binney reprint, 1858:64).

Promenetus exacuous (Say), F. C. Baker, 1935, Nautilus, 49:48.

TYPE LOCALITY: "Inhabits Lake Champlain" (Say, 1821).

GENERAL DISTRIBUTION: "United States east of the Rocky Mountains, north to Alaska and the Mackenzie River, south to New Mexico (Baker, 1928). Taylor (1975, in litt.). by synonomizing *P. coloradensis* extended the range to include most of western North American south to northeastern California to northern New Mexico.

TEXAS DISTRIBUTION: Fossil County Records: SWISHER (Cummins, Singley in Strecker, 1935); CALLAHAN (Cheatum et. al., 1972, Brazos River drift); KAUFMAN (Thurmond (1967), in Willimon (1972); EDWARDS, HARDEMAN, KNOX, WICHITA, DONLEY and BRISCOE (DMNH Coll.).

DESCRIPTION: "Shell small (maximum diameter 5 mm), flattened, planorbiform, ultradextral, pale brown to dark brown, and with the outer edge of the body whorl acutely angled. In many specimens, this angle is sharply keeled; in others the keel is present but rounded. Keel close to or below the centre of the body whorl. Whorls about 4 in adults and rapidly increasing in size. Spire low-convex or flattened. Sculpture of fine lines of growth (which may be slightly elevated) and fine spiral lines. Umbilicus narrow, deep, and exhibiting all the whorls. Aperture prosocline, obtusely triangular or ovate, and expanded near the periphery. Outer lip thin to slightly thickened. Inner lip with a thin callus" (Clarke, 1973).

ECOLOGY/BIOLOGY: Mozley (1938) cited the habitat preference of _P. exacuous_ as "temporary ponds, small lakes, marshes and the bottom of large lakes." Clarke (1973) found it in such areas across Canada. The bottom types were diverse, but most were of mud, and in all the lotic habitats, the current was slow. Vegetation was moderately thick to dense at all sites. In Meade County, Kansas, _P. exacuous_ occurred in shallow perennial or sub-permanent, quiet-water bodies, such as ponds, ox-bow lakes, marshes, sloughs or backwaters of streams. In these habitats, it was usually found on submerged vegetation (Hibbard and Taylor, 1960). Baker (1928, 1945) described the anatomy of _P. exacuous_.

DISCUSSION: Apparently, _Promenetus exacuous_ and the closely related _P. kansasensis_ disappeared from Texas waters by the post-Wisconsin drying trend. Hibbard and Taylor (1960) cited _P. kansasensis_ as occurring in High Plains deposits dating from Pliocene to Late Pleistocene. They then stated that P. exacuous occurred as a fossil from the Late Pleistocene and is the only Recent species, and that it evolved from P. kansasensis.

Promenetus exacuous is easily identified by its smallness, the extremely flattened (lenticular-shaped) shell and by the extremely strong "carination" going to the lip, making it appear v-shaped peripherally. P. kansasensis is slightly larger and has a strong sculpture of riblets rather than simple growth lines. Otherwise, the two species are extremely similar. Branson (1961) cited P. exacuous (based on bleached shells) as living at two Oklahoma localities.

Promenetus kansasensis (F. C. Baker), (Fig. 15b).

Menetus kansasensis F. C. Baker, 1938, Nautilus, 51(4):129.

Promentus kansasensis (Baker), Taylor, 1956, Wyom. Geol. Assoc. Guidebook, No. 111:123-125.

Promenetus pearlettei (Leonard, 1948), Taylor, 1956, Wyom. Geol. Assoc. Guidebook, No. 111:123, fig. 4.

Promenetus exacuous kansasensis (Leonard), Miller, 1966, Malacologia, 4(1):173-260.

TYPE LOCALITY: Upper Pliocene deposit (Rexroad Local Fauna), Kansas. Holotype - No. P6778, Mus. Natur. Hist. Univ. Ill.

GENERAL DISTRIBUTION: Fossil Only. Pliocene in southern Idaho, northern Texas, and southwestern Kansas; early Pleistocene in Nebraska and Kansas; middle Pleistocene in the Great Plains, from Iowa to Texas, late Pleistocene in southwestern Kansas (Hibbard and Taylor, 1960).

TEXAS DISTRIBUTION: Fossil County Records: KAUFMAN (Thurmond, 1967); DALLAS (Willimon, 1972); DONLEY (DMNH Coll.); KNOX (Hibbard and Dalquest, 1966). No Recent records.

DESCRIPTION: Shell lenticular as in M. exacuous (Say). Periphery carinate with a "pinched" border. Whorls 3.5. Umbilicus wide, shallow, the whorls rounding into it. Sculpture, consisting of more or less regularly spaced ribs extending from the suture in a backward curve over the periphery to the base and into the umbilicus. The ribs may be equally spaced, with strong growth lines between or they may be so crowded together as to form a continuous series of ribs without intervening spaces. The surface above and below is covered with strong spiral lines. Baker (1938) listed the holotype measurements: diameter 5.0 mm, height 1.0 mm.

ECOLOGY/BIOLOGY: "Presumably Promenetus kansasensis lived in situations similar to those in which its close relative, P. exacuous, lives today" (Hibbard and Taylor, 1960).

DISCUSSION: (See Promenetus exacuous). P. kansasensis has been referred to several times in the literature as a subspecies of P. exacuous. Hibbard and Taylor (1960) placed Promenetus pearlettei (Leonard, 1948) into synonomy with P. kansasensis stating, "The range of variation of the series from the Cudahy Fauna of Kansan age, from which A. B. Leonard described Menetus pearlettei, overlaps the older samples to such an extent that it cannot be consistently distinguished." After examining several specimen series from Texas deposits, I concur with their opinion. The major shell character used to separate P. pearlettei and P. kansasensis was the degree of cross-hatching in the body whorl which proved to be meaningless when large series were examined.

Promenetus umbilicatellus (Cockerell), (Fig. 14b).

Planorbis umbilicatus Taylor, 1885, J. Conch., 4:351, text figs., type locality: "Brandon, Birele, etc., Manitoba."

Planorbis umbilicatellus Cockerell, 1887, Conch. Exch., 2:68. New name for Planorbis umbilicatus Taylor, 1885, von Muller, 1774.

Promenetus umbilicatellus (Cockerell), F. C. Baker, 1935, Nautilus, 49:48.

(?) Planorbis (Gyraulus) carus (Pilsbry and Ferriss, 1906), Taylor, 1975 (in litt.).

Promenetus blancoensis Leonard, 1952, Hibbard and Taylor, 1960, Contrib. Mus. Paleon. Univ. Mich., 16:110.

TYPE LOCALITY: "Brandon, Birthle, etc., Manitoba" (Taylor, 1885).

GENERAL DISTRIBUTION: "Widespread in North America; Alaska, south to northeastern California, central Nevada, northern Utah and northern New Mexico" (Taylor, 1975, in litt.).

TEXAS DISTRIBUTION: Fossil County Records: WARD and PECOS

(Leonard and Frye, 1962); ECTOR (Wendorf, 1961); CLAY (Allen and Cheatum, 1961); HOWARD and UVALDE (Cheatum, et. al., 1972); MOTLEY (Quitaque Creek Local Fauna) and CLAY (Byers Local Fauna) (Cheatum and Allen, 1965); KNOX (Hibbard and Dalquest, 1966). Late Pliocene (Red Corral Local Fauna), OLDHAM (Hibbard and Taylor, 1960); HOWARD, MOTLEY, CLAY, HALL, WICHITA and BRISCOE (DMNH Coll.).

DESCRIPTION: "Shell small (maximum diameter 3 mm), depressed, planorbiform, dextral, pale yellowish to brownish, and with a glossy surface sculpture with fine collabral lines and fine revolving striae. Whorls about 4.25 in adults, regularly increasing in diameter except slightly expanded near the aperture. Spire flattened or with the first 2 whorls slightly depressed below successive whorls. Sutures deeply impressed. Base of body whorl flatly rounded. Umbilicus prominent, large, deep, and showing all whorls. Aperture rounded, sub-triangular. Outer lip narrow and parietal wall with thin callus" (Clarke, 1973). Long considered a species of the genus _Gyraulus_, Baker (1935) showed that it is anatomically related to _Promenetus_. He later detailed its anatomy (1945).

ECOLOGY/BIOLOGY: Literature citations concerning the habitat of _Promenetus umbilicatellus_ vary somewhat. Taylor (1975, in litt.) stated that it occurs in ponds, ditches and marshes that have seasonal water; Leonard and Frye (1962) explained that it lives in quiet waters, particularly where there is abundant aquatic vegetation; Mozley (1938) listed it as occurring only in temporary ponds and Clarke (1973) Canada, found it in a muddy, slow-moving creek with much tall grass in and near the water.

DISCUSSION: Judging from literature records of *P. umbilicatellus*, this species occurs in Texas only as a fossil. Being a more northerly distributed species (recorded alive only at two localities in Kansas (Leonard, 1959) and not at all in Oklahoma), this concept seems entirely plausible. However, Taylor (1975, in litt.), by including *P. carus* (Pilsbry and Ferriss, 1906) as a synonym of *P. umbilicatellus*, clouded the issue of whether *P. umbilicatellus* occurs only as a fossil in Texas.

According to Pilsbry and Ferriss (1906), *P. carus* (Fig. 13d), is a distinct species, occurring in the arid, extreme southwestern region of the state. The type locality is "Canyon of the Pecos River about a mile above the High Bridge, Val Verde County." They also collected specimens from "Sinking Springs" near San Marcos, Hays County; Guadalupe River, about four miles above New Braunfels, Comal County, Rio San Felipe and Devil's River (Val Verde County).

DESCRIPTION: "Shell discoidal, biconcave, the spiral on the left side slightly more sunken and narrower than on the right. Whorls 3-1/2, convex, the last round periphery and on both sides, curving more abruptly into the concavity on the left side. Sculpture of *close*, *very regular obliquely* radial, rounded striae separated by slightly narrower deep grooves. Pale brown in color. Aperture but slightly oblique, heart-shaped, peristome thin, acute, a trifle dilated at its insertions. Diameter 3.3 mm, altitude (thickness) 1 mm. This little *Planorbis* is very distinct by its beautiful sculpture, constant in numerous specimens from five rivers in central and western Texas. It is much more abundant in the Rio Grande drainage than in Hays and Comal counties. It is about the size of *G. parvus*, but the aperture is less oblique and the sculpture differs. It was found with *G. parvus* in Comal county and in the Pecos canyon" (Pilsbry and Ferriss, 1906).

DISCUSSION: I observed 3 (all drift specimens) lots of *P. carus* in the DMNH collection from Texas. In each series, a few specimens conformed to *P. carus*, but most were *P. umbilicatellus* or *Gyraulus parvus*. Bequaert and Miller (1973) stated that *P. carus* was "definitely Recent in Trans-Pecos and Central Texas." However, I feel that, based upon current information, that *P. carus* be considered a nomen dubium until live populations can be found and studied. I also disagree that it be considered a synonym of *P. umbilicatellus*. The distribution alone of the two "species" makes Taylor's opinion incompatible.

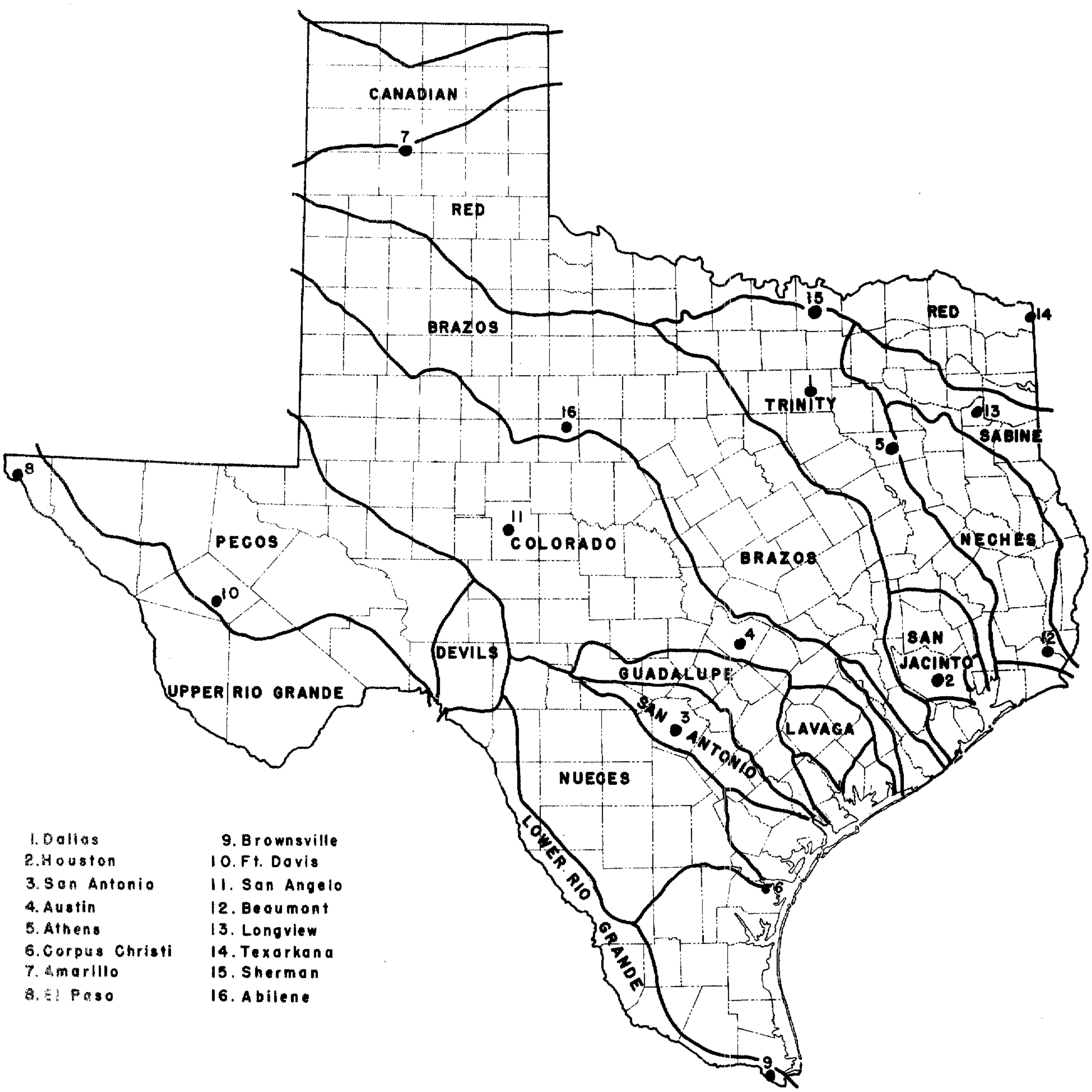
Summary of Texas Planorbidae

Thirteen planorbid genera, 39 species and subspecies have been recorded for Texas. Based on my own analysis, and that of other recent workers, I consider 9 genera and 19 species and subspecies valid for the State. Six occur only as fossils, Armiger crista, Gyraulus circumstriatus, Planorbula armigera, Promenetus exacuous, P. kansasensis and P. umbilicatellus.

With the exception of Promenetus carus (considered here a dubious species), no indigenous Texas planorbid species exist. Including all the fossil species, fourteen have northern affinities (Helisoma anceps, Micromenetus dilatatus, M. sampsoni and Gyraulus parvus), eight all extant, Neotropical in origin (Antillorbis aeruginosus, Biomphalaria obstructa, Drepanotrema cimex, D. kermatoides, Helisoma foveale, H. trivolvis lenta and H. t. intertextum) and Helisoma duryi is an introduced species from Florida. The origin of Promenetus kansasensis is unknown.

Figure 1

Major river drainages in Texas.



1. Dallas
2. Houston
3. San Antonio
4. Austin
5. Athens
6. Corpus Christi
7. Amarillo
8. El Paso
9. Brownsville
10. Ft. Davis
11. San Angelo
12. Beaumont
13. Longview
14. Texarkana
15. Sherman
16. Abilene

Figure 2

Biotic Provinces of Texas (Blair, 1950).

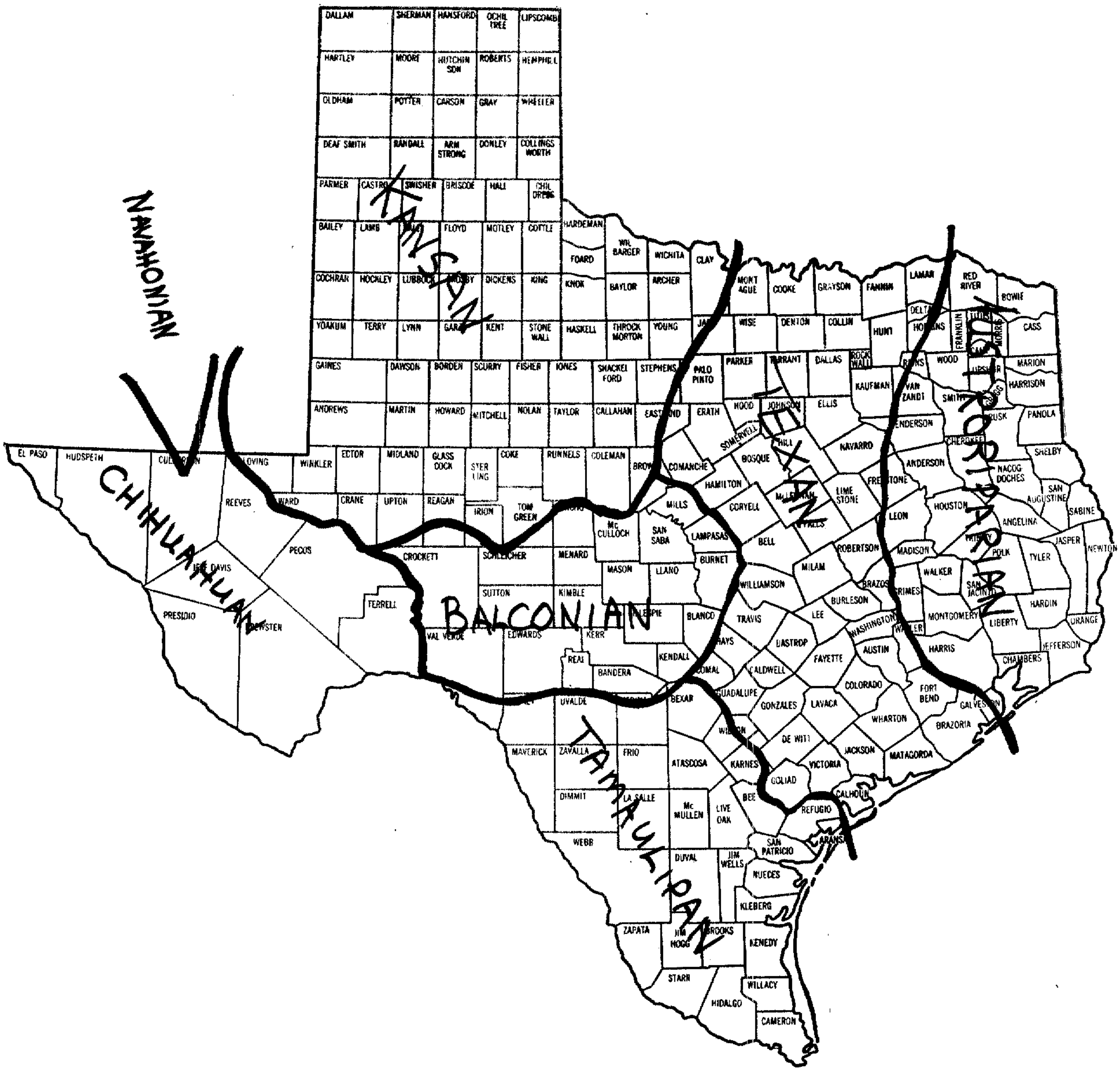

NAVAHONIAN
KANSAN
CHIHUAHUAN
BALCONIAN
TEXAN
AUSTRORIPARIAN
TAMAULIPAN

Figure 3

Family Assimineidae

a. *Assiminea succinea* x14. D. W. Collection, Texas coast.

b. *Assiminea taylor* x15. sp. nov.; Holotype, DMNH 1509.

Family Hydrobiidae

c. *Amnicola limosa* x8.2. ANSP 67405, Utah.

d. *A. limosa* x9.6. Fossil, DMNH 2041, Delta Co., Texas.

e. *Birgella subglobosa* x6.7. Redrawn from Baker, 1928.

f. *Cincinnatia comalensis* x11.0. Type; ANSP 91323, Comal Co., Texas.

g. *Cincinnatia cincinnatiensis* x8.1. ANSP 32335, Gillespie Co., Texas.

h. *Cincinnatia cincinnatiensis* (*integra*) x7.4.

i. *Pyrgophorus coronatus* (*spinosus*) x8.4. Cameron Co., Texas.

j. *Pyrgophorus coronatus* (*texana*) x8.9. Comal Co., Texas.

k-m. *Pyrgophorus coronatus* x6.0. Variations of spine formation.

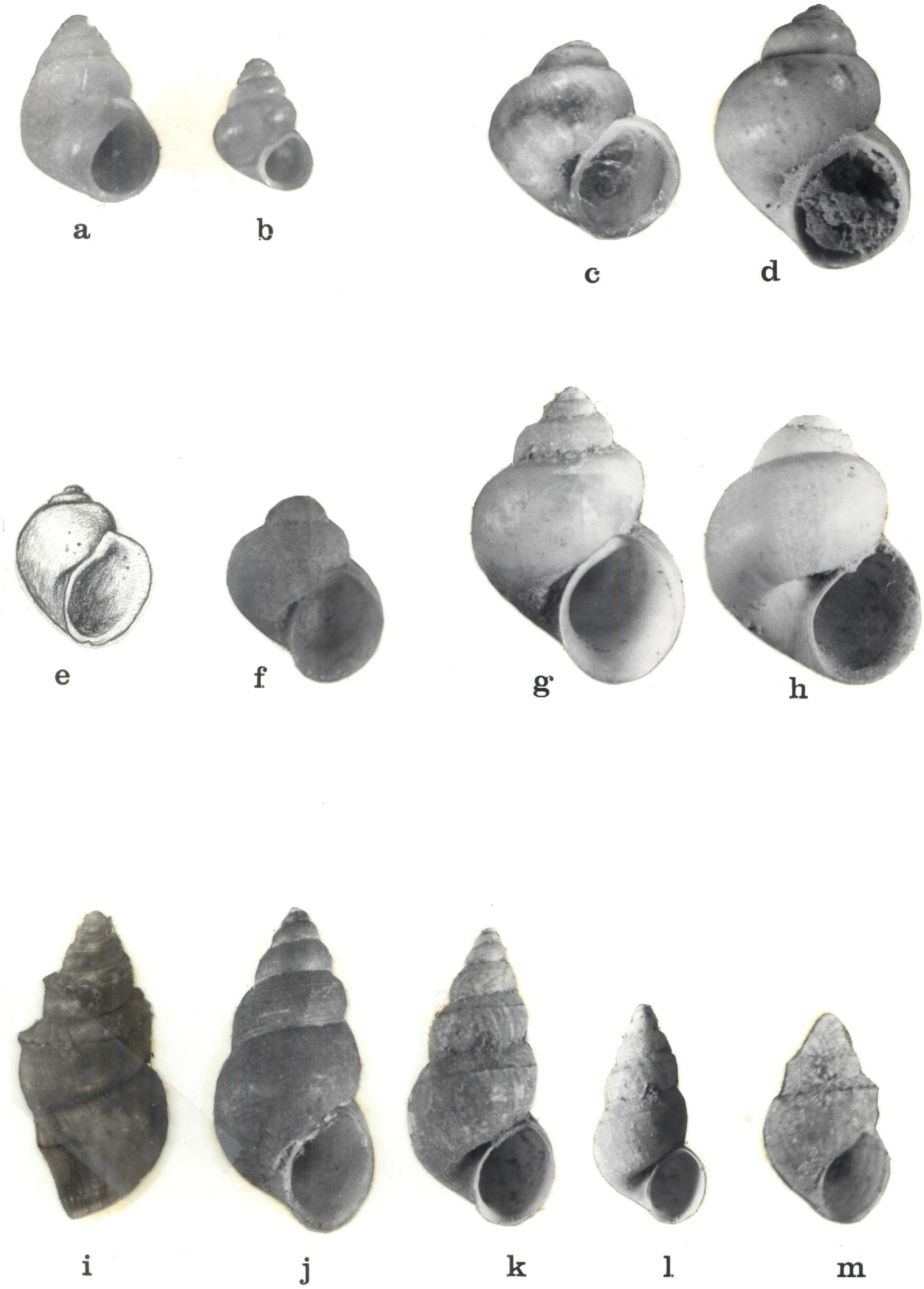

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Figure 4

Family Hydrobiidae (cont'd)

a. *Somatogyrus depressus* x6.6. Fossil, DMNH 1306, Delta Co., Texas.

b. *Tryonia cheatumi* x13.5. Topotype, DMNH 0263, Reeves Co., Texas.

c. *Fontelicella palomasensis* x12.0. ANSP 167050, Jeff Davis Co., Texas.

d. "*Amnicola*" *peracuta* x14.0. Variation in shell characters of Texas specimens labeled "*peracuta*."

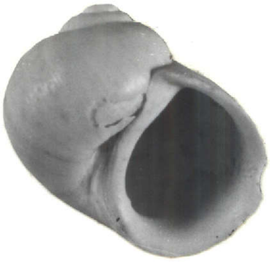
e. *Tryonia pecosensis* x8.7. Fossil, Terrel Co., Texas.

f. *Tryonia circumstriata* x13.3. Fossil, Terrell Co., Texas.

g. *Tryonia protea* x13.0. Fossil, DMNH 1442, California.

h. *Tryonia matheri* x17.6. sp. nov.; Holotype, DMNH 1510, Zavala Co., Texas.

i. *Pomatiopsis lapidaria* x5.7. Recent, DMNH 1329, Oklahoma.



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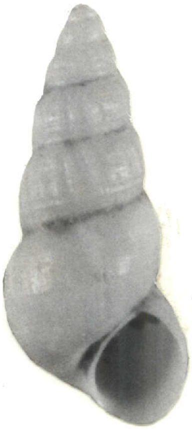

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Figure 5

Family Hydrobiidae (cont'd)

a. *Cochliopina riograndensis* x11.4. (banded form) Uvalde Co., Texas.

b. *Cochliopina riograndensis* x10.5. (non-banded form) Kinney Co., Texas.

c. *Cochliopina guatemalensis* x9.2. UMMZ 65481, Petén, Guatemala.

d. *Cochliopina texana* x18.7. Topotype. Reeves Co., Texas.

e. *Horatia micra* x43. Comal Co., Texas.

f. *Paludiscala* sp. x34.5. Bexar Co., Texas.

Family Orygoceratidae

g. *Orygoceras* sp. x16.6. Real Co., Texas.

Family Pilidae

h. *Pomacea paludosa* x.09. DMNH 1372, Harris Co., Texas.

Family Pleuroceridae

i. *Elimia comalensis* x2.9. (smooth form), Topotype, DMNH 0672, Comal Co., Texas.

j. *Elimia comalensis* x1.8. (channeled form), Topotype, DMNH 0675, Comal Co., Texas.

k. *Elimia comalensis* (fontinalis) x1.1. (dwarf form), Comal Co., Texas.

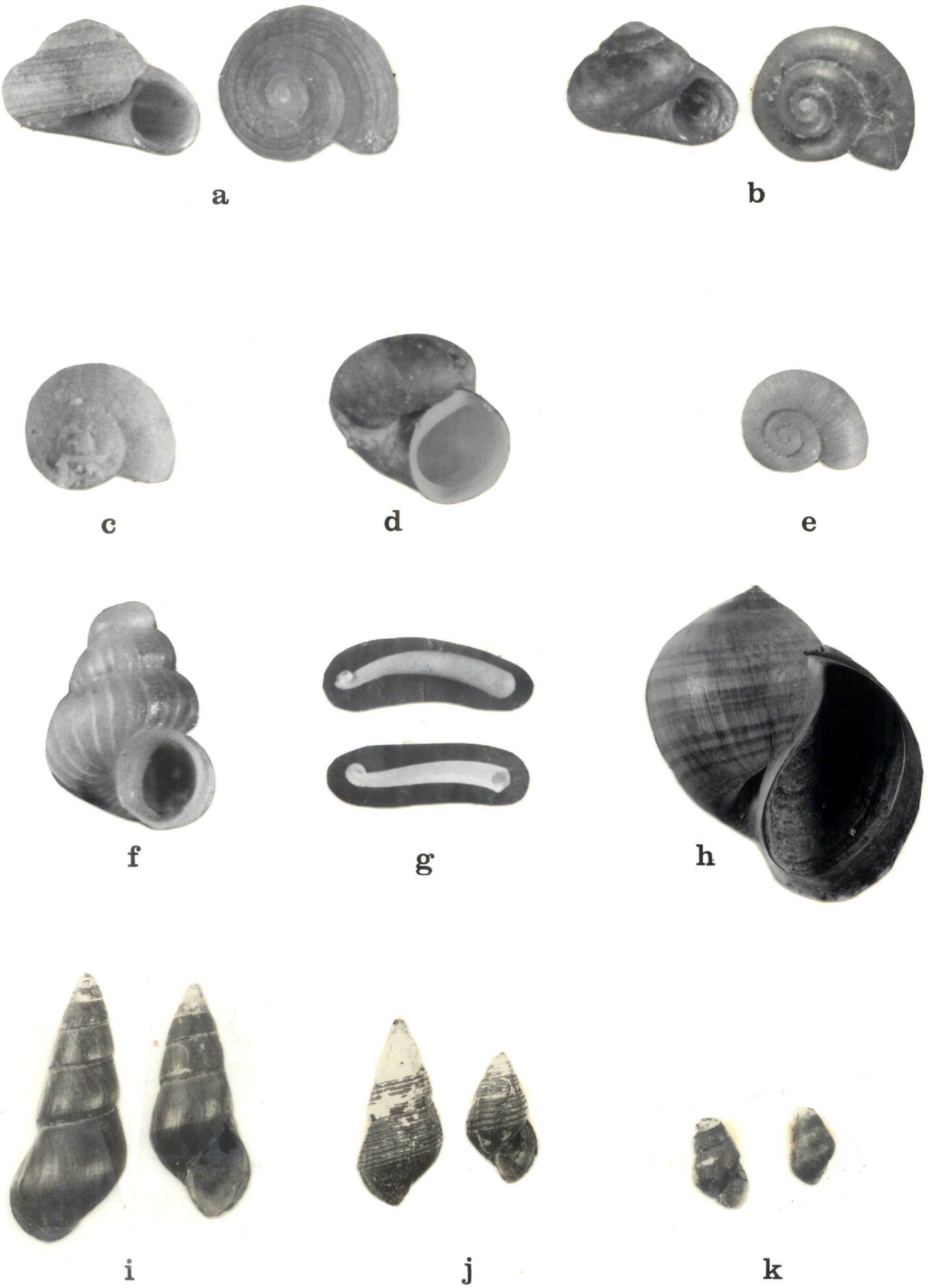
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Figure 6

Family Thiaridae

a. *Thiara tuberculata* x1.6. DMNH 1495, Comal Co., Texas

b. *Thiara granifera* x1.5. Comal Co., Texas.

Family Valvatidae

c. *Valvata tricarinata* x4.3 DMNH 1466, Iowa.

Family Viviparidae

d. *Campeloma rufum* x1.4. UMMZ 95792, Tennessee.

e. *Campeloma lewisii* x1.6. UMMZ 28757, Louisiana.

f. *Campeloma crassula* x1.5. DMNH 1070, Ohio.

g. *Viviparus subpurpureus tamaulipasensis* x1.6. Subsp. nov.; DMNH 1511; Holotype, Zavala Co., Texas.

h. *Viviparus georgianus* x1.4. (non-banded form), Florida.

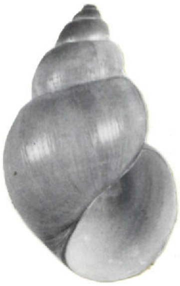
i. *Viviparus georgianus* x1.5. (banded form), UMMZ 22741, Georgia.

j. *Viviparus subpurpureus* x1.6. ANSP 27715, "Texas."

a

b

c



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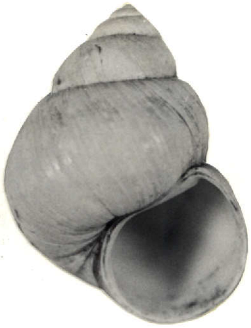

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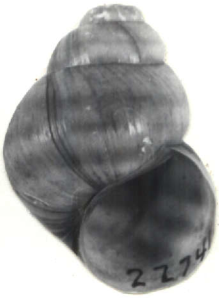

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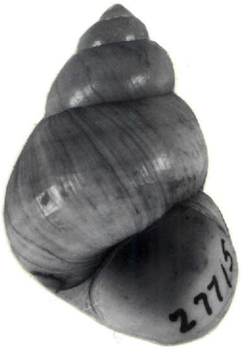

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Figure 7

Family Viviparidae (cont'd)

a. *Viviparus intertextus* x1.8. UMMZ 143786, Louisiana.

b. *Cipangopaludina japonica* x1.7. DMNH 0916, Japan.

c. *Cipangopaludina chinensis malleatus* x1.0. Dallas Co., Texas.

Family Ancylidae

d. *Laevapex diaphanus* x7.2. UMMZ 77797, Tennessee.

e. *Laevapex fuscus* x7.7. DMNH 1663, Dallas Co., Texas.

f. *Ferrissia parallela* x10.3. Fossil, DMNH 1177, Knox Co., Texas.

g. *Ferrissia californica* (*fragilis*) x9.4. ANSP 192683, Brooks Co., Texas.

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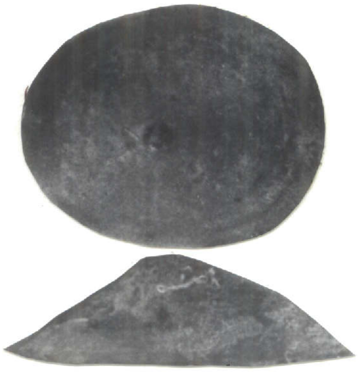

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Figure 8

Family Ancylidae (cont'd)

a. Ferrissia rivularis x8.1. DMNH 0452, Michigan.

b. Gundlachia radiata x6.4. DMNH 1110, Comal Co., Texas.

c. Ferrissia walkeri x7.0. ANSP 104526, Indiana.

Family Physidae

d. Physa gyrina x2.8. Fossil, DMNH 0070, Kansas.

e. Physa virgata x3.0. DMNH 0061, Callas Co., Texas.

f. Aplexa hypnorum x2.8. DMNH 1246, Michigan

g. Physa virgata x1.4. (shell variation).

a

b

c

d

e

f

g

Figure 9

Family Lymnaeidae

a. *Pseudosuccinea columella* x3.8. DMNH 1104, Hays Co., Texas.

b. *Lymnaea stagnalis appressa* x1.2. DMNH 1095, Michigan.

c. *Stagnicola cockerelli* x2.5. Fossil, DMNH 0816, Lubbock Co., Texas.

d. *Stagnicola caperata* x2.7. DMNH 1024, Illinois.

e. *Stagnicola exilis* x1.9. DMNH 1313, Michigan.

f. *Fossaria dalli* x12.7. Fossil, DMNH 0697, Edwards Co., Texas.

g. *Stagnicola reflexa* s.89. DMNH 1142, Michigan.

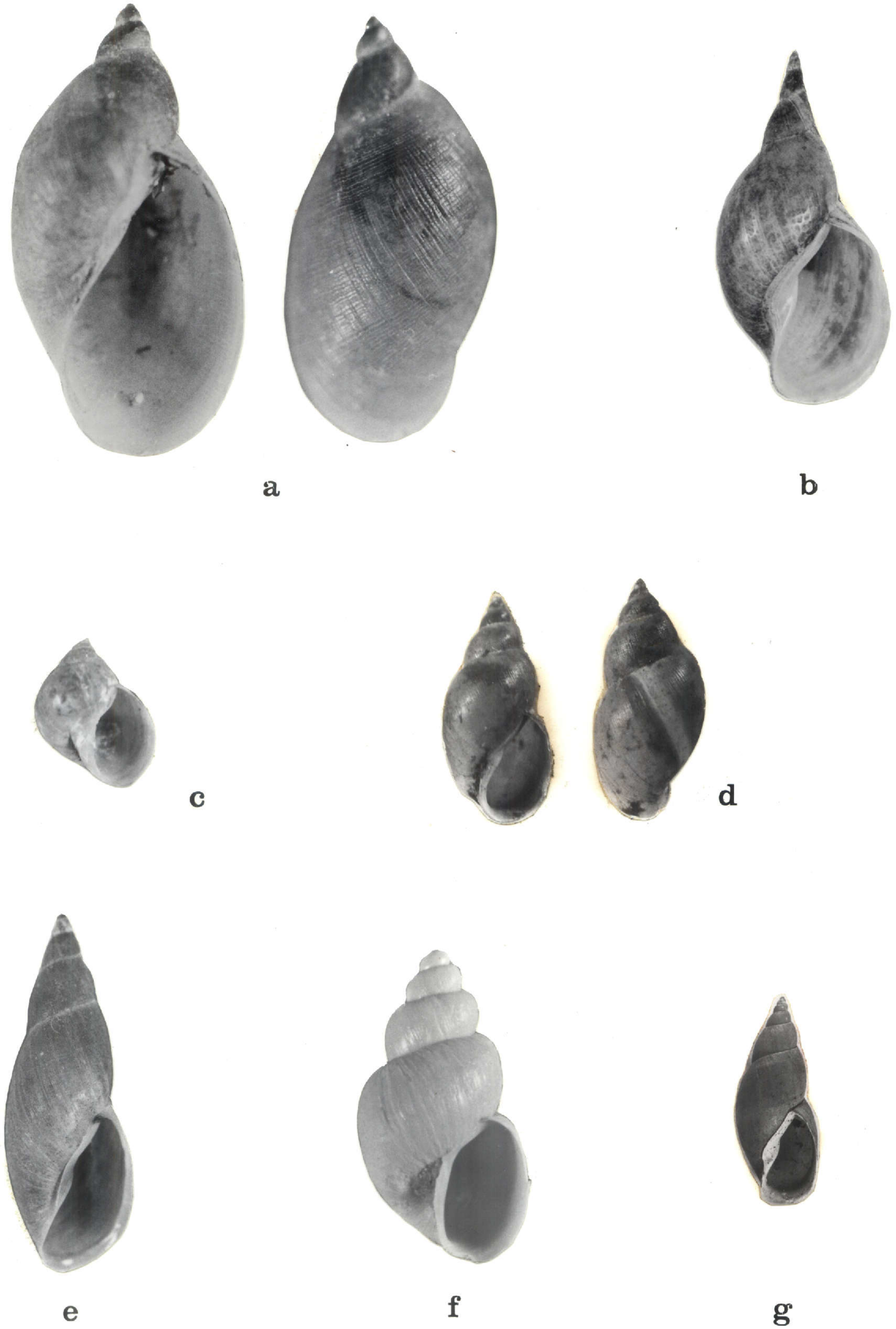
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Figure 10

Family Lymnaeidae (cont'd)

a. *Stagnicola elodes* (*palustris*) x3.4. Fossil, DMNH 0740, Foard Co., Texas.

b. *Stagnicola elodes* x6.3. Detail of the interrupted, closely spared growth lines.

c. *Stagnicola bulimoides techella* x4.4. Fossil, DMNH 1404, Dallas Co., Texas.

d. *Fossaria obrussa* x4.6. Fossil, DMNH 0368, Foard Co., Texas.

a

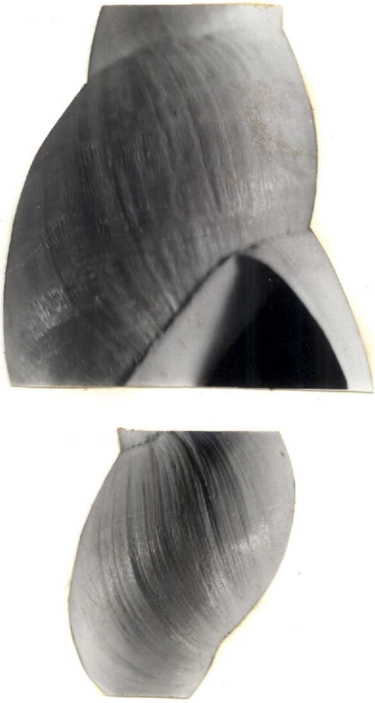

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Figure 11

Family Lymnaeidae (cont'd)

Columellar differences between Texas species

a. *Stagnicola caperata*.

b. *Stagnicola exilis*.

c. *Lymnaea stagnalis appressa*.

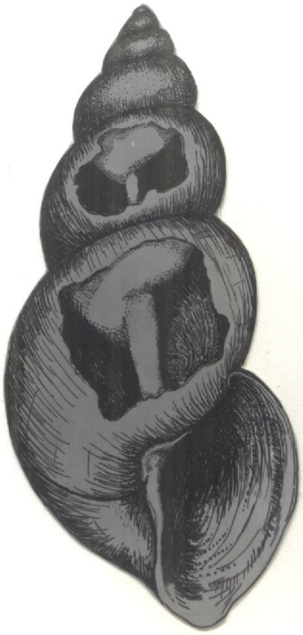
d. *Stagnicola elodes*.

e. *Stagnicola bulimoides techella*.

f. *Fossaria obrussa*.

g. *Fossaria dalli*.

h. *Stagnicola reflexa*.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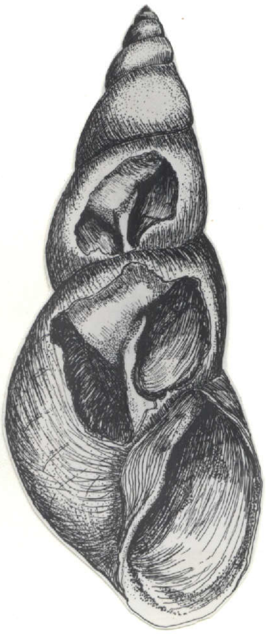
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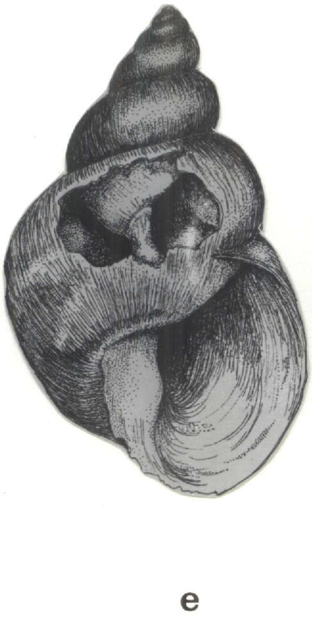
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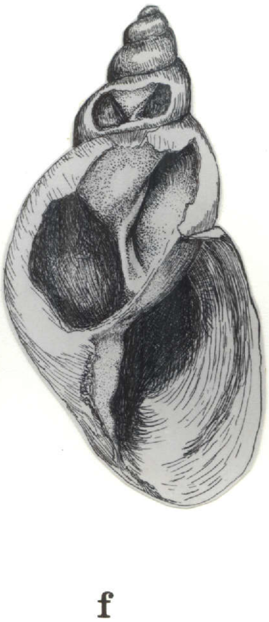
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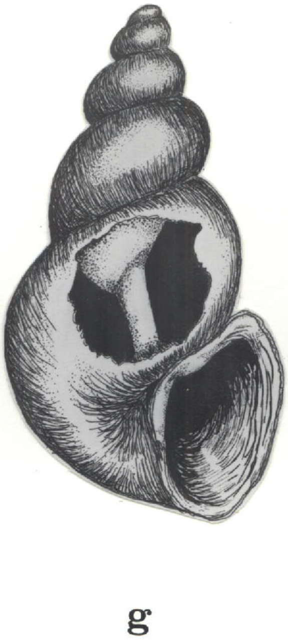
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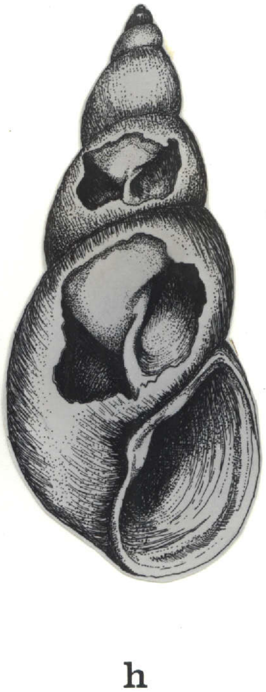

h

Figure 12

Family Planorbidae

a. *Helisoma duryi* x2.3. DMNH 2791, Harris Co., Texas.

b. *Helisoma trivolvis lenta* x1.7. DMNH 0788, Dallas Co., Texas.

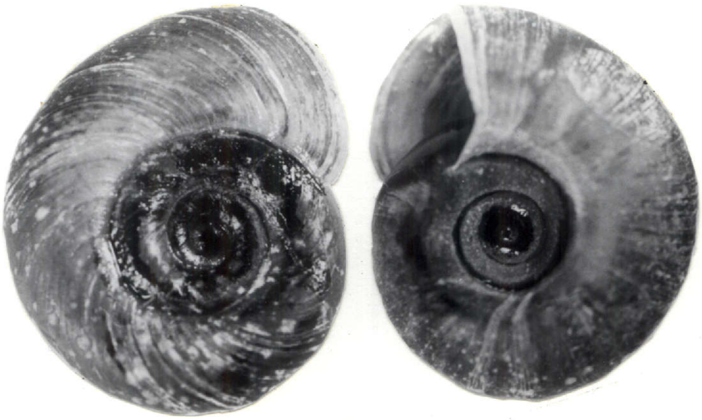
c. *Helisoma anceps* x1.8. Fossil, DMNH 0930, Foard Co., Texas.

d. *Helisoma foveale* x2.0. DMNH 0543, Jeff Davis Co., Texas.

e. *Helisoma foveale* (*tenue*) s1.5. DMNH 0529, Frio Co., Texas.

f-g. *Antillorbis aeruginosus* (*sonorensis*) s9.5. D. W. Taylor Collection, Arizona.

h-i. *Drepanotrema cimex* x6.3. UMMZ 156463, Brazil.



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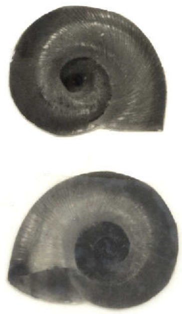

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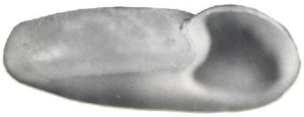

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i

Figure 13

Family Planorbidae (cont'd)

a. *Planorbula armigera* x14.6. DMNH 0617, Michigan (3 views).

b. *Armiger crista* x17.0. D. W. Taylor Collection, California (3 views).

c. *Gyraulus parvus* x8.1 DMNH 1013, New York (3 views).

d. *Promenetus carus* x8.4. Fossil, DMNH 1139, Delta Co., Texas (3 views).

a

b

c

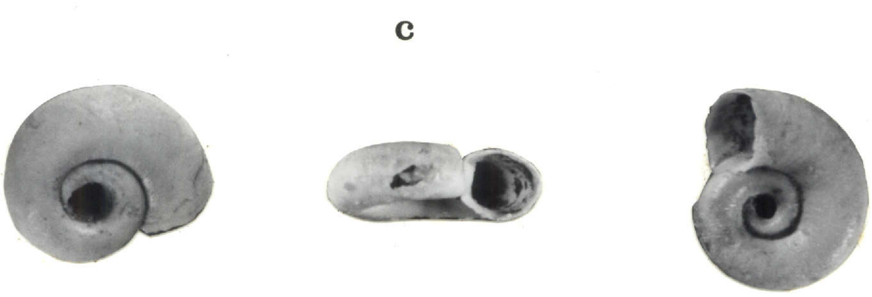

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Figure 14

Family Planorbidae (cont'd)

a. Gyraulus circumstriata x10.6. Fossil, DMNH 0486, New Mexico.

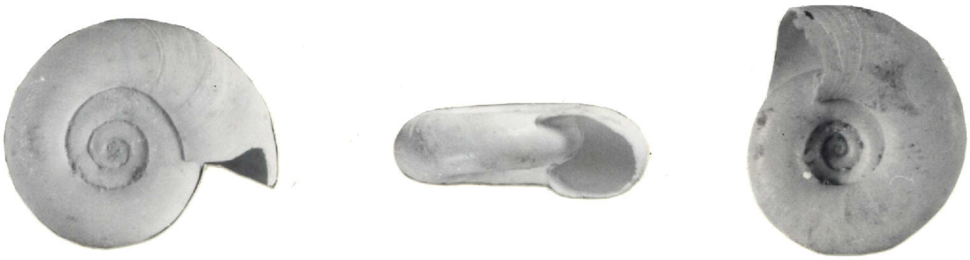
b. Promenetus umbilicatellus x12.0. Fossil, DMNH 0281, Foard Co., Texas.

c. Micromenetus dilatatus x9.3. DMNH 1032, Bowie Co., Texas.

d. Drepanotrema kermatoides x3.3. DMNH 773, San Patricio Co., Texas.

e. Biomphalaria obstructa x2.7. DMNH 0833, Comal Co., Texas.

a



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e

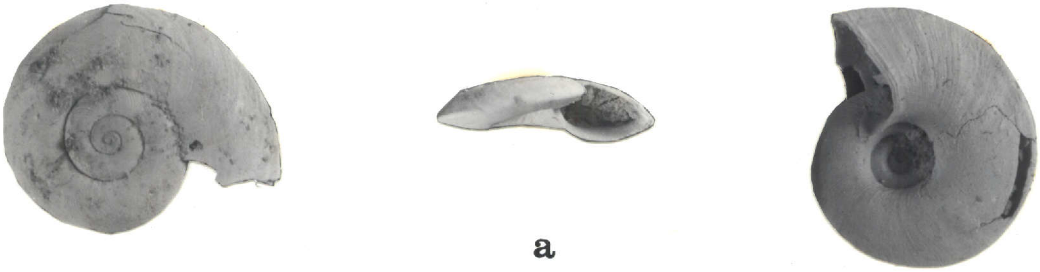
Figure 15

Family Planorbidae (cont'd)

a. Promenetus exacuous x12.6. Fossil, DMNH 1277, Wichita Co., Texas.

b. Promenetus kansasensis x18.1. Fossil, UMMZ 182970, Lubbock Co., Texas.

c. Micromenetus sampsoni x5.5. DMNH 1044, Michigan.



a

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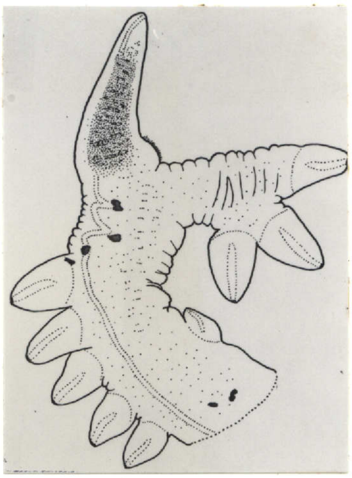
Figure 16

a-e. External variation in the penial complex of *Pyrgophorus coronatus* (Hydrobiidae). x50.0.

f. Dorsal view of female *Pyrgophorus coronatus*. x25.0. Five fecal pellets appear in the lower intestine.

a

b



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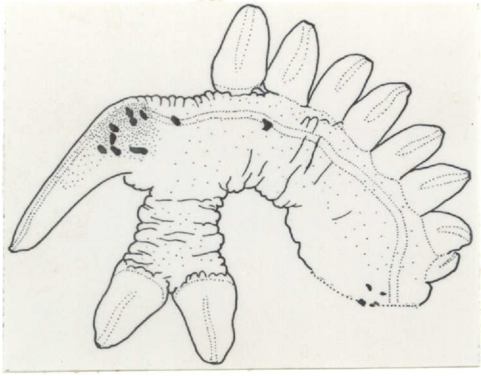

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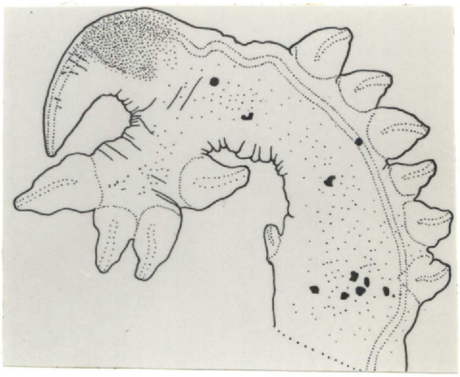

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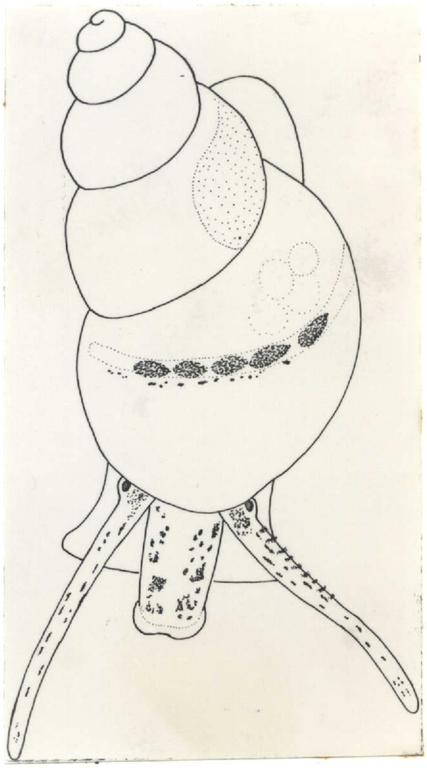


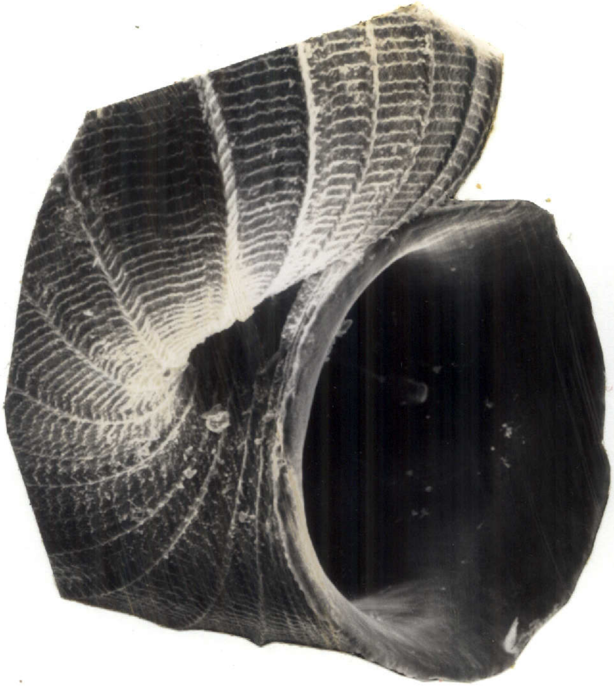
f

Figure 17

a. Paludiscala sp. x150. Aperture view; SEM, 15KV.

b. Paludiscala sp. x70. Protoconch showing early reticulation; SEM, 10KV.

c. Paludiscala sp. x750. Body whorl showing radial striae crossing over the transverse ribs; SEM, 15KV.



a

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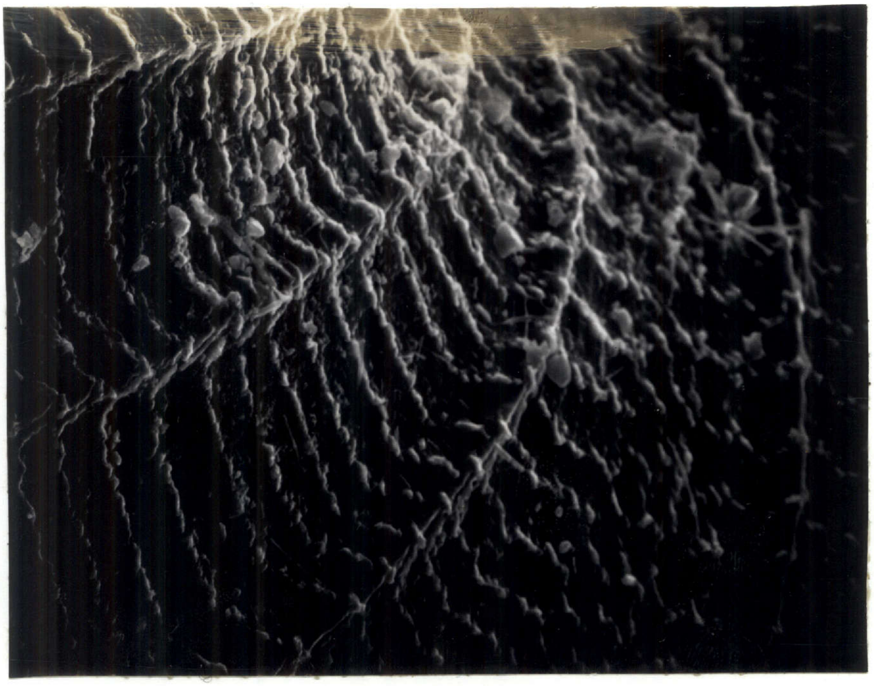

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