

PALEOECOLOGICAL ASPECTS OF A LATE WISCONSINAN AQUATIC MOLLUSK ASSEMBLAGE ASSOCIATED WITH MASTODON BONE RECOVERED FROM THE NORTH FORK OF WARD CREEK, BATON ROUGE, LOUISIANA

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I. ABSTRACT

A well-preserved freshwater molluscan assemblage is documented and illustrated. The malocofauna was collected from sediment samples closely associated with mastodon ulna fragments recovered from the base of a stream-cut bank in Baton Rouge, Louisiana in 1991. Mollusks and mastodon bone were deposited in a clay sediment varying to silty clay loam, dated 21,220 ± 360 yr B.P. The mollusk assemblage is indicative of a perennial, well-vegetated, quiet, shallow water environment. Mollusks differ markedly from typical Peoria Loess mollusks. It is suggested that the clay/silty clay loam containing fossil mollusk shell and mastodon bone correlates with properties of basal zone loess reported by Miller and others (1985) as forming a transition zone between the Prairie Terrace and initial late Wisconsinan loess. Shell dates, soil traits, mollusk species,

and paleoecology suggest that the excavation unit yielding a fossil mastodon ulna is part of a late Pleistocene swamp subsurface where Prairie Terrace clay combined with silts derived from reworked eolian loess as well as from probable glacial silt depositions. The fossil mollusk assemblage may be indicative of basal mixed zones in other localities.

II. INTRODUCTION

Molluscan macrofossils and radiocarbon dates from the base of an exposure on the North Fork of Ward Creek, within the city limits of Baton Rouge, East Baton Rouge Parish, Louisiana, provide information on the late Wisconsinan environment in southeastern Louisiana. The site is located in NW 1/4 Section 39, Township 7S, Range 1E, at an approximate position of 30 deg. 24.9 min. N. Latitude and 91 deg. 5.5 min. W Longitude. The North Fork of Ward Creek is tributary to the Amite River (Fig. 1), which discharges into Lake Pontchartrain. However, during the late Wisconsinan, the area presently occupied by Ward Creek was incorporated within the flood-

Key Words: Aquatic Gastropods, Late Pleistocene, Soil Geochronology, Basal Peoria Loess, Mastodon Preservation

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plain of the Mississippi River (Sibley, 1972), and the Amite River was part of an ancestral river basin, which drained into the Gulf of Mexico (Autin, 1993). Ward Creek empties into Bayou Manchac (Fig. 1), which has a history of flowing alternatively west into the Mississippi River or east into the Amite River. In 1814 Andrew Jackson dammed the entrance of Bayou Manchac into the Mississippi River for strategic purposes (Sibley, 1972).

As described by Saucier (1991), during the glacial maximum, sea-level in the Gulf of Mexico was lowered about 100 meters. The area of Baton Rouge probably represents the farthest extent upvalley of direct influence of this sea-level fall. The Baton Rouge fault, which was active in the Pleistocene, is part of an east-west trending hinge line separating an area of uplift to the north from an area of active subsidence and downwarping to the south. Saucier (1991) further states that the Lower Mississippi Valley during the glacial maximum of the late Wisconsinan was characterized by extensive systems of braided streams depositing massive amounts of glacial outwash. As glaciation waned, braided stream patterns changed to meandering stream patterns, and slow, vertical accretion occurred in interbasin and backswamp areas. Transformation to a meandering regime occurred about 12,000 B.P. at the latitude of Baton Rouge. During times of glacial waning, loess was deposited in upland regions. Loess represents silt deflated from braided stream deposits. The amount of loess deposited was enormous. For instance, Peoria Loess has a maximum thickness of 27 meters in the Natchez/Vicksburg area. This wind-blown sediment in the uplands provided a source for reworked loess in lowlands. In the interglacial preceding the glacial maximum, sediments are associated with the Prairie Complex. Saucier (1991) defines the Prairie Terrace as the youngest of four major Pleistocene interglacial fluvial morphostratigraphic units. Sedimentary sequences of the Prairie Terrace consist mostly of clay, silt, and sand. Massive backswamp-clay units up to 30 meters thick are known.

Pollen analysis by Jackson and Givens (1994) suggests that during the period of late Wisconsinan ice advance (22,000-17,000 yr B.P.), the uplands in the Tunica

Hills north of Baton Rouge, in the region encompassing Bayou Sara (Fig. 1), were dominated by spruce (*Picea* sp.) forests with some oak (*Quercus* sp.) admixture. Spruce forests were similarly abundant in the central Mississippi Valley during this time period. Species poor pine forests were dominant in northwest Florida from 29,000 to 14,000 yr B.P., at which time spruce had a brief period of dominance (Watt *et al.*, 1992). Presence of pine or mixed pine/hardwood forests has been suggested for several regions of the north Gulf Coastal Plain during the glacial maximum (Delcourt and Delcourt, 1977, 1983; Watts, 1970).

At the excavation site in Baton Rouge, a lowland swamp environment is indicated by the molluscan assemblage, which includes approximately 18 in-place species. Presently, these gastropod and pelecypod species are widespread in temperate regions of North America. The macrofossils retrieved from Ward Creek excavation units consist largely of mollusk shells (chiefly freshwater gastropods and clams) and mastodon bone fragments. In addition, there are two minute bone fragments of questionable origin, fine plant residue in the lower unit, and numerous plant macrofossils in the upper unit.

III. METHODS AND MATERIALS

Mastodon bone was recovered from a 70 cm x 40 cm x 25 cm area of blue/gray clay-like sediment drying to a light tan near low water level of the North Fork of Ward Creek (Fig. 2). Sediment samples were obtained from bone matrices as well as directly above and below the fossil bone and from various positions along the exposed length of a 2 meter excavation site. Additional samples were obtained in 1995 from both the upper unit and lower unit, at locations 20 to 30 cm directly behind the previously excavated bone and from the downstream boundary. The excavation site included two units (Fig. 3), the lower depositional unit being a fossiliferous blue-gray clay/silty clay loam and the upper depositional unit being a dark brown organic rich sandy clay/loam (Fig. 3). Sediment samples were disaggregated in tap water and screened for organic/inorganic matter using a screen with 2.0 mm x 2.5

mm openings. Screened concentrate was dried at low heat to preserve the samples for future reference. Material recovered within each sample was sorted and identified. Shell recovered was separated by its condition (whole or broken). Whole shells were identified by species and enumer-

ated. Broken shell matter from those fossil-yielding samples which indicated absence of intrusive material was sent for ¹⁴C radiocarbon dating analysis (based on carbon dioxide extracted from the shell).

Four screened 1991 samples and five un-screened 1995 samples were subjected to

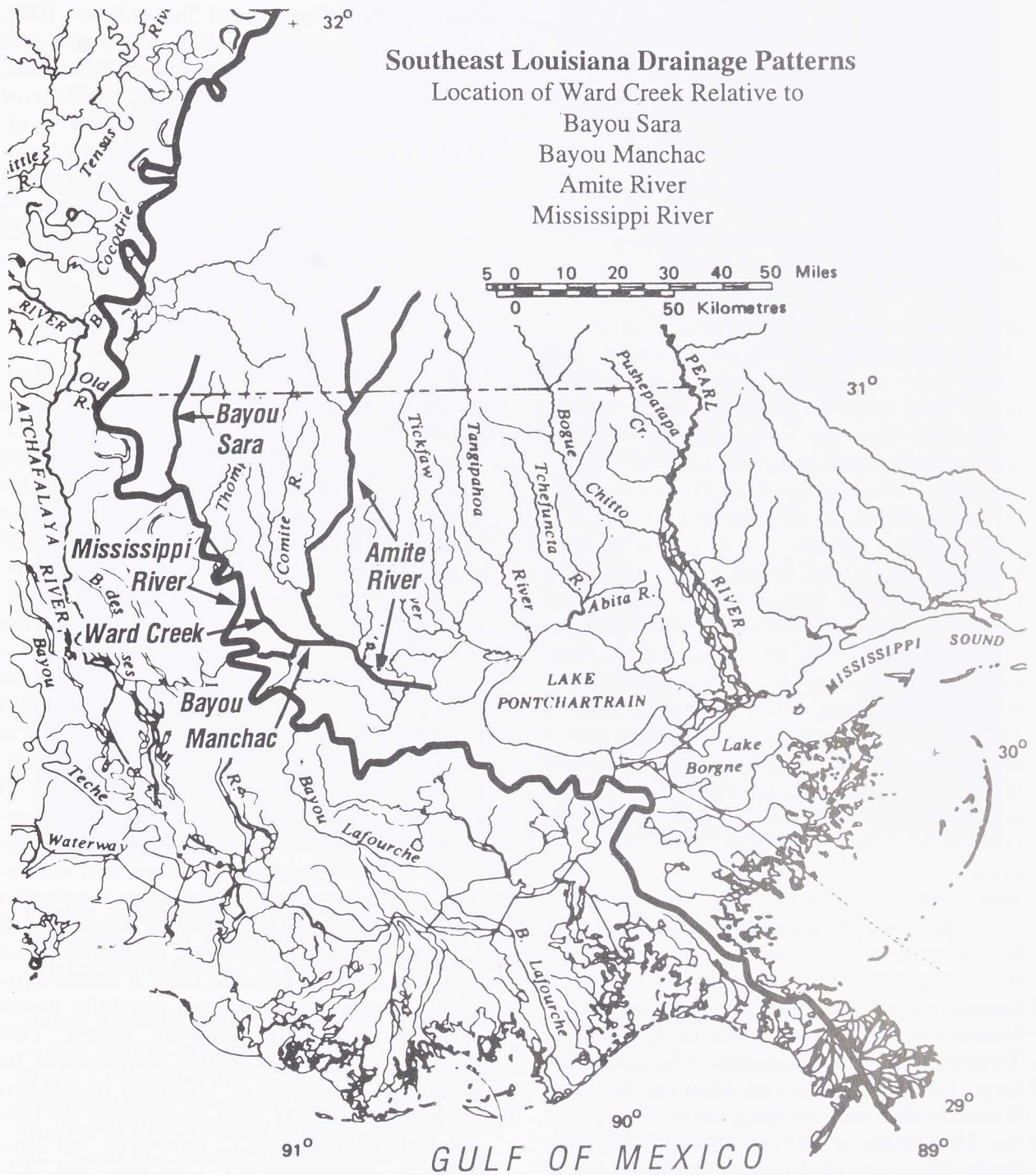


Figure 1. Location of Ward Creek relative to other southeastern Louisiana drainage systems, especially Bayou Sara, Bayou Manchac, Amite River, and Mississippi River.

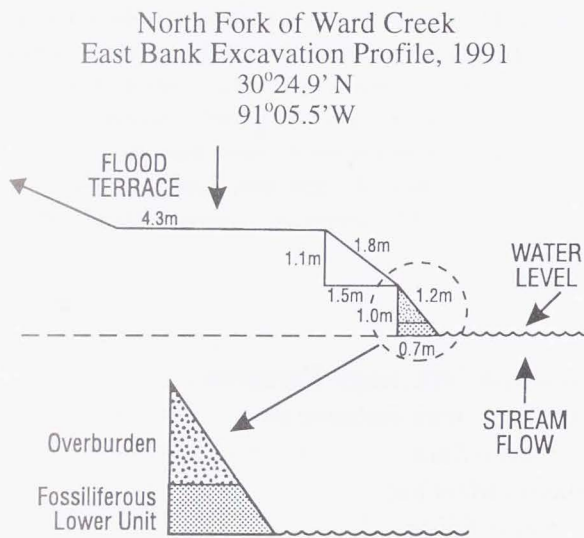


Figure 2. Diagram of the excavation profile at North Fork of Ward Creek.

granulometric analysis. These samples included six from the fossil-yielding unit, and three from the upper unit. A limited attempt was made to isolate pollen from six 1995 fossil-yielding unit samples using a scanning electron microscope and following procedures outlined by Traverse (1988) for retrieving fossil palynomorphs.

The bone matter was initially dry brushed with a soft brush and rinsed with tap water. Bone fragments were scanned under a microscope to confirm their osseous nature. A >400 gram sample of representative smaller bone fragments was submitted to Beta Analytic Inc. of Miami, Florida for conventional ^{14}C radiocarbon analysis of bone collagen. A small sample of what appeared to be carbonized bone was submitted to Beta Analytic Inc. to ascertain its potential for dating by ^{14}C accelerated mass spectrometry (AMS) (see Stafford, 1988 or Stafford, 1990).

Large bone fragments were identified by reference to literature on mastodon bone (especially Olsen, 1979) and by use of comparative collections at Louisiana State University Museum of Natural Science, Tulane University Museum of Natural History, Dallas Museum of Natural History, Houston Museum of Natural Science, and the University of Oregon Thomas Condon State Museum of Fossils. Comparison of bone quality was made to a nearly complete mastodon skeleton (LSUMG 586) recovered from the same site in 1974 (Rice,

1981). That find is in the collection of the Louisiana State University Museum of Natural Science (formerly the LSU Museum of Geoscience).

Mollusk shells were identified by reference to descriptive and pictorial literature on mollusks. Of importance in this procedure were the following references: Andrews, 1981; Baker, 1945; Burch, 1962; Burch, 1975; Burch and Tottenham, 1980; Clarke, 1981; Dennis, 1928; Emerson and Jacobson, 1976; Jacobson and Emerson, 1961; Leonard, 1959; Richards, 1938a and 1938b, and Thompson, 1968. Turgeon *et al.* (1988) provided a source for current taxonomic nomenclature and revised common names. Specimens reported by Richards (1938a and 1938b) and curated at LSUMNS provided reference to a comparative collection.

IV. RESULTS

Bone fragments of a large mammal recovered on Oct. 18, Nov. 1 and 17, 1991 are those of the mastodon *Mammot americanum* (Kerr, 1792) of late Pleistocene age (Rancholabrean N. A. Land Mammal Age) (Olsen, 1979; Gilbert, 1990). The larger bone fragments form part of a mastodon right ulna shaft (Fig. 4). Greatest representation is of the medial midshaft, which allows a midshaft antero-posterior diameter measurement of 118 mm. Also present is a flattened anterior portion where the radius permanently crosses the ulna. The medial proximal shaft antero-posterior diameter is approximately 230 mm. Articulated fragments give a shaft length measurement of approximately 390 mm. These measurements correspond to those recorded by Olsen (1979) for similar portions of a mastodon ulna and closely match a mastodon model displayed at Houston Museum of Natural Science. However, measurements are only slightly greater than a mature juvenile mastodon ulna with partially fused epiphyses (Condon Museum 29247). The bone recovered in 1991 is comparable in quality to the bone of an adult mastodon skeleton (LSUMG 586) excavated at this site in 1974 (Rice, 1981). However, no ulna bone is described for LSUMG 586. Although reference to comparative collections at the Louisiana State University Museum of Natural Science indicates that



Figure 3. Excavation Unit at the North Fork of Ward Creek 11/17/91. Loose dark brown soil supporting vegetation (upper unit) overlays calcareous clay shelf (lower unit). Arrows point to Bone #4, enclosed within the lower unit.

young juvenile mastodon bone was recovered previously from the North Fork of Ward Creek (LSUMG 588), no young juvenile mastodon bone was recovered in 1991. Bone fragments found in close proximity to the mastodon ulna could reasonably be assigned to missing portions of the ulna. Numerous minute bone fragments were closely associated with the larger fragments in the screened samples.

Granulometric analysis of unscreened sediment adjacent to the bone indicates that the mastodon bone was enclosed in a calcareous clay/silty clay loam. Screened samples of the bone matrix indicate a silty clay loam (Table 1). The fossil-bearing unit (Fig. 3) is characterized by bleached freshwater mollusk shell, calcareous/clay concretions (especially calcareous nodules), clay aggregations, iron oxide nodules,



Figure 4. Composite of mastodon right ulna shaft fragments retrieved from the lower excavation unit: (a) interior view of medial shaft, (b) exterior view of medial shaft. Scale is 1 cm.

bone, and some black gravel and fine plant residue. No pollen was isolated from this unit, possibly a reflection of the high carbonate fraction (Table 1). Pollen exines are sensitive to a high pH over long periods (Traverse, 1988). In contrast, the unit overlying the fossil-bearing unit (Fig. 3) is

characterized by freshwater mollusks retaining abraded periostracum, mixed gravels, quartz/agate sand, plant materials (fragments of seeds, stems, wood, leaves, and roots), and intrusive materials such as glass and plastic. Granulometric analysis of the unit overlying the fossil-yielding unit

varies from sandy clay loam to clay (Table 1). This sediment appears to be a combination of recent alluvium and colluvial slumped deposits, showing strong but varied influence of the underlying clay.

Bone collagen had been leached out or replaced by organic/inorganic components in the submitted >400 grams of bone. Therefore, bone collagen radiocarbon dating was not feasible. An attempt to obtain a direct date from bone by using the ^{14}C AMS method on a small sample of possibly carbonized bone proved similarly fruitless.

The sediment surrounding mastodon bone fragments contained numerous fossil freshwater mollusk shells (Table 2; Figs. 5-11). A radiocarbon date of $21,220 \pm 360$ yr B.P. (Beta-54921, 1992) obtained from 10 grams of shell retrieved from sediment associated with the mastodon bone and the whole shell places this molluscan faunal assemblage within a late Pleistocene, late Wisconsinan time frame (22,000 to 17,000 yr B.P.). This date corroborates a date of $20,595 \pm 225$ yr B.P. (Beta-1854, 1979) obtained by Alford, Kolb, and Holmes from shell in this vicinity (Alford, pers. comm.). This age was corroborated later by Clark *et al.* (1989) who applied the amino acid racemization method of dating to three samples of cf. *Mesodon* sp. from the same stratigraphic unit at Ward Creek used to determine the above mentioned $20,595 \pm 225$ yr B.P. radiocarbon date. Clark *et al.* (1989) reported a total acid hydrolysate value of 0.16 ± 0.03 for these Ward Creek

gastropods, a value which they related to overlapping ratios for Peoria Loess and Roxana Silt in the Mississippi Valley.

Although some taxonomic designations have changed (Turgeon *et al.* 1988), the species documented (Table 2) closely correspond to Pleistocene species cited by Richards (1938a) from Bayou Manchac and basal zone Peoria Loess at Little Bayou Sara. Bayou Manchac is immediately to the south of Baton Rouge. Little Bayou Sara is an upland stream bordering the Mississippi River valley in the Tunica Hills, West Feliciana Parish (Fig. 1).

Aquatic mollusks retrieved at Ward Creek are sphaeriid bivalves and gastropods represented by planorbids, hydrobiids, succineids, pomatiopsids, pyramidellids, physids, and lymnaeids. Beyond the excavation borders but within the same soil profile, there is, additionally, very limited representation of terrestrial polygyrids. Most species are presently known throughout the Mississippi Valley, ranging from Southeast Canada to Florida and Texas, and some are more generally known from temperate latitudes of North America. Several of the fossil species have been documented at other Pleistocene localities (*e.g.*, Richards, 1938a; Baker, 1945; Taylor, 1985; W. Miller, 1989). Most species are known from perennial, freshwater habitats characterized by a mud substrate and low-energy, well-vegetated, shallow water. A few are known to inhabit vegetation at the water's edge.

TABLE 1. Granulometric Analysis of Ward Creek Base Sediments.

Sample#	Sediment Type	Carbonate Fraction %	Organic Fraction %	Particle Size %		
				Sand	Silt	Clay
PLEISTOCENE BASE UNIT						
*WC-91-30b	silty clay loam	high	15.0	5.5	68.5	26.0
*WC-91-20	silty clay loam	high	20.0	4.8	60.9	34.3
WC-95-5	clay	14.34	low	9.2	39.9	50.9
WC-95-11a	silty clay loam	high	low	5.0	57.6	37.4
WC-95-11b	silty clay loam	high	low	4.8	55.8	39.4
WC-95-7	clay	7.33	low	15.5	20.1	64.4
WC-95-15	silt loam	13.00	low	31.0	58.8	10.2
HOLOCENE OVERBURDEN UNIT						
*WC-91-16	sandy clay loam	low	50.0	47.5	24.9	27.6
*WC-91-28	silty clay	low	40.0	12.5	44.3	43.2
WC-95-12	clay	0.73	high	32.3	16.6	51.1

* = pre-screened sample

TABLE 2. Mollusks (Gastropoda and Bivalvia) recovered from the 1991 Ward Creek Mastodon excavation by sediment unit: Number of Identified Specimens of represented taxa. Comparison to Louisiana Pleistocene sites* reported by Richards (1938a) is provided.

Family	Species/Common Name**	NISP***
<i>PLEISTOCENE FOSSIL-YIELDING UNIT</i>		
CLASS BIVALVIA		
Sphaeriidae:	<i>Musculium partumeium</i> (Say, 1822) swamp fingernailclam	1
	<i>Pisidium</i> sp. unidentified species	4
	<i>Pisidium ?compressum</i> Prime, 1852 ridged-beak peaclam	1
	Similar to <i>P. variabile</i> of Richards (1938a) LBS, BM	
	<i>Pisidium ?equilaterale</i> Prime, 1852 round peaclam	1
	<i>Pisidium ?variabile</i> Prime, 1852 triangular peaclam	1
	Similar to <i>P. compressum</i> of Richards (1938a) LBS, BM	
Corbiculidae:	<i>Corbicula fluminea</i> (Muller, 1774) intrusive Asian clam	1
Total Pleistocene Unit Bivalve Specimens		9
CLASS GASTROPODA		
Hydrobiidae:	<i>Amnicola limosus</i> (Say, 1817) [some ? <i>Cincinnati</i> sp.] mud amnicola/?siltsnail	46
	Richards (1938a) reports <i>Cincinnati cincinnatiensis</i> LBS, BM	
Pomatiopsidae:	<i>Pomatiopsis lapidaria</i> (Say, 1817) slender walker	10
	Similar to <i>P. lapidaria</i> of Richards (1938a) LBS, BM	
Pyramidellidae	? <i>Fargoa gibbosa</i> (Bush, 1909) odostome	8
Lymnaeidae:	<i>Fossaria parva</i> (I. Lea, 1841) pygmy fossaria	3
	Richards (1938a) reports <i>Lymnaea obrussa</i> LBS	
Physidae:	<i>Physella heterostropha</i> (Say, 1817), small form pewter physa	4
	Similar to <i>Physa gyrina elliptica</i> of Richards (1938a) LBS, BM	
Planorbidae:	<i>Gyraulus parvus</i> (Say, 1817) ash gyro	206
	Similar to <i>G. parvus</i> of Richards (1938a) BM	
	<i>Helisoma anceps</i> (Menke, 1830) two-ridge rams-horn	10
	Similar to <i>H. anceps</i> of Richards (1938a) LBS, BM	
	<i>Planorbella trivolis</i> (Say, 1817) marsh rams-horn [<i>P.t. lentum</i> = southern subspecies]	2
	<i>Planorbella</i> sp. unidentified species	3
	<i>Micromenetus alabamensis</i> (Pilsbry, 1895) marsh sprite	4
	? <i>Micromenetus</i> sp. unidentified species	1

	? <i>Vorticifex</i> sp. ? <i>V. effusus</i> (I. Lea, 1856)	1
	[resembles the extinct <i>Parapholyx pusilla</i> Baker, 1945]	
Succineidae:	<i>Succinea</i> sp. ? <i>S. forsheyi</i> (I. Lea, 1864)	7
	amber snail	
	Richards (1938a) reports <i>Succinea</i> sp.	
	LBS	

Total Pleistocene Unit Gastropods 305

PLEISTOCENE EXPOSED BANK

CLASS BIVALVIA

Corbiculidae:	<i>Corbicula fluminea</i> (Muller, 1774) intrusive Asian clam	2
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Total Exposed Bank Pleistocene Bivalves 2

CLASS GASTROPODA

Physidae:	<i>Physella heterostropha</i> (Say, 1817), large form pewter physa	4
	Size comparable to <i>Physa holei</i> of Richards (1938a)	
	LBS	

Planorbidae:	<i>Planorbella trivolis</i> (Say, 1817) marsh rams-horn [<i>P.t. lentum</i> = ?Southern subspecies]	9
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Polygyridae:	<i>Triodopsis albolabris</i> (Say, 1816) whitelip	1
	<i>Mesodon</i> sp.	1
	unidentified species	

Total Exposed Bank Pleistocene Gastropods 17

TOTAL PLEISTOCENE ASSEMBLAGE BIVALVES 11

TOTAL PLEISTOCENE ASSEMBLAGE GASTROPODS 322

TOTAL PLEISTOCENE MOLLUSK SPECIMENS 331

HOLOCENE ALLUVIUM/COLLUVIUM

CLASS BIVALVIA

Sphaeriidae:	<i>Sphaerium striatinum</i> (Lamarck, 1818) striated fingernailclam	28
	<i>Sphaerium ?fabale</i> (Prime, 1852) river fingernailclam	1
	<i>Musculium transversum</i> (Say, 1829) pond fingernailclam	10
Corbiculidae:	<i>Corbicula fluminea</i> (Muller, 1774) Asian clam	4
	? <i>Polymesoda</i> sp. unidentified clam	1

Total Holocene Bivalve Specimens 44

CLASS GASTROPODA

Hydrobiidae:	<i>Amnicola limosus</i> (Say, 1817) [some ? <i>Cincinnati</i> sp.] mud amnicola/?siltsnail	48
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Lymnaeidae:	<i>Fossaria parva</i> (I. Lea, 1841) pygmy fossaria	3
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Physidae:	<i>Physella heterostropha</i> (Say, 1817)/ <i>P. ?gyrina</i> (Say, 1821) pewter physa/tadpole physa	14
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Planorbidae:	<i>Gyraulus parvus</i> (Say, 1817) ?intrusive ash gyro	4
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	<i>Planorbella armigera</i> (Say, 1821) thicklip rams-horn	1
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Zonitidae:	? <i>Ventridens ligera</i> (Say, 1821) globose dome	1
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Total Holocene Gastropod Specimens 71

(Continued next page)

TOTAL HOLOCENE ASSEMBLAGE BIVALVES	44
TOTAL HOLOCENE ASSEMBLAGE GASTROPODS	71
TOTAL HOLOCENE ASSEMBLAGE MOLLUSK SPECIMENS	115

* LBS = Little Bayou Sara

BM = Bayou Manchac

** Following Turgeon *et al.*, 1988.

*** Numbers comparable only within sediment unit; enumerations representative of individuals except for the Holocene bivalves, *Sphaerium striatinum* and *Musculium transversum*.

Planorbidae is the best represented gastropod family in the Ward Creek excavation unit associated with mastodon bone. The most abundant species (206 specimens retrieved) is *Gyraulus parvus* (Fig. 5a), a small species of the lung-breathing family Planorbidae. At Ward Creek, *Gyraulus parvus* ranges in size from 1 to 4 mm in width and approximates 1.5 mm or less in height. An uncommon planorbid in this size range is *Micromenetus alabamensis* (Fig. 6a), with 4 specimens present. The shell is very small and 'ultradextral. A larger (approximately 7 mm width) planorbid is *Helisoma anceps* (Fig. 5b). This ultradextral bicarinate species is characterized by a prominent carina on the shoulder of the body whorl. An even larger planorbid species recovered at Ward Creek is sinistral in orientation and is identified as *Planorbella trivolis* (Fig. 7a). The larger of these specimens are 16-18 mm in width with a height of approximately 6 mm. Some also resemble *Planorbella pilsbryi*. One incomplete planorbid present resembles an extinct Pleistocene species from the western United States, recorded by Baker (1945) as *Parapholypus pusilla* (Fig. 6c), a genus now incorporated within *Vorticifex* (Turgeon *et al.*, 1988).

The gill-breathing Hydrobiidae (Fig. 8a) is the next most frequently represented gastropod family at Ward Creek. A flattened nuclear whorl and 3.5 to 4.5 body whorls identifies *Amnicola limosus* as the most common representative of hydrobiids (Clarke, 1981). Some specimens, however, resemble the siltsnail, *Cincinnatia* sp. (Thompson 1968; Burch and Tottenham, 1980). Pyramidellidae are questionably represented by *Fargoa gibbosa* (Fig. 8b), known from beach habitats.

Less frequently occurring amphibious species in the Ward Creek fossil-bearing

unit are of the families Lymnaeidae (Fig. 8c), Pomatiopsidae (Fig. 9a), and Succineidae (Fig. 9b) (Leonard, 1959; Jacobson and Emerson, 1961; Burch and Tottenham, 1980; Andrews, 1981; Clarke, 1981). Characteristics of the reproductive system are utilized to distinguish species of Succineidae (Spamer and Bogan, 1993). The Ward Creek species resembles *Succinea oblonga*, known from freshwater Pleistocene mammal localities of western Europe (Tate, 1866). It is similar to *Succinea forsheyi* (formerly *Succinea concordialis*, a species previously recognized from Louisiana) (Turgeon *et al.*, 1988). Larger specimens of *Succinea* sp. are associated with another nearby mastodon skeleton, the Morgantown Mastodon from Natchez, southwestern Mississippi, which is part of the collection at LSUMNS.

Taxonomic relationships of the family Physidae are presently in a state of flux (Clarke, 1981; Turgeon *et al.*, 1988; Spamer and Bogan, 1993). Polymorphisms in *Physa* shells are more often a reflection of environmental influence than of speciation events (Emerson and Jacobson, 1976). *Physa* shells in the Ward Creek clay/silty clay loam come in two forms (Fig. 7b-c), differentiated by size and color. The larger form with a thicker, bleached pink shell is identified here as *Physella heterostropha* (large form). It resembles *Physa halei* (Richards, 1938a) and *Physa hawnii* (Leonard, 1959), species not listed by Turgeon *et al.* (1988). Clarke (1981) reports that shells of *P. integra*, a lake species, are thicker and heavier than the thin shells of *P. heterostropha* or *P. gyrina*. A small species with a bleached white thin shell is identified here as *Physella heterostropha* (small form). It resembles *Physa gyrina elliptica* (Richards, 1938a) and *Physa anatina* (Leonard, 1959). Clarke (1981) re-

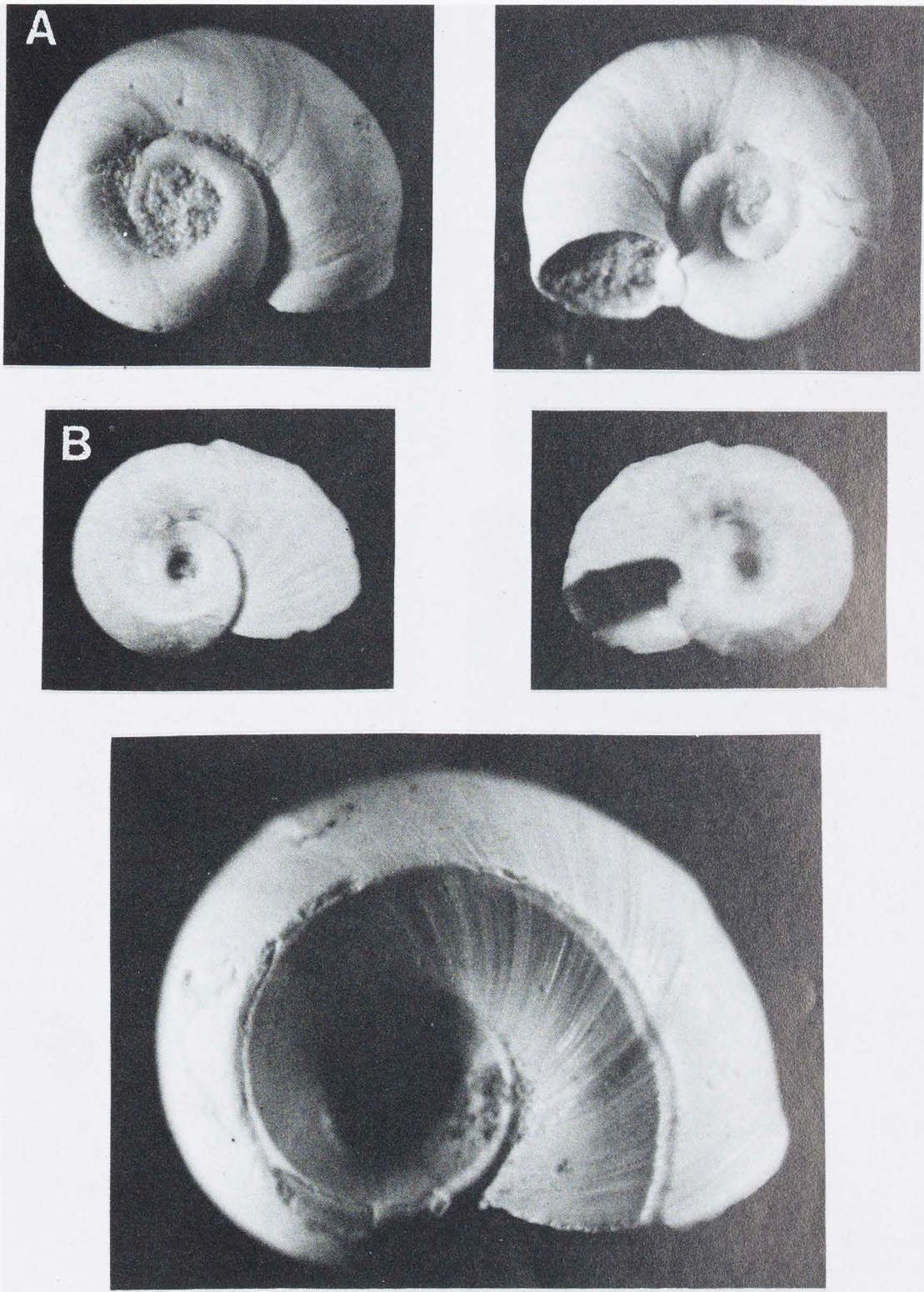


Figure 5. Ward Creek Pleistocene planorbids, apical and umbilical views: (a) *Gyraulus parvus* [x 16.7, WC-91-30b]; (b) *Helisoma anceps* [macroscopic view x 2.5, WC-91-19; (c) *Helisoma anceps* [microscopic view x 13.6, WC-91-20].

ports that *P. heterostropha* and *P. gyrina* may be more closely related than indicated by their nomenclature.

Small clams (3-4 mm) of the subfamily Pisidiinae (Fig. 10) also occur in the bone-bearing unit. *Pisidium* species (peaclams) are frequently left unidentified in fossil collection reports due to difficulties of positive identification (Burch, 1975; W. Miller, 1989). Because several species are present at Ward Creek, an attempt is made here to provisionally identify some of these species. Typical of these peaclams is *Pisidium compressum*. Other species present appear to be *P. variabile* and *P. equilaterale*. There is a single representative of the swamp fingernailclam (Fig. 11), *Musculium partumeium* (Burch, 1975; Clarke, 1981).

Just beyond the excavation site but within the fossil-yielding unit, two non-intrusive terrestrial gastropods of the family Polygyridae were recovered, *Triodopsis albolabris* and *Mesodon* sp. (Leonard, 1959; Jacobson and Emerson, 1961; Burch, 1962).

The molluscan assemblage of the sediment that overlies the bone-bearing unit at Ward Creek is distinctly different from the Pleistocene assemblage. Common to the upper unit are Sphaeriinae, Hydrobiidae and Physidae. Also present in the upper unit are the introduced bivalves of the family Corbiculidae. Lymnaeidae is represented by *Fossaria parva*. Within the upper unit, small *Physella* species retaining a thin, shiny gray/yellow periostracum are identified as *P. heterostropha*/?*gyrina*. Planorbids are rare in the upper unit. One specimen of *Planorbella armigera* was recovered (Clarke, 1981). Absence of periostracum from four specimens of *Gyraulus parvus* suggests that *G. parvus* is intrusive to the upper unit. Recall that absence of periostracum is a characteristic of the bone-bearing unit. Possible sources of contamination include reworking of soil by crawfish noted near the mastodon bone, movement of soil through degraded pipes noted at the upstream boundary, or displacement of soil by stream erosion.

V. DISCUSSION

Distribution patterns for aquatic gastropods and pelecypods of North America

suggest that the Ward Creek faunal assemblage occurs over a broad latitudinal and temperature range (Burch and Tottenham, 1980; Clarke, 1981; Taylor, 1985; Spamer and Bogan, 1993). A few corresponding aquatic mollusk species have been reported for the Mammoth Site, Hot Springs, South Dakota, dated ca. 26,000 yr B.P. (Mead *et al.*, 1990), and from a mammoth kill-butcherer locality on the edge of a late Pleistocene pond or marsh in the White River Badlands, South Dakota, ca. 11,000 B.P. (Hannus, 1990). Although biogeography of terrestrial snails has been used to infer paleoclimatic changes (McCraw, 1990), aquatic mollusks present at Ward Creek are not conducive to such analyses. Taylor (1985) asserts that Pleistocene aquatic habitats were not subject to the intense cyclical fluctuations characteristic of Pleistocene terrestrial habitats.

Interpretation of southeastern Louisiana paleoclimate is more accurately reflected by pollen analysis. Although fossil flora at the excavation site evidently differed from the dominant spruce forests reported for contemporaneous sites in the Tunica Hills by Givens and Givens (1987) and Jackson and Givens (1994), the proximity of these locations suggests regional influence and concordant similar though not identical paleoclimates. Jackson and Givens (1994) indicate that the Tunica Hills region of Louisiana represents the southernmost documented occurrence of widespread late Wisconsinan spruce forests and infer from pollen analysis that late Wisconsinan climate in the Tunica Hills region was cooler than present, but not boreal in nature. A slightly warmer condition is inferred for the pine or mixed pine/hardwood forests apparently typical of full-glacial vegetation of the Gulf Coastal Plain (Delcourt and Delcourt, 1977, 1983; Watts, 1970, Watts *et al.*, 1992).

A date in the range of 21,220 \pm 360 yr B.P. corresponds to a time of greatest extent of the Laurentide ice sheet (Catto and Mandryk, 1990; Meltzer, 1993). The date and associated mastodon bone suggests that, like the Tunica Hills region approximately 50 kilometers to the northwest, the climate at Ward Creek was temperate but not boreal. Reasons for a cooler regional paleoclimate are related to global cooling during the late Wisconsinan glacial maxi-

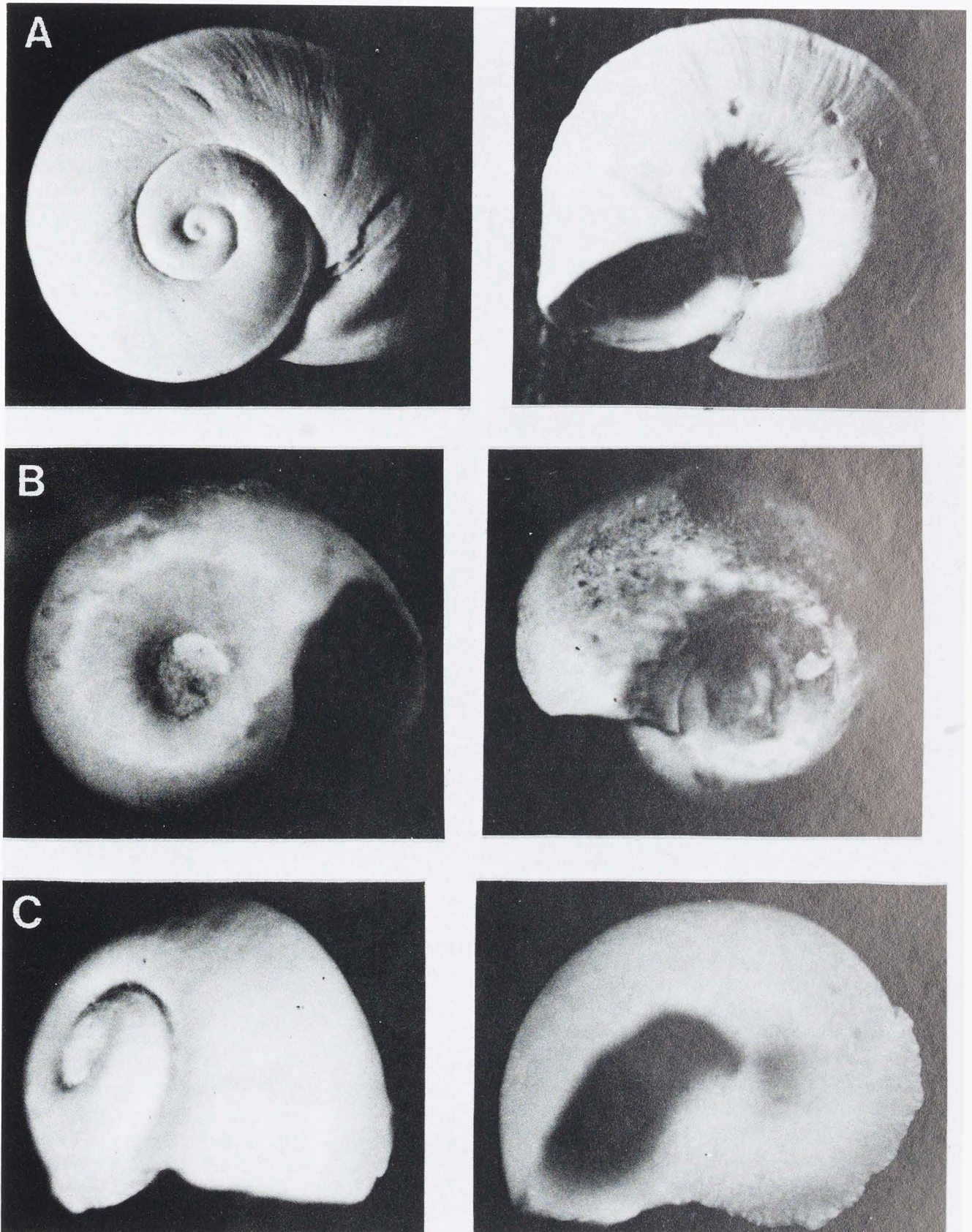


Figure 6. Ward Creek Pleistocene planorbids, apical and umbilical views: (a) *Micromenetus alabamensis* [x 13.5, WC-91-32]; (b) ?*Micromenetus* sp. [x 23.5, WC-91-19]; (c) ?*Vorticifex* sp. [x 34.2, WC-91-30c].

num and its multiple side effects such as presence of glacial meltwater in the Mississippi Valley, low sea level, and lower than present sea level temperature.

Dates acquired from aquatic mollusks are problematic. MacDonald *et al.* (1991) report that aquatic mollusks have a tendency to take on the carbon isotope balance of lake water which tends to be deficient in ^{14}C relative to the proportion of ^{14}C in the atmosphere. Limnic sediments may reflect "old carbon" and may be several thousand years younger than radiocarbon dating indicates. However, large, shallow lakes with slow turnover of water are less prone to this error than small, deep lakes (MacDonald *et al.*, 1991). The Ward Creek mollusk assemblage suggests a shallow water environment with little movement of water.

Despite limitations on inferring paleoclimate directly from the aquatic mollusk assemblage, distribution of mollusk species through space and time can be informative. Identification of mollusk species recovered from two vertically adjacent sediment units at the excavation site provides information on the micro-paleoenvironmental history at Ward Creek. The paleoecology inferred from biostratigraphy and species composition contrasts with current ecological conditions. Within the fossil-yielding unit, the molluscan assemblage is indicative of a swamp. Most molluscan species are aquatic or amphibious, known to inhabit perennial, shallow, still-water habitats characterized by abundant vegetation and a mud substrate (Clarke, 1981). Most species, including the dominant species *Gyraulus parvus*, fall into what Taylor (1985) classifies as Group E, snails of seasonal or perennial water bodies of limited extent. However, Taylor's (1985) Groups B and C, Sphaeriidae and snails of larger perennial water bodies, are represented by *Pisidium compressum* and *Helisoma anceps*. Species recorded are not indicative of cold, clear, fast-running water (Baker, 1945).

Gastropods of the family Planorbidae are abundant in the fossil-bearing sediment. These gastropods are part of a food chain suggesting associated faunal presence of wading birds, ducks, songbirds such as red-winged blackbirds, fish, tur-

tles, frogs, newts, salamanders, crawfish, leeches, and dragonflies (Baker, 1945).

Several of the Ward Creek species (*e.g.*, *Gyraulus parvus*, *Planorbella trivolis*, *Helisoma anceps*, *Pomatiopsis lapidaria*, *Fossaria parva*) are known intermediate hosts for blood parasites (Baker, 1945; Clarke, 1981). This suggests to the author that blood parasites were a probable environmental stress for mastodons inhabiting the Ward Creek region.

Within the Holocene upper unit, common species represent hydrobiids, physids, and freshwater sphaeriid clams (*Musculium transversum*, *Sphaerium striatinum*, and *Sphaerium ?fabale*), species which conform with the present Ward Creek stream habitat from which they were retrieved. Dominance of *Musculium transversum* and *Physella* sp. is sometimes associated with organic pollution and a reduced oxygen environment (Clarke, 1981). Numerous indicators of extant chemical and organic pollution are present at the Ward Creek site. Species composition supports a designation of the upper unit as recent alluvium.

Aquatic and amphibious mollusk species identified in the fossil-bearing sediment correspond closely to species identified by Richards (1938a) from Pleistocene localities in Louisiana and Mississippi such as the aquatic clay at Bayou Manchac or basal zone Peoria Loess at Little Bayou Sara. In contrast, these are not the common terrestrial gastropod species that are frequently identified in supra-basal zones of Peoria Loess in the Tunica Hills region of Louisiana and Mississippi (Richards, 1938b; McCraw, 1990; McCraw, pers. comm., 1994). A single representative of two terrestrial gastropods common in Peoria Loess (*Triodopsis albolabris* and *Mesodon* sp.) was retrieved from the exposed bank adjacent to the lower unit excavation borders and one (*Ventridens ligera*) in the upper unit [although Clark *et al.* (1989) report cf. *Mesodon* sp. characteristic of three samples from Ward Creek]. Numerous calcareous concretions common to loess, what Fisk (1938) refers to as "loess dolls," were found in the lower unit.

Maximum numbers of planorbids are reported to occur in shallow water areas not exceeding 2 meters in depth (Baker, 1945). *Planorbella trivolis* is common in shallow

areas bordered by *Typha* and sedge (Baker, 1945). Algae are a major component of the diet of *Gyraulus parvus*. Leonard (1959) reports that, in Kansas, *G. parvus* is frequently found on or among aquatic plants such as *Chara*, *Typha*, *Spirogyra*, and duckweed and on submerged blades of living and dead grasses or on dead tree

leaves in water or water-logged driftwood. In New York, Jacobson and Emerson (1961) associate *G. parvus* habitat with the underside of floating wood, lily pads, and rotting leaves and fronds of aquatic plants. Dennis (1928) reported *G. parvus* within a water temperature range of 22°C to 27°C in the Bass Island region of Lake Erie as-

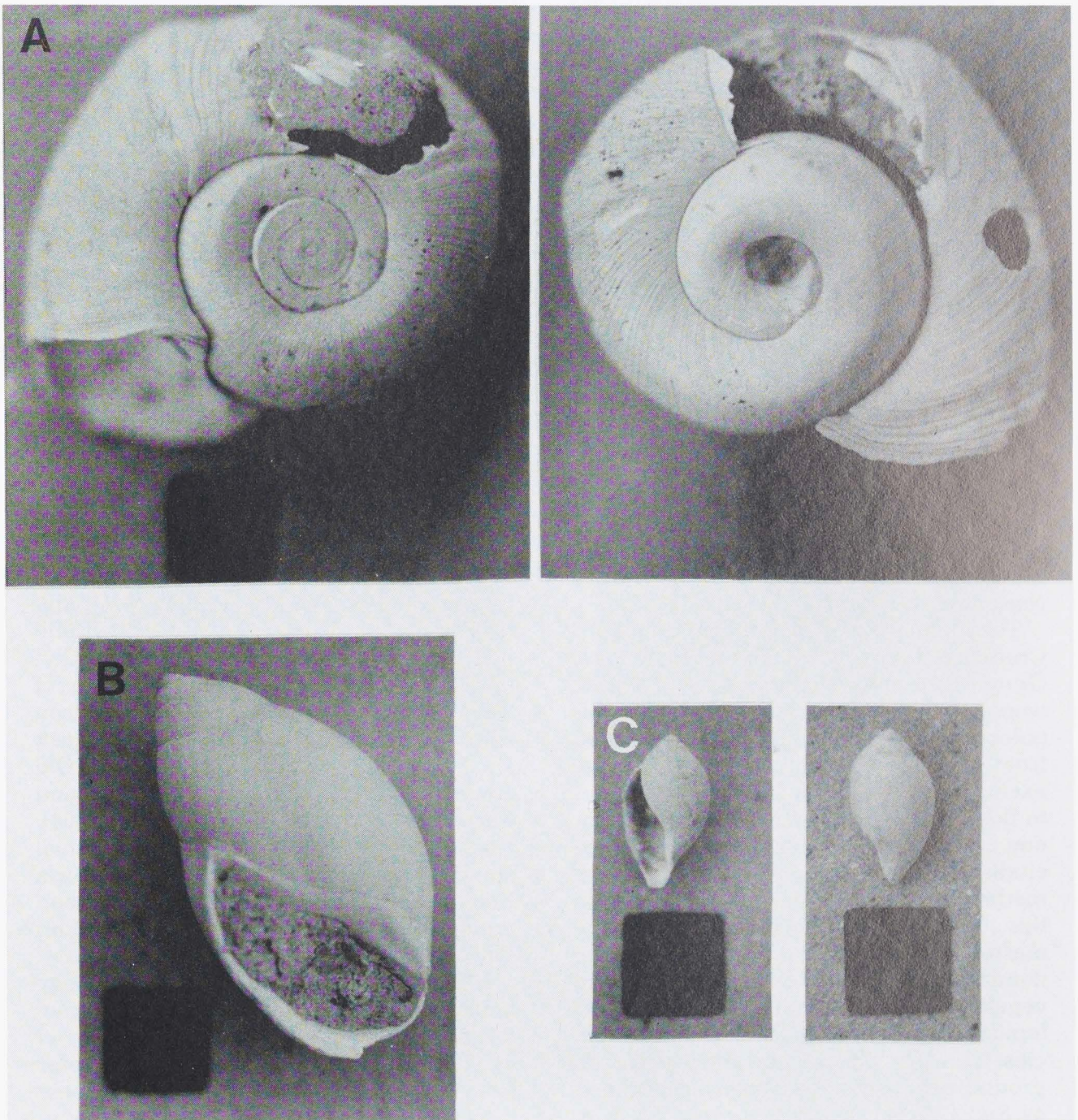


Figure 7. Ward Creek Pleistocene planorbid and physids: (a) apical and umbilical view of *Planorbella trivolis* [x 2.5, WC-91-26a]; (b) sinistral view of *Physella heterostropha* (large form) [x 2.6, WC-91-46]; (c) sinistral and dextral view of *Physella heterostropha* (small form) [x 2.6, WC-91-30b].

sociated with a habitat of abundant vegetation and low velocity, shallow water. Similarly, *Planorbella trivolis* and *Amnicola limosus* are associated with well-vegetated shallow water. The micro-environment at Ward Creek could have been influenced by mastodon bone itself; numerous crevices within cancellous bone structure may have favored algae proliferation. Dominance of *G. parvus* may be a reflection of this altered osseous environment and its associated algal scum. The congregation of these mollusks around the mastodon [as indicated by an inventory of screened sediment samples (Lewis, 1994) and from carbonate fraction (Table 1)] might have facilitated the preservation of mastodon bone by providing an abundant calcium carbonate matrix. This situation could have enhanced the preservation properties of a clay matrix.

Planorbids on the whole can survive in low-oxygen, organic-polluted environments because of their lung-breathing capabilities (Baker, 1945), thus they would not be eliminated from a decaying mammal site. If this was the site of entrapment of this mastodon (for which there is no direct evidence), dominance of planorbids, during a probable Pleistocene decay period for this mastodon, would be a reasonable outcome.

Taxonomic diversity gradients at Ward Creek are informative. The dominance of *Gyraulus parvus* suggests that this gastropod was the superior competitor in this paleoenvironment. Expectations derived from the ecologic postulate of competitive exclusion would be for only a few species to flourish in a given environment and for one species to predominate but not exclude those employing similar feeding methods (Raup and Stanley, 1971). Within this small unit of sediment surrounding the mastodon ulna, *Gyraulus parvus* is the dominant pulmonate feeder of submersed vegetation. *Succinea* sp. and *Pomatiopsis lapidaria* are co-dominant amphibious species. However, *P. lapidaria* inhabits wet ground near water/land interface, whereas *Succinea* sp. clings to vegetation in or

near water or inhabits wet leaf mold at the edge of water (Clarke, 1981). *Amnicola limosus* is the dominant non-pulmonate gastropod and is associated with unpolluted, perennial-water habitats where aquatic vegetation grows (Clarke, 1981).

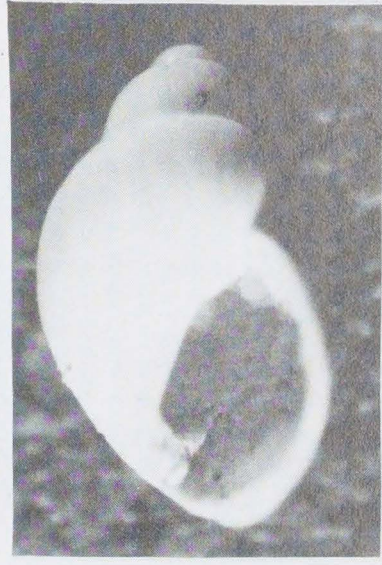
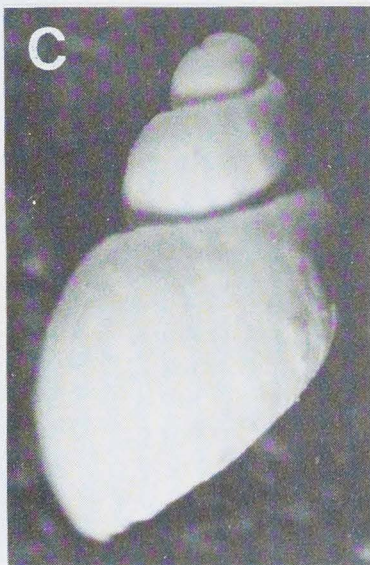
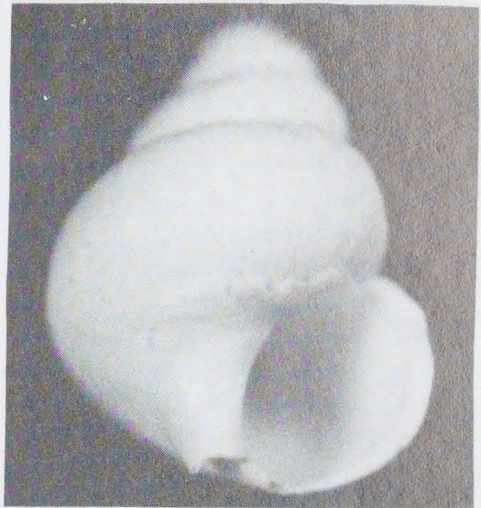
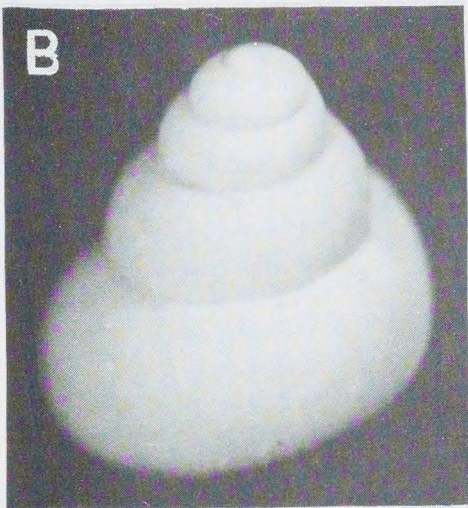
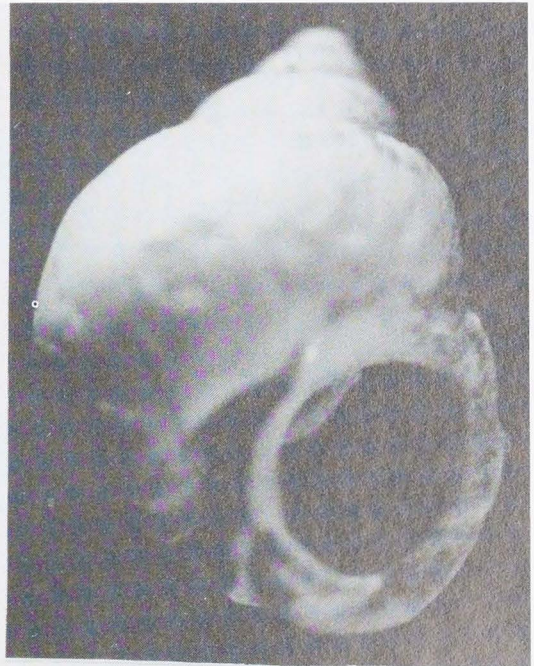
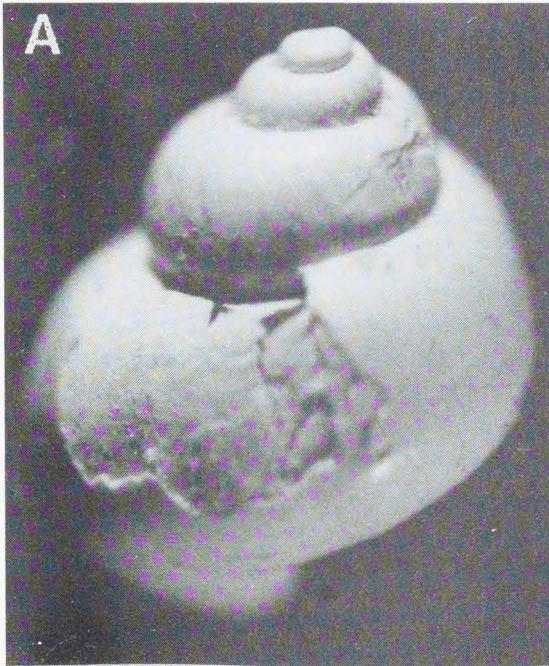
Whether mollusks retrieved from this small excavation unit are representative of a true fossil mollusk community remains an open question. Sampling limitations and differential preservation are factors to be considered. Nonetheless, the dominance of a few species coincides with expectations for a reconstructed fossil microcommunity in this paleoenvironment. It is also to be expected that small numbers of inferior competitors will remain part of the assemblage (Raup and Stanley, 1971). Such appears to be the case at the 1991 Ward Creek excavation site, suggesting that the mollusk assemblage within this microenvironment is indicative of a true fossil community.

As stated previously, the molluscan assemblage from the fossil-yielding unit at Ward Creek is similar to the molluscan assemblage of basal zone Peoria Loess at Percy Bluff along Little Bayou Sara (Richards, 1938a). Peoria Loess in Louisiana is presently assigned earlier inclusive time frames than previously reported (Alford *et al.*, 1983; W. Miller, 1983; B. J. Miller *et al.*, 1985; Clark *et al.*, 1989; B. J. Miller, 1991; Saucier, 1991; Jackson and Givens, 1994). More regionally, an age of 23,900 yr was calculated using electron spin resonance (ESR) dating of mollusk shell from basal Peoria Loess at the Old River section, Tennessee (Skinner and Mirecki, 1993 *in* Mirecki and Miller, 1994). Further north in the Driftless Area, snail shells 25 cm above the base of the Peoria Formation yielded an AMS radiocarbon date of 24,250 \pm 970 ^{14}C yr B.P. (Leigh and Knox, 1994).

Besides evidence from geochronology and mollusk assemblage, sediment characteristics are similar to what B. J. Miller *et al.* (1985) and B. J. Miller *et al.* (1988) refer to as a basal mixed zone of Peoria Loess discernible in the Lower Mississippi Val-

Figure 8. Ward Creek Pleistocene hydrobiid, pyramidellid, and lymnaeid, sinistral and dextral views: (a) *Amnicola limosus* [x 15.0, WC-91-19], (b) ?*Fargoa gibbosa* [x 21.6, WC-91-30c]; (c) *Fossaria parva* [x 23.3, WC-91-6].

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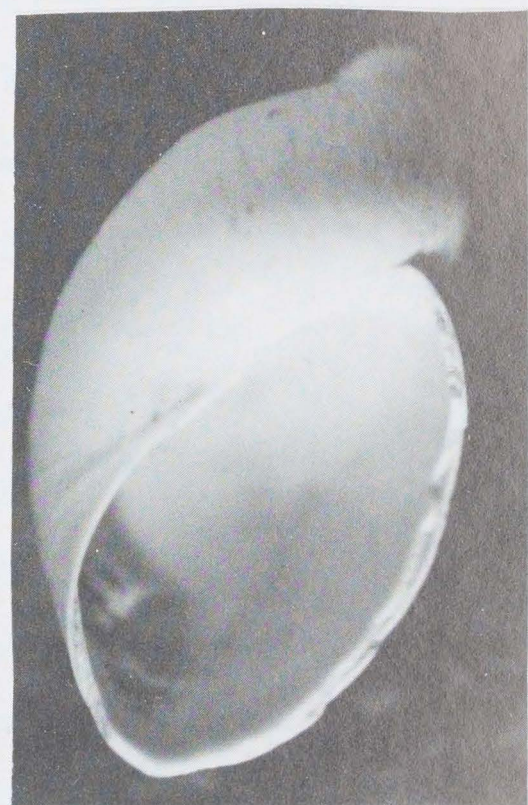
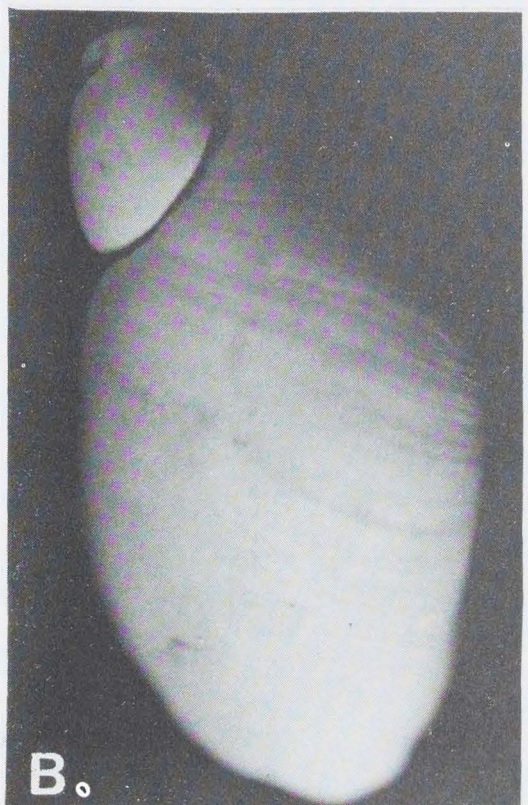
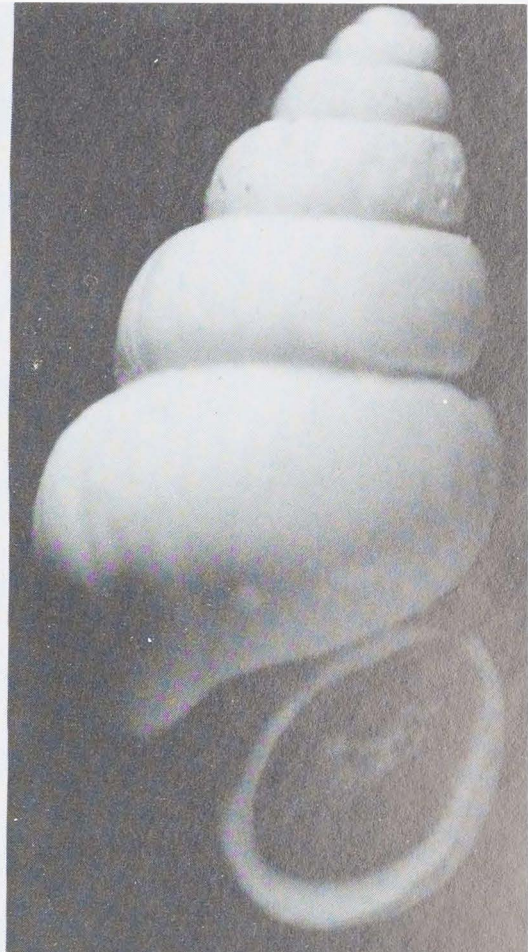
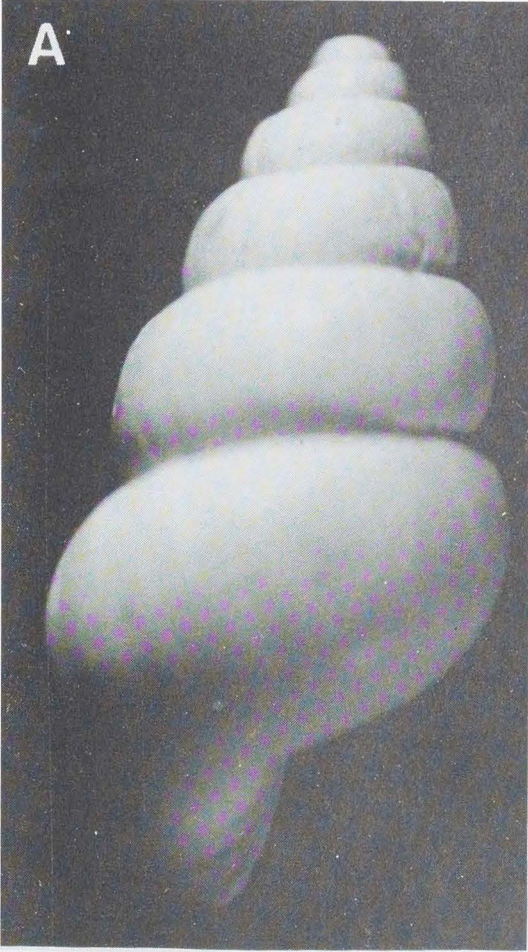


ley. A body of literature has emerged in recent years documenting a silty clay loam transition zone at basal loess deposits. Basal mixed zones refer to zones exhibiting mixing of loess with underlying material as the result of the processes of bioturbation and pedoturbation (B. J. Miller *et al.*, 1988). Miller (1987) suggests that late phase terrace construction overlapped the early phase of Peoria Loess deposition. Several examples of a mixed zone or transitional silty clay loam, similar in granulometric analysis to screened samples reported here for Ward Creek, are recorded for several sites in Louisiana by B. J. Miller *et al.* (1985). In the Amite River Valley, the oldest Holocene alloformation, the Watson, is underlain by the clay Prairie Terrace (Autin, 1992). Thus, basal zones of the Watson might reflect the apparently ubiquitous presence of loess in the Lower Mississippi Valley during this time period and may be similar to basal Peoria Loess as a result of similar transition zone mixing of silt, silt derived loess, and Prairie Terrace clay. Autin (1993) reports that although the Watson is primarily a Holocene alloformation, the age of initial Watson deposition may be late Wisconsinan when the Amite River was still tributary to an ancestral Florida Parishes drainage basin. At a Ward Creek site Pleistocene swamp, wind blown loess would have been filtered through swamp water, rather than deposited on an exposed surface, the latter being a typical situation for Peoria Loess.

Likewise for the midcontinental United States, McSweeney *et al.* (1988) report of loamy zones containing characteristic pedorelicts which occur as transitional deposits between Wisconsinan loess and underlying soil units. Pedorelicts, such as calcareous nodules and iron oxide nodules, retrieved in screened sediment samples from the fossil yielding clay/silty clay loam at Ward Creek could reasonably be related to *in situ* pedogenic reorganization. This contrasts transition zones of the midcontinental United States where pedorelicts are indicative of disruption, transport, or reorganization of soil (McSweeney *et al.*, 1988).

Bones recovered in 1991 appear to belong to a larger bone assemblage recovered previously at Ward Creek. Although only a mastodon ulna was retrieved at the excavation site on the North Fork of Ward Creek in 1991, previous excavation at this site in 1974 and additional retrieval of bone from 1974 to 1981 yielded a relatively complete adult mastodon skeleton, as well as a limited number of fragments of a juvenile mastodon and isolated elements from additional (two?) adult mastodons. No ulna elements were identified previously. Paleoecology suggests that the Ward Creek mastodons were buried in Pleistocene sediments forming the surface bottom of a shallow water lowland swamp, which was in proximity to upland spruce forests. Studies by Delcourt and Delcourt (1977, 1983) suggest that pine and hardwoods would have been components of this swamp. W. E. Miller (1987) reports that the vast majority of *Mammot americanum* fossils have been recovered from bog, swamp, marsh, or sinkhole situations associated with regions where spruce was abundant. Similarities to the Ward Creek site are discernible in a recent report of a Columbian mammoth (*Mammuthus columbi*) excavated from the Wasatch Mountains of Utah, which indicates that this mammoth became mired in clayey silts of a shallow fossil glacial lake rimmed with sedge and containing spruce macrofossils (Gillette and Madsen, 1993). Interestingly, a high percentage of juvenile or young adult mastodon fossils in these situations suggests that becoming mired in bog-swamp-marsh-sinkhole deposits was a common danger for inexperienced mastodons (W. E. Miller, 1987). For example, a clay-plugged sinkhole resulting from water seepage along a fault line in a spruce/fir region defines the location of juxtaposed fossil sub-adult and mature mastodons excavated from the Wasatch Mountains, Utah (W. E. Miller, 1987). Proximity of the Baton Rouge Fault to the Ward Creek excavation site (Sibley, 1972) poses interesting potential influences and parallels. The Baton Rouge Fault intersects the North Fork of Ward Creek ap-

Figure 9. Ward Creek Pleistocene pomatiopsid and succineid, sinistral and dextral views: (a) *Pomatiopsis lapidaria* [x 16.2, WC-91-30b]; (b) *Succinea ?forsheyi* [x 16.2, WC-91-30b].



proximately 0.2 kilometers upstream of the excavation site.

Although the bone is depleted of collagen, the well-preserved cortex retains indicators of muscle attachment sites and vascular or nerve impressions. A few examples of parallel marks consistently spaced 3 mm apart suggest postmortem interaction with this bone by a small mammal. Markings on bone do not resemble those reported as butchering marks from Clovis site mammoths in New Mexico (Saunders *et al.*, 1994) and South Dakota (Hannus, 1990). Although Fisher (1984) reported presence of burned bone at a Paleoindian mastodon site in Michigan, what initially appeared to be charred bone at Ward Creek is better designated post-mortem staining of bone.

VI. CONCLUSIONS

Shell dates, sediment traits, mollusk species, and paleoecology suggest that the excavation unit yielding a fossil mastodon ulna is part of a late Pleistocene swamp subsurface where silt derived from both reworked eolian loess and probable glacial silt deposits combined with terminal Prairie Terrace depositions. This sediment unit is also associated with initial deposition of late Wisconsinan basal loess (sometimes referred to as basal Peoria Loess or pre-Peoria Loess) by correlation with gastropod species (Richards, 1938a), by radiocarbon dates at other sites near the range of $21,220 \pm 360$ yr B.P. reported on here (Alford, Kolb, and Holmes, 1983; B. J. Miller *et al.*, 1985; Givens and Givens, 1987; Clark *et al.*, 1989; Autin *et al.*, 1991; Jackson and Givens, 1994), and by sediment characteristics (Richards, 1938a; B. J. Miller *et al.*, 1985; B. J. Miller *et al.*, 1988; McCraw and Autin, 1989; B. J. Miller, 1991). Granulometric analysis suggests this late Wisconsinan sediment to be a clay/silty clay loam. Sediment characteristics and stratigraphy suggest admixture of the Pleistocene Prairie Terrace with initial late Wisconsinan loess at a basal transition zone (B. J. Miller *et al.*, 1985; B. J. Miller *et*

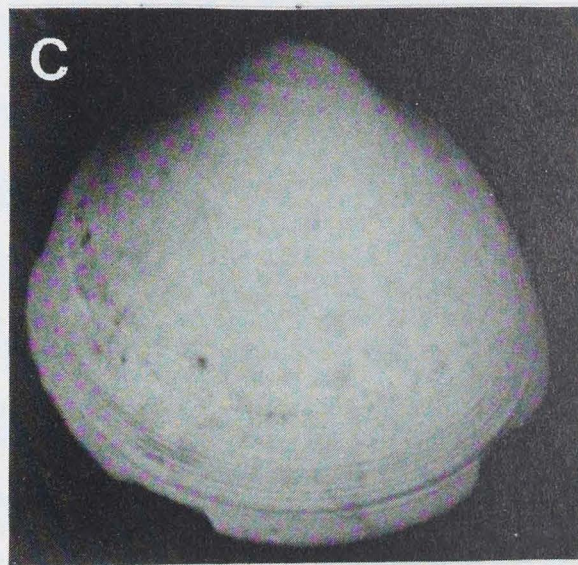
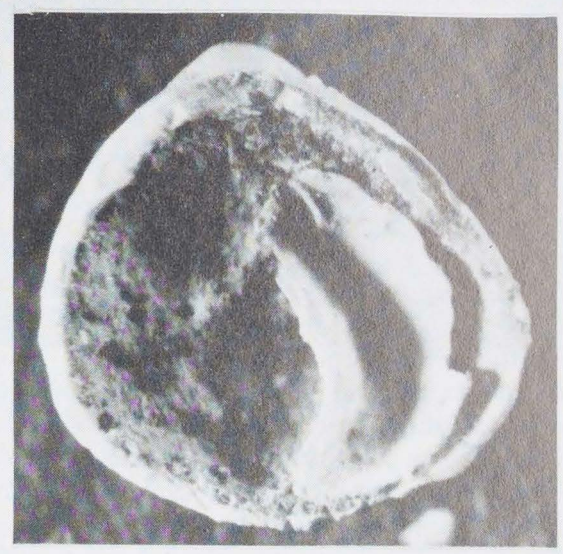
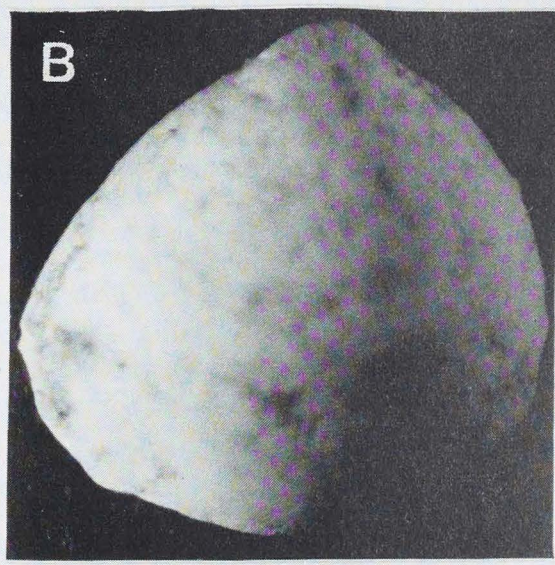
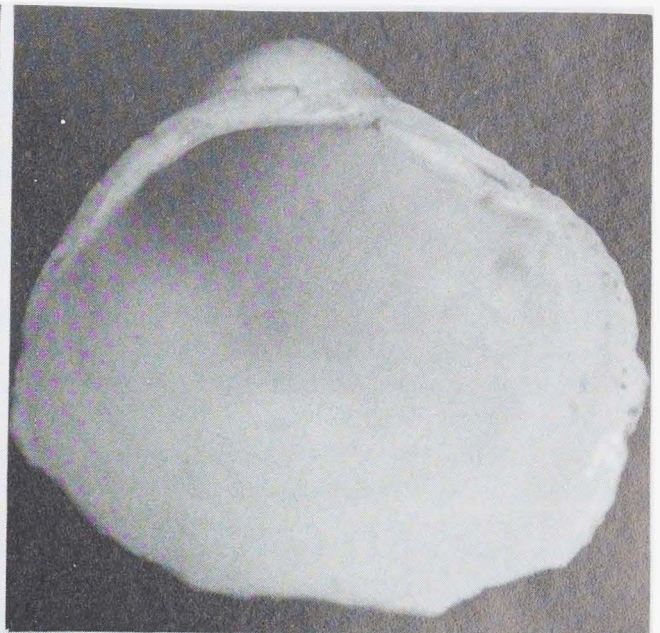
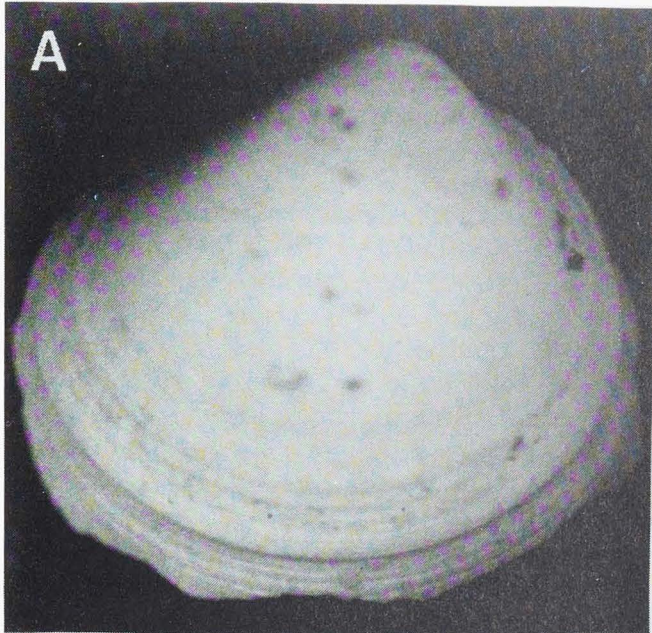
al., 1988). In the Amite River Valley, this transition zone would be between the Pleistocene Prairie Terrace and the overlying Watson alloformation. The fossil yielding unit contrasts more typical and more recent Peoria Loess by mollusk assemblage, radiocarbon date, and sediment characteristics (B. J. Miller *et al.*, 1985; Autin and McCraw, 1989; B. J. Miller, 1991). The fossil mollusk assemblage may be indicative of basal mixed zones in other localities.

The Ward Creek Mastodon ulna was buried in a shallow swamp dominated by Planorbis mollusks. This micro-environment was probably slightly warmer but similar to the synchronous temperate paleoclimate characterized by spruce forests in upland regions of the Tunica Hills north of Ward Creek. Pine and hardwood trees were probable components of this swamp. Influence of climatic factors related to the glacial maximum is inferred.

A few speculations are ventured. Inferred paleoenvironment in conjunction with proximity of this mastodon ulna with previously excavated adult and juvenile mastodon fossil bone from this site on the North Fork of Ward Creek encourages speculation that this was the site of entrapment of these animals. Inferred paleopathology leads the author to speculate that parasitic infection was an environmental stress for mastodons inhabiting a Ward Creek swamp. The dominant mollusk species, *Gyraulus parvus*, as well as several other species retrieved directly from the matrix of this mastodon ulna are known to be intermediate hosts for blood parasites. The density of aquatic mollusk shell around the bone, as determined from inventories of material screened from sediment samples (Lewis, 1994) and carbonate fraction analysis (Table 1), appears to have facilitated preservation of this bone by providing a calcium carbonate matrix.

There is no direct evidence for pre-mortem interaction with this mastodon bone by Paleoindians nor of butchering marks associated with mastodon/mammoth sites

Figure 10. Ward Creek Pleistocene sphaeriid peaclams: (a) left valve *Pisidium ?variable* [x 17.0, WC-91-41]; (b) left valve *Pisidium ?compressum* [x 15.0, WC-91-19]; (c) right valve *Pisidium ?equilaterale* [x 16.8, WC-91-19]. >



elsewhere in North America. There is some evidence for limited postmortem gnawing on the bone by a small mammal. Most markings on the cortex appear to be muscle attachment sites or nerve/vascular impressions.

Frequency of mollusk families within two contrasting excavation units, the bone-bearing Pleistocene unit and the overlying Holocene alluvium/colluvium, is informative. Considering the Class Gastropoda, of the 331 identified individual specimens reported here for the Pleistocene assemblage, planorbids comprise 73% (236/322) of the gastropods present. *Gyraulus parvus* is the most abundant species present, comprising 87% (206/236) of planorbids and 64% (206/322) of gastropods present in the Pleistocene assemblage. Hydrobiids, mainly *Amnicola limosus*, comprise 14% (46/322) of Pleistocene gastropods. Of the 115 specimens identified here for the Holocene unit overlying the fossil-yielding unit, Hydrobiids represent 68% (48/71) and Physids comprise 20% (14/71) of gastropods present in the Holocene assemblage. Planorbids only represent 7% (5/71) of gastropods present in the Holocene assemblage, and this figure may be high due to their suggested intrusive presence in the upper unit. Considering the Class Bivalvia, in the Pleistocene fossil yielding unit, *Pisidium* is the most common bivalve genus, but represents only 2% (7/331) of the Pleistocene mollusks. In contrast, in the Holocene excavation unit, *Sphaerium* and *Musculium* are common.

VII. ACKNOWLEDGMENTS

I thank Dr. John J. Alford for pointing out the research potential at the North Fork of Ward Creek site, for his constructive comments on my interpretations, and for his assistance with the initial excavation at the site along with Joseph Holmes and Dr. Anthony Lewis. Dr. Anthony Lewis of Louisiana State University (LSU) Department of Geography and Anthropology provided ongoing technical and personal support as well as reviews of the manuscript and a site photograph (Fig. 3). Anthropology students of Dr. Heather McKillop, LSU Department of Geography and Anthropology, assisted at the excavation site on 11/1/91. Dr. Lauri Anderson, LSU De-

partment of Geology, provided use of a microscope with a camera. Cindy Henk, LSU Department of Microbiology, assisted with SEM scanning for pollen. Dr. Greg Stone and graduate student Charles K. Armbruster, LSU Department of Geography and Anthropology, provided granulometric analysis of selected samples. Mary Lee Eggart, LSU Department of Geography and Anthropology, prepared the map and site diagram. Dr. Whitney Autin, Louisiana Geological Survey, provided information on regional soils. Bryan Harmon, City of Baton Rouge Drainage Engineer, granted permission for the excavation. Dr. Judith Schiebout and Alvin Phillips of LSU Museum of Natural Science, John Caruso and Michael Taylor of Tulane University Museum of Natural History, Charles Finsley of Dallas Museum of Natural History, Dr. Chris Cunningham of Houston Museum of Natural Science, and Dr. William Orr of the University of Oregon Thomas Condon State Museum of Fossils generously granted access to comparative collections. I thank the reviewers for their helpful comments.

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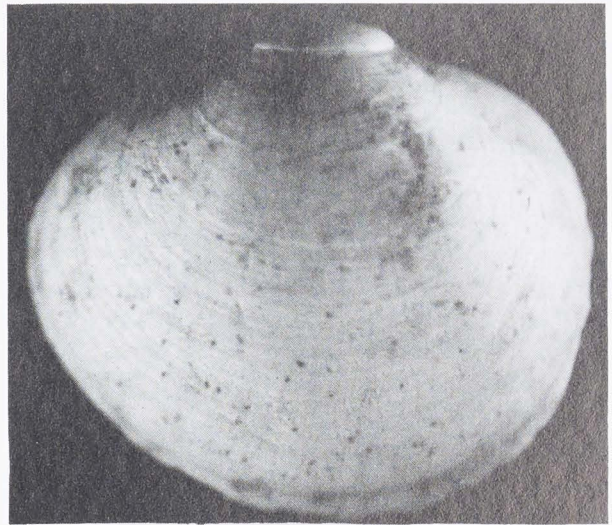


Figure 11. Ward Creek Pleistocene sphaeriid fingernailclam, *Musculium partumeium* [x 12.0, WC-91-20].

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