PLEISTOCENE LAND AND FRESH-WATER MOLLUSKS FROM NORTH TEXAS*

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Prior to the use of Carbon 14 dates, many local Pleistocene molluscan faunas associated with sparse vertebrate remains were incorrectly dated. Since the date determinations were postulated upon the basis of the vertical range records of fossil mollusks in the Mid-Continental United States, the misconceptions are easily understood. Southern species appearing in the faunules are unknown from the Mid-Continent region. Collections of fossils from many localities were considered as isolated local faunas and few attempts were made to correlate them.

Detailed studies in recent years of formations such as the T-2 terrace (Slaughter, *et al.*, 1962), Good Creek (Dalquest, 1962), and Groesbeck (Dalquest, 1965) brought forth inconsistencies in earlier conceptions of the Pleistocene in Texas. Some investigators had predetermined an early extended period of desiccation to have occurred during the Illinoian epoch, surmising that post-Illinoian faunas would reveal a noticeable climatic change.

The Carbon 14 dated faunas in this study reveal that if such a period of desiccation existed, its occurrence was some time after 9,000 B.P. (before present), near the close of the Wisconsin epoch. Records of the Kansan age faunas from formations in Texas such as the Cudahy (Hibbard, 1944, 1949; Frye and Leonard, 1952, and others), and the Seymour (Hibbard and Dalquest, 1960) were better determined because of the presence of the overlying Pearlette volcanic ash, and the presence of abundant vertebrate remains.

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Fossil Molluscan Faunas

The fossil molluscan assemblages in this study have been re-examined since early publications and as a result, there will be additions to and deletions from the faunas. The additions are often the result of continued collections made from the localities after publication.

All of the fossil shells were collected from Pleistocene sediments in large pieces of matrix which were then stored in burlap bags until dry; they were then washed through screens in the manner described by Hibbard (1949). Many of the smaller shells were dipped from the water as they floated free from the submerged matrix. Others were sorted from the remaining solids that failed to pass through the screen. The collected shells were soaked in detergent overnight then boiled briskly for thirty minutes to remove the sediment clays from the shell apertures. Tiny specimens were boiled separately to prevent their being sucked into the larger shells during the cleaning process. The shells were then dried, examined, sorted, catalogued, and then placed in the shell depository in the Department of Biology at Southern Methodist University. Catalogue numbers accompany the listed species.

In tables presented in this report the approximate abundance of species in one gallon of concentrate is indicated as follows: A = over 50, C = 21-50, S = 20, and R = 1-5 shells.

FOSSIL MOLLUSCAN ASSEMBLAGES

The Good Creek Local Fauna, Good Creek Formation, Foard County, Texas

Cummins (1893) was the first to observe and publish on vertebrate fossils in Pleistocene beds in north central Texas. One of these sites was near Good Creek in Foard County. For many years, these Pleistocene beds were considered to be a part of the Seymour Formation which was probably of a Kansan glacial age (Hibbard and Dalquest, 1960). Subsequently Dalquest (1962) re-examined these classic deposits and postulated them to be of Sangamonian age by vertebrate faunal inference.

Land and fresh-water fossil shells were abundant in the sediments of these deposits. Most of the shells came from breccia layers throughout the gray clay sediments. The concentrations of shells as noted could be indicative of repeated rapid deposition from the intermittent streams of ancient Good Creek. The unusual number of land species present would furnish supplementary evidence of this postulation.

Fossil shells were collected from the following three localities, and after comparison all were found to contain the same species, and hence considered contemporaneous.

Localities:

1. The Easley Ranch local fauna (Dalquest, 1962) was collected from the Easley Ranch where State Farm Market Road 654 crosses Monument Creek. This locality is considered the type locality of the Good Creek formation. This locality furnished the most abundant fossil shells.

2. Collections were also made from the Leslie McAdams ranch downstream from the Easley ranch.

3. Additional collections came from the J. D. Smith ranch which is located upstream from the type locality. Caliche encrusted fossil shells of *Quadrula forsheyi* were abundant from concentrated terrace gravels at this site. Although the clam shells were not found in the other localities, the fossil land and fresh-water fauna also taken from the Smith Ranch was composed of substantially the same species as from the Easley and McAdams ranches.

Specimens from all locations were in excellent preservation and in some instances the small sphaeriids, such as *Sphaerium striatinum* were found articulated.

The Good Creek formation has been assigned a late Sangamonian age on the basis of a substantial collection of vertebrate remains and upon geological evidence.

List of Molluscan Species

	Relative Abundance
Pelecypoda	
Quadrula forsheyi Lea - SMU P 737	R
Elliptio dilatatus (Raf.) - SMU P 738	R
Sphaerium striatinum (Lamarck)	C
Pisidium nitidum Jenyns - SMU P 723	S
Gastropoda	
Amnicola limosa (Say) - SMU P 713	R
Helisoma trivolvis (Say) - SMU P 722	R
H. anceps (Menke) - SMU P 704	S
Gyraulus circumstriatus (Taylor) - SMU P726	S
G. parvus (Say) - SMU P 719	A
G. crista (Linnaeus) - SMU P 731	R
Physa anatina Lea - SMU P 702	A
P. gyrina Lea - SMU P 703	S
Stagnicola palustris (Müller) - SMU P 707	R
S. caperata (Say) - SMU P 708	C
Fossaria dalli (Baker) - SMU P 706	S
F. obrussa (Say) - SMU P 705	S
Gastrocopta armifera (Say) - SMU P 714	R
G. procera (Gould) - SMU P 715	R
G. pentodon (Say) - SMU P 716	C
G. corticaria (Say) - SMU P 728	R
G. cristata (Pils. & Van.) - SMU P 730	S
G. pellucida hordeacella (Pils.) - SMU P 727	R
Pupilla blandi (Morse) - SMU P 711	R
Vertigo ovata (Say) - SMU P 717	C
V. milium (Gould) - SMU P 718	C
Pupoides albilabris (C.B. Adams) - SMU P 712	C
Discus cronkhitei (Newcomb) - SMU P 709	C
Vallonia gracilicosta Reinhardt - SMU P 725	R
Hawaiia minuscula (Binney) - SMU P 701	C
Euconulus fulvus (Müller) - SMU P 733	R
Succinea sp. - SMU P 720	S
Stenotrema leai (Binney) - SMU P 724	S
Mesodon indianorum (Pilsbry) - SMU P 734	R

Ecology

The most unusual species in this assemblage is *Gyraulus crista* (pl. 1, fig. 5), since its present range is from Michigan to Maine. Only two species of shells are listed as abundant, *Physa anatina* and *Gyraulus parvus*, and these are species which prefer quiet waters and abundant algae. The presence of the pelecypods and *Amnicola* indicates perennial waters. Moist woodlands with abundant humus are indicated by *Vertigo milium*, *V. ovata*, *Vallonia gracilicosta*, *Stenotrema leai* and *Carychium exiguum*.

Among the seventeen species of land snails listed, *Vallonia gracilicosta*, *Vertigo milium*, *Pupilla blandi*, and *Discus cronkhitei* range north of Texas today. *Gyraulus circumstriatus*, *Gyraulus crista*, *Stagnicola palustris*, and *Stagnicola caperata* are all aquatic species which today range north of Texas.

Assuming that the present day environmental needs of the species present in the Good Creek deposit are essentially the same as they were in the Sangamon, then these shells would partially support Dalquest's (1962) conclusions. Dalquest postulated for the area a marshy stream flowing through a 'rather arid grassland.' 'More humid woodlands must have occurred along the immediate banks of the stream, to permit the existence of such forms as the short-tailed shrew, rice rat, fulvus harvest mouse, etc.' However, as far as temperatures are concerned, there would be no reason to conclude that the winters were any milder than they are today, but by inference based upon the shells of current northern distribution, the summer temperatures apparently did not show the sustained high extremes as they do at present.

Moore Pit Local Fauna of the T-2 Trinity River Terrace

Shuler (1918) first described vertebrate fossils from the Pleistocene Trinity River terrace deposits near Dallas, Texas. Slaughter and others studied and collected from the terrace deposits for several years prior to publication (Slaughter, *et al.*, 1962). The shells were taken from an exposure in the Wood Pit located at the south end of Deepwood Street, south of the southern arc of Loop 12 in Dallas. Subsequently (Slaughter, 1965) has incorporated the Wood Pit as a locality of the Moore Pit local fauna.

The fossil shells were homogeneous in gray clay beneath the familiar laminated sands of the Lower Shuler formation. Probably the gray clay represented an extinct pond on the old flood plain.

Carbon 14 dates from matrix within the Upper Shuler unit, which overlies the Lower Shuler in the Wood Pit, gave the age at slightly more than 37,000 years B.P. (Brannon *et al.*, 1957).

List of Molluscan Species	Relative Abundance
Gyraulus parvus (Say) - SMU P 469	C
G. circumstriatus (Tryon) - SMU P 474	A
Planorbula armigera (Say) - SMU P 470	C
Helisoma anceps (Menke) - SMU P 460	S
H. trivolvis (Say) - SMU P 472	S
Stagnicola caperata (Say) - SMU P 480	S
Fossaria humilis modicella (Say)-SMU P 465	S
F. dalli (Baker) - SMU P 481	R
F. obrussa (Say) - SMU P 479	S
Aplexa hypnorum (Linn.) - SMU P 482	S
Physa gyrina Say - SMU P 459	A
Bulimulus dealbatus (Say) - SMU P 451	R
Carychium exiguum (Say) - SMU P 468	S
Hawaiia minuscula (Binney) - SMU P 461	S
Retinella indentata (Say) - SMU P 477	R
Zonitoides arboreus (Say) - SMU P 475	S
Strobilops texasiana (Pils. &Ferr.)-SMU P 456	S
Helicodiscus parallelus (Say) - SMU P 464	S
Gastrocopta armifera (Say) - SMU P 466	R
G. contracta (Say) - SMU P 473	R
G. pentodon (Say) - SMU P 457	A
G. albilabris (C.B. Adams)-SMU P 453	S
Pupisoma dioscoricola (C.B. Adams) - SMU	R
Succinea sp. - SMU P 458	S
Helicina orbiculata tropica Pfr.-SMU P 452	R
Mesodon thyroidus (Say) - SMU P 455	S
Polygyra texasiana (Moricand) - SMU P 463	R
Stenotrema leai (Binney) - SMU P 454	A

Ecology

Among the 29 species listed for the Moore Pit Local Fauna of the T-2 Terrace are only five species which do not inhabit this area today. *Gyraulus circumstriatus*, *Planorbula armigera*, *Stagnicola caperata*, and *Aplexa hypnorum* are all aquatic pulmonates of a more northerly distributional range, whereas *Pu* pisoma dioscoricola ranges from extreme southern Texas to Brazil. The five species of aquatic pulmonates listed above are forms which thrive in shallow, sluggish temporary or perennial waters. They all can be considered species which can tolerate temporary desiccation assuming that moisture is still retained in the dried up slough or pond.

Indicative of moist woodland is the species *S. leai* which is listed as abundant. Associated along with this species in a humid environment are *M. thyroidus*, *Z. arboreus*, *C. exiguum*, *S. texasiana*, and *H. parallelus*. Species which can apparently thrive in humid environments as well as the more open, exposed, well-drained areas are the *Gastrocopta* species, *Helicina*, *Hawaiia* and *Bulimulus*. However, characteristic of open, well-drained woodlands is *Helicina* and *Bulimulus*, the latter genus a typical prairie species with the ability to withstand several months of desiccation by producing epiphragms over the shell aperture thus conserving body moisture.

The presence of *Pupisoma* might indicate a climatic condition which would involve greater humidity than that which exists in the area today. One might also infer that low temperature extremes for periods of several weeks did not occur because under such circumstances such genera as *Bulimulus*, *Helicina*, and *Pupisoma* probably could not have survived. We might also infer that since the species previously mentioned with a more recent northerly distribution lived in the Moore Pit area that extreme high temperatures of several weeks duration did not exist as they do today.

Quitaque Local Fauna, Motley County, Texas

In 1958, Mr. Gene Wilson of Ringgold, Texas, brought some teeth of an extinct camel (*Camelops* sp.) to W. W. Dalquest of Midwestern University. He found these in the bed of a small arroyo tributary to Quitaque Creek in the northeast corner of Motley County, south of Turkey, Texas, approximately one-half mile east and downstream from the crossing of the creek with State Farm Market Road 599. Subsequent trips by Dalquest (1965 B) yielded additional vertebrate remains and a substantial molluscan fauna.

The Quitaque deposits are assumed to be terrace sediments. The fossil remains were taken from clay beds that were probably ponds or oxbow lakes in the old flood plain. Shells of the sand clam, *Lampsilis anodontoides* Lea were abundant in one of the clay beds containing fossil bones. These shells were submitted to E. E. Bray of Socony Mobil, Dallas, Texas, for C 14 determination. The test revealed an age of 31,400 years B. P. ±5600 years. A second test gave a marginal error of only ±3200 years.

List of Molluscan Species	Relative Abundance
Pelecypoda	
**Lampsilis anodontoides* Lea - SMU P 167	C
Sphaerium striatinum (Lamarck) - SMU P 121	A
Pisidium compressum Prime - SMU P 126	C
Gastropoda	
Valvata tricarinata (Say) - SMU P 118	S
Amnicola integra (Say) - SMU P 131	R
Fossaria parva (Lea) - SMU P 119	S
F. dalli (Baker) - SMU P 134	S
F. obrussa (Say) - SMU P 135	C
Stagnicola caperata (Say) - SMU P 136	C
S. palustris (Müller) - SMU P 122	A
Gyraulus parvus (Say) - SMU P 102	A
***Gyraulus labiatus* (Leonard - SMU P 101	R
G. circumstriatus Tryon - SMU P 103	R
Promenetus umbilicatellus (Ckll.)-SMU P 125	C
Helisoma anceps (Menke) - SMU P 116	S
H. trivolvis (Say) - SMU P 129	R
Ferrissia rivularis (Say) - SMU P 137	R
Aplexa hypnorum Linn. - SMU P 138	S
Physa anatina Lea - SMU P 120	A
P. gyrina Lea - SMU P 107	A
Strobilops sparsicostata (Baker) - SMU P 105	R
Discus cronkhitei (Newcomb) - SMU P 108	A
Helicodiscus parallelus (Say) - SMU P 115	R
H. singleyanus (Pilsbry) - SMU P 117	C
H. eigenmanni (Pilsbry) - SMU P 133	R
Gastrocopta armifera (Say) - SMU P 110	S
G. procera (Gould) - SMU P 111	S
G. tappaniana (C.B. Adams) - SMU P 113	S
G. cristata (Pils. & Van.) - SMU P 112	C
G. pentodon (Say) - SMU P 114	S
Vertigo ovata (Say) - SMU P 104	A

*The shells of *Lampsilis anodontoides* are listed as common but were not collected by the technique used for the other shells. They were quite fragile and only a few perfect specimens were collected although the shells were close together in a three-inch layer at the base of the clay sediment. They were not compressed or distorted.

Pupilla muscorum (Linn.) - SMU P 124	S
Pupoides albilabris (C.B. Adams) - SMU P 109	C
Zonitoides arboreus (Say) - SMU P 127	S
Euconulus fulvus (Müller) - SMU P 130	S
Vallonia gracilicosta (Reinh.) - SMU P 122	S
Succinea ovalis Say - SMU P 133	R
Succinea sp. - SMU P 132	R
Stenotrema leai (Binney) - SMU P 123	R

Ecology

The presence of *Lampsilis anodontoides*, the sand clam, is indicative of a stream or lake habitat with sand or gravel bottoms and the water well oxygenated. Such a stream or lake would have to be of sufficient size to support the garfish which serves as intermediate host for *L. anodontoides*. W. W. Dalquest (1964) described the sand and gravel beds of the Quitaque Site and assumed the terraces resulted from the filling of an older, broader valley. The clays, according to his postulation, were 'deposited in ponds or oxbow lakes on the old floodplains.'

In this habitat the fossil shells seem to bear out the ecological assumption of Dalquest. Well aerated perennial wwters along with abundant standing waters were necessary to provide adequate habitat for the 19 species of aquatic mollusks reported for the Quitaque site. As previously mentioned, the common occurrence of *L. anodontoides* indicates clear perennial water with a flow adequate for good aeration, and a sand or gravel substrate. Lending support to such an environment is the presence of *Sphaerium striatinum, Pisidium compressum,* and *Valvata tricarinata*, all of which seldom occur in ponds, bogs, or swamps. However, an abundance of sluggish waters supporting abundant vegetation undoubtedly existed because such habitats were optimum for the genera *Fossaria, Stagnicola, Gyraulus, Helisoma, Ferrissia, Aplexa,* and *Physa*. Among the land shells, *Discus cronkhitei* and *Vertigo ovata* were the only species classified as abundant at the Quitaque site. Both of these species require humid surroundings. Both usually occur along stream beds or in well-shaded areas where moisture is retained.

Species of a more northerly distribution in the Quitaque site that to our knowledge have not been reported as Recent for Texas are *Stagnicola caperata, Stagnicola palustris, Gyraulus labiatus, Gyraulus circumstriatus, Aplexa hypnorum, Strobilops sparsicostata* (now extinct) and *Pupilla muscorum*.

** There is some question as to the validity of *Gyraulus labiatus* (pl. I, fig. 3). It is considered by many to be of large size but well within the size range of *G. parvus* (pl. I, fig. 4). In this report *G. labiatus* was separated from *G. parvus*, the separation based upon the unusually large shell diameters of *G. labiatus*

The Clear Creek Local Fauna, Denton County, Texas

In 1960, Ritchie Slaughter and Ritchie (1963) found a concentration of fossil shells in sediment revealed in an abandoned gravel pit in Denton, Texas. The fossil location lies along Clear Creek, north of Denton, Texas. This portion of Clear Creek which empties into the Elm Fork of the Trinity River is on the farm of Mr. Phillip Frietsch. Fossil fresh-water and land shells were found in a sandy clay zone overlying basal gravels. Radiocarbon tests which were run on the shells by the Socony Mobil Field Research Laborstory in Dallas, Texas (Test No. SM 534) gave a date of 28 840 4 740 B.P. for the deposit.

Pelecypoda	Relative Abundance
Sphaerium striatinum (Lamarck) - SMU P 269	S
Pisidium nitidum Jenyns - SMU P 374	S
Gastropoda	
Valvata tricarinata (Say) - SMU P 356	R
Amnicola integra (Say) - SMU P 367	C
Physa anatina Lea - SMU P 373	S
Gyraulus parvus (Say) - SMU P 357	A
Helisoma anceps (Menke) - SMU P 351	C
Fossaria dalli (Baker) - SMU P 370	R
F. bulimoides (Lea) - SMU P 379	R
Gastrocopta armifera (Say) - SMU P 354	A
G. procera sterkiana Pilsbry - SMU P 360	A
G. pellucida hordeacella Pils. - SMU P 358	A
G. contracta (Say) - SMU P 361	A
Pupoides albilabris (C.B. Adams) - SMU P 353	C
Helicodiscus parallelus (Say) - SMU P 364	C
H. singleyanus (Pilsbry) - SMU P 362	C
Anguispira alternata (Say) - SMU P 376	R
Strobilops texasiana (P. & V.) - SMU P 365	A
Vallonia gracilicosta Reinhardt - SMU P 368	R
Carychium exiguum (Say) - SMU P 359	R
Hawaiia minuscula (Binney) - SMU P 363	S

Euconulus fulvus (Müller) - SMU P 380	R
Zonitoides arboreus (Say) - SMU P 375	R
Retinella indentata (Say) - SMU P 366	S
Cionella lubrica (Müller) - SMU P 377	R
Succinea sp. - SMU P 381	R
Stenotrema leai (Binney) - SMU P 352	R
Polygyra texasiana (Moricand) - SMU P 355	R
Praticolella berlandieriana (Mor.)-SMUP 378	R
Helicina orbiculata tropica Pfr. - SMU P 372	S
Bulimulus dealbatus (Say) - SMU P 371	C

Ecology

With the exception of the fresh wwter branchiate, *Valvata tricarinata*, and the land snail *Vallonia gracilicosta* (both species of a more northerly distribution) the shells of the Clear Creek deposit are found in this area today. The land snails, *Bulimulus dealbatus* and *Helicina orbiculata tropica* are able to withstand prolonged drouth and are typical prairie and sparse woodland species. Perennial cool water was present to support the sphaeriid species and the branchiate gastropods *Valvata* and *Amnicola*. Assuming that adequate spring fed water was available to support the branchiate species of mollusks then one could postulate a prairie environment with sparse woodland, perhaps with more dense tree clusters.

Interestingly enough the above environmental assumption based upon mollusks coincides with the postulation of Slaughter and Ritchie (1963) who stated as follows concerning the fossil vertebrates of Clear Creek: 'If one does not consider the preferences of the fossil lemming species as necessarily identical with those of the living species, there is not a single mammal in the Clear Creek local fauna that would be considered a northern type. It would appear that during the time of the Clear Creek local fauna, winters were at least as warm as today, or perhaps warmer. Annual rainfall was five to ten inches less unless warmer winter temperatures made the moisture less effective.' These writers go on to say that based upon 'current rwnges of the extant species are more suggestive of an interglacial-interstadial climate than of a glacial age.' Considering the general ecology of the Clear Creek molluscan assemblage the species present could easily support the environmental postulations of Slaughter and Ritchie.

The Howard Ranch local fauna (Groesbeck formation), Hardeman County, Texas

Since 1891, when W. F. Cummins discovered mammalian remains at the forks of the Groesbeck Creek in Hardeman County, local outcroppings were considered a part of the Seymour formation. The Seymour formation has been assigned to the Kansan Glacial Age (Hibbard and Dalquest, 1960).

W. W. Dalquest, Midwestern University, Wichita Falls, Texas, in 1958 began a study of the area described by Cummins. Through collected vertebrate remains, *Bison antiquus* and *Bison occidentalis*, it became evident that the deposits were post-Kansan in age (Dalquest, 1965). Land and fresh water shells were abundant and were preserved in fossiliferous lenses of sandy gravel stratum beneath grayclay layers throughout the Groesbeck formation. On the Howard Ranch, approximately one-half mile upstream from the junction of the South and North Fork of Groesbeck Creek abundant fossil shells of the pea clam, *Sphaerium striatinum*, were taken from the shell lenses and submitted to Mr. E. E. Bray of the Socony Mobil Oil Company of Dallas, Texas, for Carbon 14 dates. Fourteen determinations were made of the shells. The mean of five determinations, all of which were within the statistical limit given, was 16,775 ±565 years B. P. Mr. Bray stated in personal correspondence that he had also made a carbon determination of the surface of the shell and that 'carbon from the surface of the shells was the same age (within experimental error) as carbon from the interior portions, indicating that partial replacement was improbable.' The Groesbeck formation was thus laid down during the Brady interstadial event of the Wisconsin Glacial age.

A second collection of shells from a locality described by Frye and Leonard (1963) on the Howard Ranch was also submitted to Mr. Bray for carbon dating. The species from this locality were used in the test and are indicated on the faunal list under Laboratory No. SM 620. A date of 19,908 ± 1,074 B.P. was obtained. The variation in the dates and some faunal differences in localities indicates a slight nonconformity. The faunas, however, are quite comparable and the carbon dates are close enough to indicate a nearly contemporaneous deposition for the two localities.

All collections of the Howard Ranch local fauna were collected entirely on the Howard Ranch near Quahnah, Texas.

Locality 1. Collections from many typical shell lenses throughout the Groesbeck formation were made between 1959 and 1963. These were kept separated until it became obvious that the fossils were all from the basin of a single lake. These lake basin faunas are listed as Locality 1.

It is interesting to note that the presence of perfect specimens of *Lymnaea stagnalis jugularis* (Pl. I, fig. 1 & 2) is recorded for the first time in Texas Pleistocene studies. The presence of this species indicates permanent water and a substantial lake described by Dalquest (1965). The first *Lymnaea stagnalis* shells collected were found in a gray clay deposit about thirty feet above the channel which was eroded into the Permian bed rock. The shells were whole but badly fractured. A few were preserved for the collections by removing them partially encased in their native clay and saturating the entire mass with shellac for preservation. Many spires and fragments of *L. stagnalis jugularis* were evident in the screenings. Thus one could see that the spires of the broken shells of this species might be misconstrued as *Acella haldemani*.

Locality 2. Collections also from the Howard Ranch known as the Windmill Site are separated from the basin faunas because of the slight faunal differences within a restricted area. This locality is located 5½ miles north and 4 miles west of Highwwys 287-283 intersection at Quanah, Hardeman County, Texas.

Locality 3. The molluscan fauna from a third locality described by Frye and Leonard (1963) and Dalquest (1965) is considered separately because of the C14 date 19,098 10,074 B.P., which shows some nonconformity. This site is described by Dalquest (1965) as follows: '... beside a small bridge on a country road on the south side of the North Fork of Groesbeck Creek, 6.4 miles north and 4.2 miles west of the intersection of Texas State Highway 283 and U.S. Highway 287, beside the courthouse in Quanah.' Spires of *Lymnaea stagnalis* were also collected from this area.

Pelecypoda	Localities 1	2	3
Sphaerium striatinum (Lamarck) *673	A	A	S
Pisidium compressum Prime *687	A	A	S

Gastropoda			
Carychium exiguum (Say) *690	R	R	A
Fossaria dalli (Baker) *655	S	S	C
F. obrussa (Say) *683	R	S	C
Stagnicola palustris (Müller) *675	A	A	A
S. caperata (Say) *681	S	R	S
Lymnaea stagnalis jugularis (Say) *680	S	S	S
Gyraulus parvus (Say) *659	A	A	A
G. crista (Linn.) *671	-	C	-
Helisoma anceps (Menke) *653	C	A	R
H. trivolvis (Say) *672	S	S	S
Ferrissia meekiana (Stimpson) *689	R	R	-
Physa anatina Lea - *651	A	A	C
Amnicola limosa (Say) *690	A	A	-
Valvata tricarinata (Say) - *691	-	-	S
Strobilops sparsicostata Baker - *660	S	-	S
Gastrocopta armifera (Say) *662	R	C	C
G. cristata (Pils. & Van.) *664	C	C	S
G. pentodon (Say) *665	C	C	S
G. procera (Gould) *663	S	S	-
Pupoides albilabris (C.B. Adams) *667	C	C	C
Pupilla blandi Morse *692	R	S	S
P. muscorum sinistra Franzen *687	S	S	S
Vertigo ovata (Say) - *668	R	C	S
Vallonia parvula Sterki *688	S	S	S
Cionella lubrica (Müller) *679	R	-	S
Succinea cf. *S. grosvenori* Lea *674	R	-	R
S. cf. *S. luteola* Gould - *678	S	R	R
Discus cronkhitei Newcomb - *669	S	-	S
Helicodiscus parallelus (Say) *657	S	C	C
Deroceras sp. *693	R	R	-
Euconulus fulvus (Müller) *670	R	S	C
Hawaiia minuscula (Binney) *670	C	C	S
Zonitoides arboreus (Say) *684	S	R	C
Polygyra texasiana (Moricand) *682	S	-	-
Stenotrema leai (Binney) - *695	R	R	C

Ecology

Dalquest (1965) in discussing ecological conditions which may have existed during Groesbeck time postulated that these conditions differed, but not sharply, from those that exist today. His assumption is based largely upon the premise that nine species of the eighteen species of indicator vertebrates still exist in the area today. Because of the existence of northern species he concludes that ex-

*The asterisk here represents the abbreviation 'SMU P' preceding the catalogue number in other tables.

treme summer temperatures were lower than those of today, and that, because of the existence of the rice rat and opossum, the winter temperatures were not lower than they are today and without the presence of cold fronts the winter temperatures would be much more uniform.

Certainly conditions of prolonged desiccation did not exist in Groesbeck time. Supporting such a conclusion is the abundance of such forms as *Sphaerium striatinum*, *Pisidium compressum*, and *Amnicola limosa*, all of which require permanent water. *S. striatinum* and *P. compressum*, particularly, are species which are seldom found even in ponds, swamps, or bogs but occur in lakes, rivers and creeks where there is usually some current action. However, marsh, bogs, and swwmp areas must have also existed in the Groesbeck as attested to by the presence of genera such as *Stagnicola*, *Ferrissia*, *Lymnaea*, *Gyraulus*, *Helisoma*, and *Physa*, all of which contain species associated with quiet waters, temporary waters, and abundant vegetation.

Among the 37 species of mollusks identified from the Groesbeck assemblage are *Stagnicola palustris*, *Lymnaea stagnalis jugularis*, *Stagnicola caperata*, *Gyraulus crista*, and *Valvata tricarinata*, all aquatic species which are largely northern in distribution. However, Wallen and Dunlap (1953) reported living *Stagnicola palustris* and *Valvata tricarinata* from Oklahoma.

The following six species of land snails are listed ws common in two of the three Groesbeck localities: *Gastrocopta armifera*, *G. cristata*, *G. pentodon*, *Pupoides albilabris*, *Helicodiscus parallelus*, and *Hawaiia minuscula*. Most of these species may be found in deep woodlands, flood plains, sparse woodlands or well-drained uplands.

Byers Local Fauna, Byers, Clay County, Texas

In 1960 some school children playing on the farm of Mrs. Paul Dowdy, three miles west of the town of Byers in Clay County, Texas, found some large elephant bones in an eroded gully. Their discovery was reported to W. W. Dalquest of Midwestern University, who began collecting matrix from the clay sediments around the bones for other possible vertebrate remains. These remains were meager, but fossil land and fresh-water shells were abundant and dispersed homogeneously throughout the deposit.

In the first report (Allen & Cheatum 1961) the age of the deposit was postulated to be glacial, possibly Illinoian based upon faunal Pleistocene studies in Texas at that time. More recent studies and Carbon 14 dating (by Socony Mobil of Dallas) reveal a Wisconsin age. The Carbon 14 tests were made on *Physa gyrina* shells and gave a date of 16,920 ± 665 B. P.

List of Molluscan Species	Relative Abundance
Pomatiopsis lapidaria (Say) SMU P 9	C
Helisoma trivolvis (Say) - SMU P 4	C
Planorbula armigera (Say) - SMU P 12	A
Gyraulus circumstriatus (Tryon) - SMU P 15	S
Promenetus umbilicatellus (Ckll.) SMU P 16	R
Physa gyrina (Say) - SMU P 17	A
Stagnicola exilis (Lea) - SMU P	S
S. caperata (Say) - SMU P 2	C
Gastrocopta armifera (Say) - SMU P 6	C
G. tappaniana (C. B. Adams) - SMU P 18	C
Pupoides albilabris (C.B. Adams) - SMU P 8	C
Vertigo ovata (Say) - SMU P 9	
Strobilops sparsicostata (Baker) - SMU P 11	R
Euconulus fulvus (Müller) - SMU P 13	R
Succinea sp. - SMU P 5	S
S. ovalis (Say) - SMU P 20	R
Oxyloma retusa (Lew) - SMU P 1	C
Helicodiscus parallelus (Say) - SMU P 7	R
Retinella electrina (Gould) - SMU P 14	S
Hawaiia minuscula (Binney) - SMU P 19	A
Stenotrema leai (Binney) - SMU P 3	C

Ecology

Allen and Cheatum (1961) postulated the Byers deposit as lacustrine, this assumption based upon the homogeneous distribution of the fossil shells and the species collected which were typical dwellers of swales, lakes and ponds. Among the species collected the following are more northerly in distribution: *Gyraulus circumstriatus*, *Planorbula armigera*, *Promenetus umbilicatellus*, *Physa gyrina*, *Succinea ovalis*, *Oxyloma retusa*, *Retinella electrina*, *Pomatiopsis lapidaria*, and *Stagnicola exilis*.

Ben Franklin Local Fauna (Sulphur River Formation), Ben Franklin, Delta County, Texas)

In 1929 a series of channels were cut through the meanders of the North Sulphur River in Delta County to reclaim flooded bottom lands. These channels shortened the distance and steepened the gradient of the stream thus resulting in a down-cutting that exposed Pleistocene alluviums for a distance of 40 or more miles (Slaughter and Hoover 1963). Snail faunas were collected over much of this distance and by comparison they proved to be essentially the same.

One charcoal and one shell sample were taken from the exposure for Carbon 14 dates. Sample No. SM-532 charcoal was dated 9,550 ± 375 B.P. The second sample, No. SM-533, composed of shells of the fresh-water clam, *Amblema perplicata*, was dated 11,135 ± 450 B.P. The Carbon 14 dates were made by Socony Mobil Oil Company at Dallas. The clam shells were taken in sites from a location in the fossil zone 813 feet west of the center of a highway bridge that crosses the Sulphur River on Highway 38, north of the small town of Ben Franklin, in Delta County. Land and fresh-water fossil shells are abundant in the sediments.

Planorbula armigera (Say) - SMU P 617	C
Helisoma anceps (Menke) - SMU P 603	A
H. trivolvis (Say) - SMU P 604	S
Gastrocopta contracta (Say) - SMU P 608	C
G. armifera (Say) - SMU P 609	S
G. procera mcclungi (Hanna & Johnston) - SMU P 612	R
G. pentodon (Say) - SMU P 610	C
Pupoides albilabris (C.B. Adams) - SMU P 615	S
Helicodiscus parallelus (Say) - SMU P 633	R
H. singleyanus (Pilsbry) - SMU P 632	C
Discus cronkhitei (Newcomb) - SMU P 626	R
Strobilops texasiana (Pils. &Ferr.) - SMU P614	A
Vallonia gracilicosta Reinhardt - SMU P 639	R
Carychium exiguum (Say) - SMU P 635	R
Hawaiia minuscula (Binney) - SMU P 634	R
Euconulus fulvus (Müller) - SMU P 638	R
Retinella indentata (Say) - SMU P 636	R
Zonitoides arboreus (Say) - SMU P 637	R
Helicina orbiculata tropica Pfr. SMU P 606	S
Mesodon thyroidus (Say) - SMU P 605	R
Stenotrema leai (Binney) - SMU P 607	S
Succinea ovalis Say - SMU P 602	S
Succinea sp. - SMU P 625	S

Ecology

The present ranges of *Ferrissia meekiana*, *Planorbula armigera*, *Valvata tricarinata*, *Somatogyrus depressus*, *Stagnicola reflexa*, and *S. caperata* are more northerly today. Their distributional patterns follow cooler climates, greater moisture, or combinations of both. All of these preceding species are either listed as common or abundant in the Ben Franklin fauna.

The most abundant shells in the Ben Franklin site were those of *Valvata tricarinata*. This branchiate species requires perennial, cold or cool water. The requirements for *Amnicola integra* are similar to those of *Valvata*. Perennial waters were also necessary for species under the genera *Pisidium* and *Sphaerium*. Today, *Sphaerium partumeium* and *Pisidium nitidum* thrive best in the soft muddy bottoms of lakes and rivers, whereas *Sphaerium striatinum*, *Pisidium walkeri*, and *P. compressum* occur in larger bodies of water or rivers where the substrate is more compact than flocculent.

Cheatum and Allen (1963) in discussing the ecology of the Ben Franklin state the following: 'The mollusks of the Ben Franklin local fauna, together with those of other Wisconsin deposits suggests that the final glaciation of the Pleistocene brought with it much moisture, and provided many lakes and streams of cool or cold running water in Texas. The fauna contains several species indicative of such an environment. Increasing aridity, the high summer temperatures of the sub-Recent, and continued seasonably severe winters must have eliminated from the local scene those species which now exist in more northern localities.

Recent and sub-Recent shells are also abundant in cross-channel fills but are easily recognizable not only by the visible differences in the make-up of the deposits, but also in the color of the shells. Carbon 14 determinations of sub-Recent clam shells from the base of the channel fills revealed a date of 1835 ± 144 B.P. (Socony Mobil, Dallas). Other channel fills in the exposure were dated 1123 ± 366 B.P. and 1170 ± 157 B.P. which would indicate a near contemporaneous deposition. The channel fill species are listed as follows:

Physa anatina Lea	R
Helisoma trivolvis (Say)	S
Fossaria dalli (Baker)	R

Stagnicola bulimoides techella (Hald.)	R
Gastrocopta armifera (Say)	C
G. contracta (Say)	A
G. procera (Gould)	A
G. pentodon (Say)	S
Pupoides albilabris (C.B. Adams)	C
Carychium exiguum (Say)	C
Vallonia sp. ?	R
Helicodiscus eigenmanni (Pilsbry)	C
Anguispira alternata (Say)	R
Hawaiia minuscula (Binney)	A
Retinella indentata paucilirata (Morelet)	C
Zonitoides arboreus (Say)	R
Euconulus chersinus (Say)	R
Strobilops texasiana (Pilsbry & Ferriss)	C
S. labyrinthica (Say)	C
Mesodon thyroidus (Say)	R
Polygyra texasiana (Moricand)	A
Bulimulus dealbatus (Say)	C

The superimposition of the sub-Recent and channel fill molluscan assemblage over the older Ben Franklin assemblage provided an excellent opportunity for comparative studies of the two faunas.

The channel fill fauna could not have been changed much by man's intervention as the species lived, died and became deposited some 1500 years ago. At the same time of the channel fill deposition the common, hardy Texas Recent species such as *Bulimulus dealbatus*, *Polygyra texasiana*, and *Anguispira alternata* had become wbundant, thus attesting to climatic conditions as variant as those which exist today. None of the northern species found were present in the channel fill. A period of desiccation could have been responsible for their disappearance, but a remarkable climatic change that ended the more equable temperatures of the late Pleistocene probably brought about their extinction in the area. The seasonable highs and lows of the winter and summer temperatures of today must have reached their inclemency during the interim of the two depositions.

Domeba Local Fauna, Stecker, Caddo County, Oklahoma

In April, 1962, fossil land and fresh-water shells were collected from an excavation site of an apparent mammoth kill nesr Stecker, in Caddo County, Oklahoma. Mr. Adrian Anderson, of the Museum of the Great Plains, Lawton Oklahoma, who was directing the excavation, assisted in collecting the shells from the sediments containing the mammoth remains. Mr. Bob Slaughter of the Shuler Museum, SMU, also made several trips to the site to recover matrix from the fossil zone and the shells separated from the resulting concentrate are included in this report. Carbon 14 tests (made by Mr. E.E. Bray of Socony Mobil Oil Company in Dallas) on lignitic wood which was removed from black silt about two feet from above the actual mammoth remains placed the date of the wood at 10,123 ± 280 years B.P.

List of Molluscan Species

	SMU P Number
Pelecypoda	
Sphaerium occidentale Prime	832
Pisidium variabile Prime	827
Uniomerus tetralasmus (Say)	824
Gastropoda	
Valvata tricarinata (Say)	825
Pomatiopsis lapidaria (Say)	803
Stagnicola caperata (Say)	804
S. palustris (Müller)	806
Fossaria dalli (Baker)	805
Physa anatina Lea	807
P. gyrina (Say)	807
Gyraulus parvus (Say)	821
Promenetus umbilicatellus (Cockerell)	822
Carychium exiguum (Say)	810
Gastrocopta contracta (Say)	811
G. pellucida hordeacella (Pilsbry)	814
G. armifera (Say)	812
G. pentodon (Say)	813
Vertigo ovata (Say)	815
Cionella lubrica (Müller)	831
Helicodiscus parallelus (Say)	826
H. singleyanus (Pilsbry)	830
Discus cronkhitei (Newcomb)	817
Strobilops labyrinthica (Say)	816
Vallonia gracilicosta Reinhardt	820
Euconulus fulvus (Müller)	823
Retinella electrina (Gould)	828
R. indentata (Say)	829
Hawaiia minuscula (Binney)	818
Succinea ovalis Say	808
Succinea sp	809
Stenotrema leai (Binney)	802
Mesodon thyroidus (Say)	800

Ecology

The largest number of shells collected from the sediments of this site fell under the species which prefer shallow, quiet water. The drouth-tolerant species constituted the smallest number of shells present and the other species indicate permanent water surrounded by woodlands and abundant moist humus. Cheatum and Allen* (1965) described the ecology of the site as follows: 'Judging from our data at hand the area in which the mammoth was found was probably a spring-fed marsh or bog with a luxuriant growth of vegetation. Surrounding the marsh or bog was woodland ranging from sparse to dense. Considering the shell size of *L. caperata* (many reaching a length of 20 mm), *P. gyrina* (prevalent with many shells 18 mm long), and *L. dalli* (some 6.5 mm long) growth conditions were apparently at the optimum for these species. *S. leai* and *P. lapidaria* also indicate greater moisture in this area than that which exists today since these species thrive best in broadleaf deciduous tree zones where the annual rainfall varies from 30 to 60 inches. The southern geographical range of *H. singleyanus* and *G. pellucida hordeacella*, which are seldom found living north of the 42° parallel, can be used to indicate a relatively mild winter climate. Sub-freezing temperatures (if encountered) would have been of short duration. On the other hand the presence of *V. tricarinata*, *P. umbilicatellus*, *D. cronkhitei*, and *L. caperata* which seldom range to the south of the 35° would indicate the absence of the seasonable high temperatures of Oklahoma today.

Summary

Seventy-five species of gastropods have been recorded for the eight Pleistocene deposits reviewed. According to our known records the following eleven species among the seventy-five species recorded for Pleistocene are not extant today in Texas and Oklahoma: *Stagnicola caperata*, *S. reflexa*, *S. exilis*, *Lymnaea stagnalis jugularis*, *Aplexa hypnorum*, *Gyraulus labiatus*, *Somatogyrus depressus*, *Pupisoma dioscoricola*, *Discus cronkhitei*, *Strobilops sparsicostata*, and *Retinella electrina*. Among these eleven species eight are aquatic species which may indicate that the land species are much more tolerant to changing climatic conditions than the aquatic forms.

It is also significant that such species as *Pomatiopsis lapidaria*, *Valvata tricarinata*, *Stagnicola palustris*, *Planorbula armigera*, *Armiger crista*, and *Promenetus umbilicatellus* are recorded as Recent for Oklahoma but not for Texas. It should be further noted that *Valvata tricarinata* and *Stagnicola palustris* are, according to Branson (1961) considered rare in Oklahoma and Taylor (1960) regards the record of *Promenetus umbilicatellus* in the Ozark Mountains of northeastern Oklahoma as 'an isolated occurrence.'

Seven of the eight Pleistocene sites reviewed are located in Texas. The total number of extant species listed for Oklahoma is greaterthan the total number of species extant for Texas, and, as previously stated, some of these species are definitely of a more northerly distributional range with Oklahoma apparently serving as a southerly distributional limit.

Based on the molluscan faunas studied in this report, there was no apparent major faunal change in post-Kansan times until after 9,000 B.P. Each fauna contains some species that are allopatric today. Using the premise that the ecological requirements of the species in our study are essentially the same as they are today, there apparently is no area in the continental United States today where all species represented in our study are sympatric. This assumption implies that the species listed have, from the standpoint of environmental preference, been genetically stable over the span of Pleistocene times.

Broecker *et al.* (1960) postulated an 'abrupt world-wide change in climate close to 11,000 years ago marking the end of the Wisconsin glacial period.' Their evidence was drawn from studies on deep-sea sediments from the Atlantic Ocean and adjacent seas, deposits from the pluvial lake area of the western U.S.A., sediments from the Great Lakes and their associated drainage networks and the pollen sequences of northwestern Europe. This abrupt world-wide change in climate was first recognized by Ewing (1956) as a result of studies on deep sea cores. Later, Ericson *et al.* (1956) presented

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*This paper titled 'Ecological Significance of the Fossil Fresh-water and Land Shells from the Domeba Mammoth Kill Site in Caddo County, Oklahoma' will be published by the Great Plains Museum, Lawton, Oklahoma.

radiocarbon measurements on these cores. All of the correlated evidence supported the conclusion concerning the abrupt change in climate near the end of the Wisconsin period.

Hester (1960), on the basis of C 14 dates in an archeological study indicated that many of the larger mammals becsme extinct at this time. He stated that 'most herding animals such as the Columbian mammoth, horse, camel, and extinct bison (*Bison antiquus*) as well as the dire wolf, rapidly becsme extinct 8 000 years ago.'

Coinciding with Broecker's postulation and Hester's conclusion there is also a noticeable change between the Recent molluscan fauna of the study area today and the Ben Franklin and Domeba local faunas of some 9,000—12.000 B.P. The Pleistocene species in our collection which today are northern in distribution have to a certain extent been replaced by species of a more southerly distribution. To our knowledge, these southern species have not, heretofore, been recorded in fossil collections for this area. Much is to be desired in information concerning the vertical range of the Recent species in Texas and the broad distributional picture cannot be clarified until extensive field studies are conducted in Mexico, Central and South America whence these southern species may have originated.

In comparing the molluscan study faunas with those of post-Kansan age in the mid-continental region of the United States, there seems to be little evidence to support any radical difference between the post-Kansan mean annual temperatures of the two areas. The now predominant Texas land snails, *Bulimulus dealbatus*, and *Helicina orbiculata tropica* which do appear in the Clear Creek local fauna (28,840)B.P.) and the Sulphur River local fauna (9,550 B.P.) are not recorded in post-Kansan faunas from the mid-continental United States. Both species are hardy land snails that survive periods of drought and summer temperatures in excess of 100° F. They are not, of course, active during the excessive hot, dry, day time temperatures but, nocturnally are active in 90° F. temperatures even in dry seasons. They are comparatively few in Pleistocene collections and at most would indicate only the possibility of a somewhat warmer temperature in Texas. However, they do help to reinforce the premise that the winter temperatures during the Wisconsin were no more severe than they are in Texas today. The dominant Pleistocene species would, however, require much more moisture and permanent water than is indicated by the presence of *Bulimulus*, which is known locally as the prairie snail.

In order to support the larger species of Lymnaeids which at present do not live in Texas and southern Oklahoma, the periods prior to each deposition were probably of a much more equable humid climate. Major climatic changes were, of course, possible between the recorded depositions for they generally represent time periods of several thousand year intervals. If such periods of desiccation did occur, there apparently is to date no evidence based upon known fossil molluscan collections which would support such conclusions.

We are aware of weaknesses involved in the interpretation of fossil environments by using taxonomic paleoecolkgy. Undoubtedly many of our species have not reached a habitat equilibrium, therefore, their presence would not imply that the environment is ideal for their existence. However, we do feel that the pre-

EXPLANATION OF PLATE I OPPOSITE

1. *Lymnaea stagnalis jugularis* (Say), X1½, (Groesbeck) Hardeman Co., Texas.
2. *Lymnaea stagnalis jugularis (Say), X1½*, (Groesbeck) Hardeman Co., Texas, spire only.
3. *Gyraulus labiatus* (Leonard), X 5½ (8 mm.), (Quitaque) Motley Co., Texas.
4. *Gyraulus parvus* (Say), X 10 (4 mm.), (Quitaque) Motley Co , Texas.
5. *Gyraulus crista* (Linnaeus), X 17 (2 mm (Good Creek) Foard Co., Texas.

6 & 7. *Ferrissia rivularis* (Say), X 9½ (Quitaque) Motley Co., Texas.

8. *Strobilops labyrinthica* (Say), X 15. (Domeba), Caddo Co., Oklahoma.
9. *Strobilops texasiana* (Pils. & Ferr.), X 1? (Sulphur River) Delta Co., Texas

sence or absence of several species in a given area, rather than the selection of one indicator species lessens the chance of error in paleoecological interpretation. Genetic changes may also have occurred in species which would lead to physiological differences. Thus, the habitat demand of the species living thousands of years ago may not be the same as it is for the same species today. Yet with these weaknesses that could exist we feel that by the use of large taxonomic fossil assemblages, a fairly accurate environmental picture can be obtained of past environments.

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RELATIVE ABUNDANCE OF MOLLUSK SPECIES COLLECTED IN EIGHT PLEISTOCENE DEPOSITS IN TEXAS AND OKLAHOMA

For explanation of abbreviations, see page 16.

	1	2	3	4	5	6	7	8	9
Class Pelecypoda									
Amblema plicata perplicata (Conrad)	-	-	-	-	-	-	X	-	X
Ell:pt:o dilatatus (Raf.)	X	-	-	-	-	-	-	-	-
Lamps·l·s anodontoides (Lea)	-	-	X	-	-	-	-	-	X
Unicmerus tetralasmus (Say)	-	-	-	-	-	-	-	X	X
Quadrula forsheyi (Lea)	X	-	-	-	-	-	-	-	X
Sphaerium striatinum (Lamarck)	R	-	A	S	A	-	S	-	X
S. partumeium (Say)	-	-	-	-	-	-	S	-	-
S. occidentale (Prime)	-	-	-	-	-	-	-	S	-
Pisidium compressum (Prime)	-	-	C	-	A	-	S	-	X
P. nitidum (Jenyns)	S	-	-	S	-	-	S	-	X
P. walkeri (Sterki)	-	-	-	-	-	-	S	-	-
P. variabile (Prime)	-	-	-	-	-	-	-	X	-
Class Gastropoda									
Amnicola integra (Say)	-	-	R	-	-	-	A	-	X
Amnicola limosa (Say)	R	-	-	-	A	-	-	-	X
Somatogyrus depressus (Tryon)	-	-	-	-	-	-	A	-	-
Valvata tricarinata (Say)	-	-	S	R	-	-	A	X	X
Goniobasis sp	-	-	-	-	-	-	R	-	X
Carychium exiguum (Say)	-	S	-	R	A	-	R	X	X
Fossaria dalli (Baker)*	S	R	S	R	C	-	S	X	X
F. obrussa (Say)	S	S	C	-	C	-	-	-	X
F. humilis modicella (Say)	-	S	S	-	-	-	-	-	X
Stagnicola bulimoides techella (Haldeman)	-	-	-	R	-	-	-	-	X
S. caperata (Say)	C	S	C	-	S	C	R	X	-
S. reflexa (Say)	-	-	-	-	-	-	S	-	-
S. palustris (Möller)	R	-	A	-	A	-	-	X	X
S. exilis (Lea)	-	-	-	-	-	S	-	-	-
Lymnaea stagnalis jugularis (Say)	-	-	-	-	S	-	-	-	-
Physa anatina (Lea)	A	-	A	-	A	-	-	X	X
P. gyrina (Lea)	S	A	A	S	-	A	S	X	X
Aplexa hypnorum (Linn.)	-	S	S	-	-	-	-	-	-

EXPLANATION OF PLATE 2

1 & 2. *Zonitoides arboreus* (Say), X 9, (Domeba) Caddo Co., Oklahoma.

3 & 4. *Retinella electrina* (Gould), X 9, (Domeba) Caddo Co., Oklahoma.

5 & 6. *Retinella indentata* (Say), X 8, (Domeba) Caddo Co., Okla.

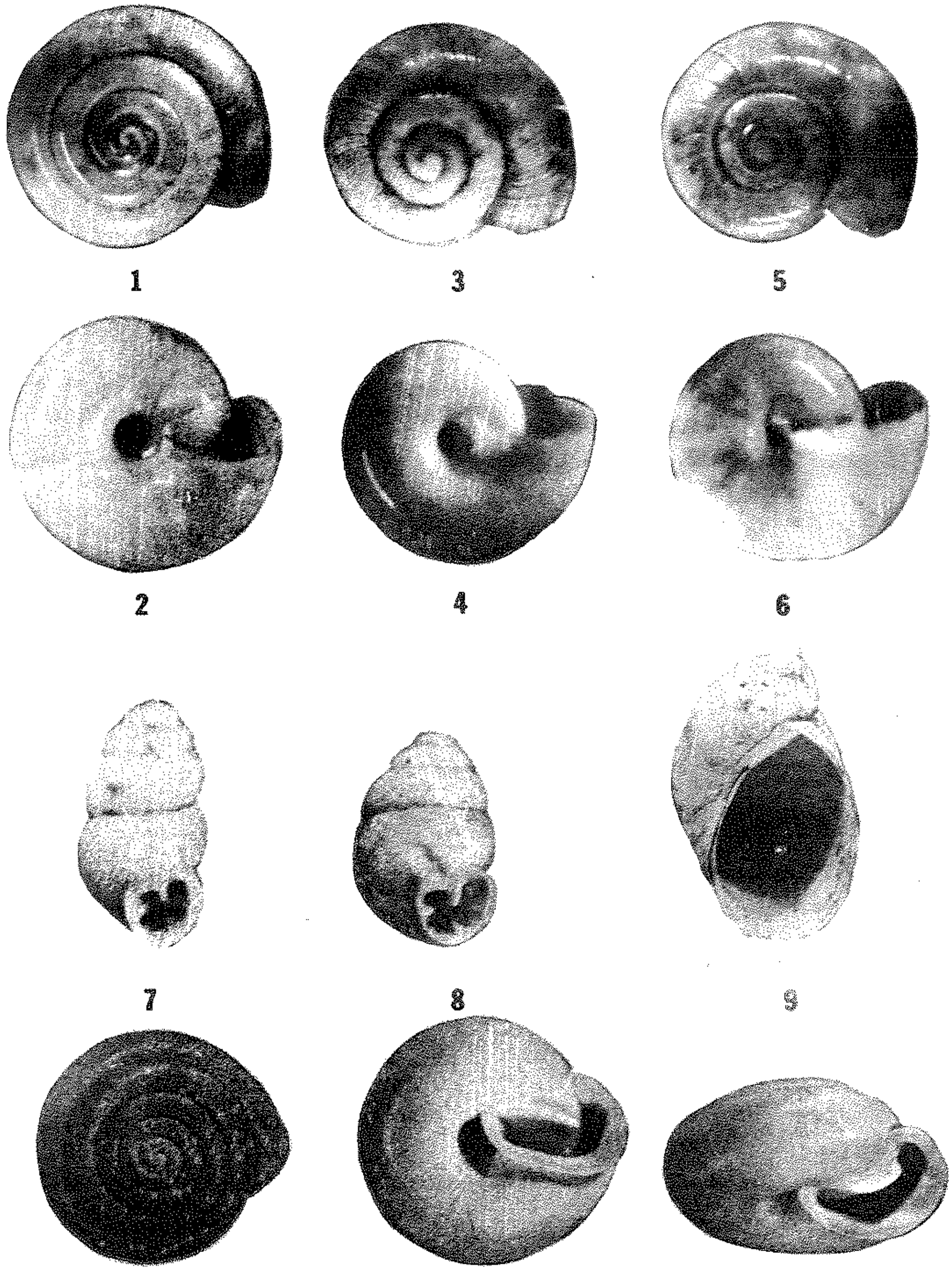
7. *Gastrocopta pentodon* (Say), X 18, (2 mm.), (Sulphur River) Delta Co., Texas.

8. *Gastrocopta tappaniana* (C. B. Adams), X 18 (1.7 mm), (Sulphur River) Delta Co., Texas.

9. *Succinea ovalis* (Say), X 2, (Sulphur River) Delta Co., Texas.

10, 11, & 12. *Stenotrema leai* (Binney), X 4, (Groesbeck) Hardeman Co., Texas.

PLATE 2

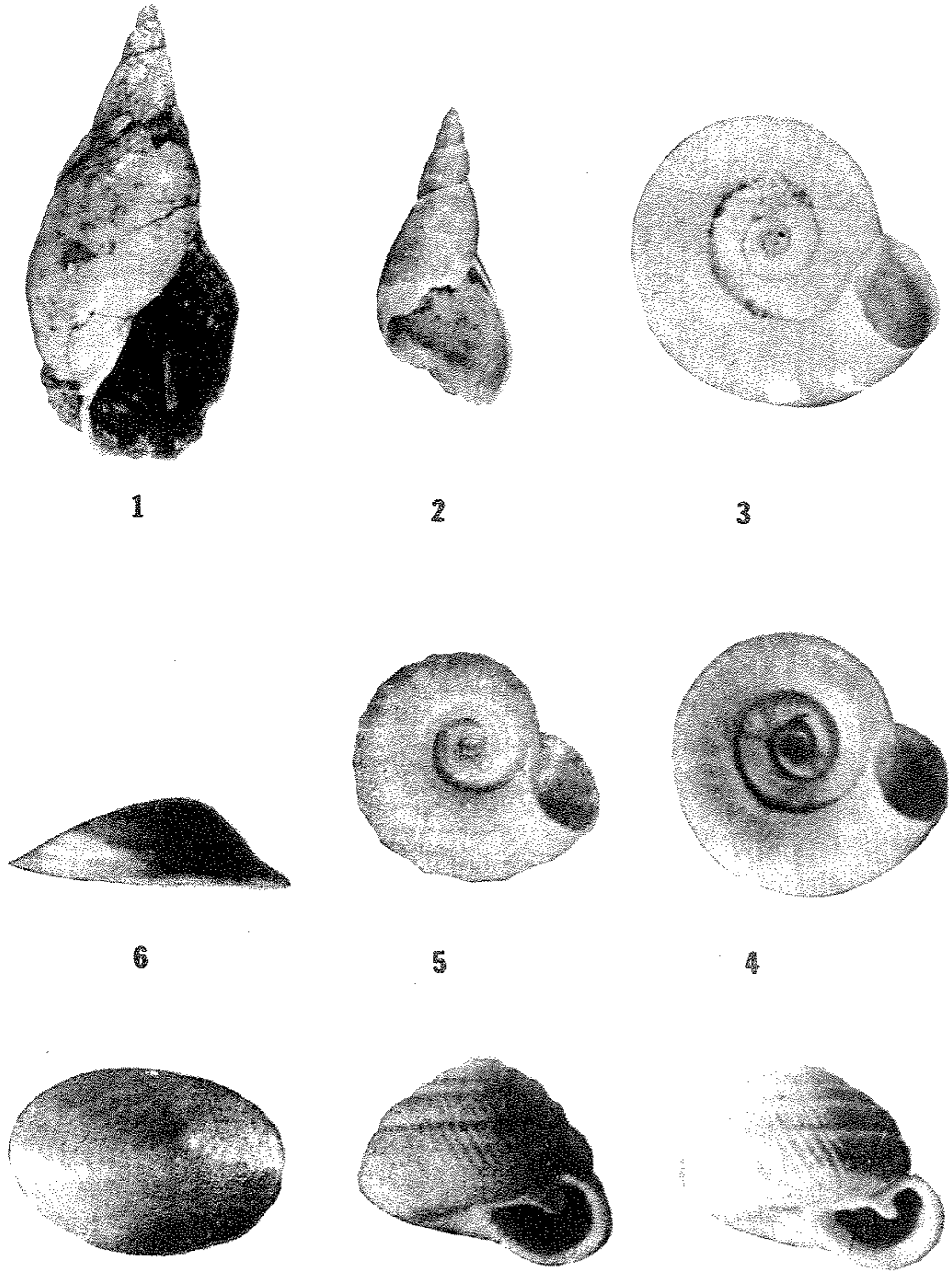


RELATIVE ABUNDANCE OF MOLLUSK SPECIES COLLECTED IN EIGHT PLEISTOCENE DEPOSITS IN TEXAS AND OKLAHOMA (Cont.)*

	1	2	3	4	5	6	7	8	9
Gyraulus circumstriatus (Tryon)	S	A	R	-	-	S	-	-	X
G. parvus (Say)	A	C	A	A	A	-	A	X	X
G. crista (Linn.)	R	-	-	-	C	-	-	-	X
G. labiatus (Leonard)	-	-	R	-	-	-	-	-	-
Helisoma anceps (Menke)	S	S	S	C	A	-	A	-	X
H. trivolvis (Say)	R	S	R	-	S	C	S	-	X
Planorbula armigera (Say)	-	C	-	-	-	A	C	-	X
Promenetus umbilicatellus (Cockerell)	-	-	C	-	-	R	-	X	X
Ferrissia rivularis (Say)	-	-	R	-	-	-	-	-	X
F. meekiana (Stimpson)	-	-	-	-	R	-	-	-	X
Pomatiopsis lapidaria (Say)	-	-	-	-	-	C	-	X	X
Cionella lubrica (Müller)	-	-	-	-	S	-	-	X	X
Gastrocopta armifera (Say)	R	R	S	A	C	C	S	X	X
G. corticaria (Say)	R	-	-	-	-	-	-	-	X
G. procera sterkiana (Pilsbry)	-	-	S	A	-	-	-	-	X
G. procera mcclungi (Hanna and Johnston)	R	-	-	-	-	-	R	-	X
G. procera (Gould)	-	-	-	-	S	-	S	-	X
G. pellucida hordeacella (Pilsbry)	R	-	-	A	-	-	-	X	X
G. cristata (Pilsbry and Vanatta)	S	-	C	-	C	-	-	-	X
G. pentodon (Say)	C	A	S	-	A	-	-	X	X
G. tappaniana (C. B. Adams)	-	-	S	-	-	C	-	-	[illegible]
G. contracta (Say)	-	R	-	-	-	-	-	X	
Vertigo ovata (Gould)	C	-	A	-	C	A	-	X	[illegible]
V. milium (Gould)	C	-	-	-	-	-	-	-	
Pupoides albilabris (C. B. Adams)	C	S	C	C	C	C	S	-	X
Pupilla muscorum (Linn.)	-	-	S	-	-	-	-	-	X
P. blandi (Morse)	R	-	-	-	S	-	-	-	X
P. sinistra (Franzen)	-	-	-	-	S	-	-	-	X
Pupisoma dioscoricola (C. B. Adams)	-	R	-	-	S	-	-	-	-
Vallonia parvula (Sterki)	-	-	-	-	S	-	-	-	X
V. gracilicosta (Reinhardt)	R	-	S	-	-	-	-	X	X
Helicodiscus parallelus (Say)	-	S	R	C	C	R	R	X	X
H. singleyanus (Pilsbry)	-	-	S	-	-	-	-	X	X
Anguispira alternata (Say)	-	-	-	R	-	-	-	-	X
Discus cronkhitei (Newcomb)	C	-	A	-	S	-	R	X	-
Helicodiscus eigenmanni (Pilsbry)	-	-	S	-	-	-	-	-	X
Strobilops labyrinthica (Say)	-	-	-	-	-	-	-	X	X
S. texasiana (Pilsbry and Ferriss)	-	S	-	A	-	A	A	-	X
S. sparsicostata (Baker)	-	-	R	-	S	R	-	-	-
Deroceras sp.	-	-	-	-	R	-	-	-	X
Bulimulus dealbatus (Say)	-	R	-	C	-	-	-	-	X
Helicina orbiculata tropica (Pfeiffer)	-	R	-	S	-	-	S	-	X
Hawaiia minuscula (Binney)	C	S	-	S	C	A	R	X	X
Euconulus fulvus (Müller)	R	-	S	R	C	R	R	X	X

* For explanation of abbreviations, see page 16

PLATE 1



RELATIVE ABUNDANCE OF MOLLUSK SPECIES COLLECTED IN EIGHT PLEISTOCENE DEPOSITS (CONCLUDED)

	1	2	3	4	5	6	7	8	9
Zonitoides arboreus (Say)	-	S	S	R	C	-	R	-	X
Retinella indentata (Say)	-	R	-	S	-	-	R	X	X
R. electrina (Gould)	R	-	-	-	-	S	-	X	-
Stenotrema leai (Binney)	S	A	R	R	R	C	S	X	X
Polygyra texasiana (Moricand)	-	R	-	R	S	-	-	-	X
Mesodon thyroidus (Say)	-	S	-	-	-	-	R	X	X
M. indianorum (Pilsbry)	R	-	-	-	-	-	-	-	X
Praticolella berlandieriana (Moricand)	-	-	-	R	-	-	-	-	X
Succinea sp.	S	S	X	X	-	X	X	X	X
S. ovalis (Say)	-	-	R	-	-	R	A	X	X
S. cf. S. grosvenori (Lea)	-	-	-	-	R	-	-	-	X
S. cf. S. luteola (Gould)	-	-	-	-	R	-	-	-	X
Oxyloma retusa (Lea)	-	-	-	-	-	C	-	-	X

**F. dalli* (Baker), *F. obrussa* (Say), and *F. humilis modicella* (Say) are considered to be synonymized under the specific epithet of *Lymnaea humilis* (Say) by Hubendick (1951).

Explanation of Abbreviations

Relative abundance of species in one gallon of matrix:

- X : occurrence
- A : over 50
- C : 21-50
- S : 6-20
- R : 1-5

1. Good Creek Local Fauna, Foard County, Texas.
2. Moore Pit (Hill-Shuler) Local Fauna, Dallas County, Texas.
3. Quitaque Creek Local Fauna Motley County, Texas. 31,400 ± 5600 B.P.
4. Clear Creek Local Fauna, Denton County, Texas. 28,840 ± 4740 B. P.
5. Howard Ranch (Groesbeck Creek) Local Fauna, Hardeman County, Texas. 19,098 ± 1074 B.P.; 16,775 ± 565 B.P.
6. Beyers Locsl Fauna, Clay County, Texas. 16920 ± 665 B.P.
7. Ben Franklin (Sulphur River) Local Fauna, Delta County, Texas. 9,550 ± 375 B.P.; 11,135 ± 450 B.P.
8. Domebo Local Fauna, Caddo County, Oklahoma. 11,045 ± 647 B.P.
9. Recent for Texas and Oklahoma.

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