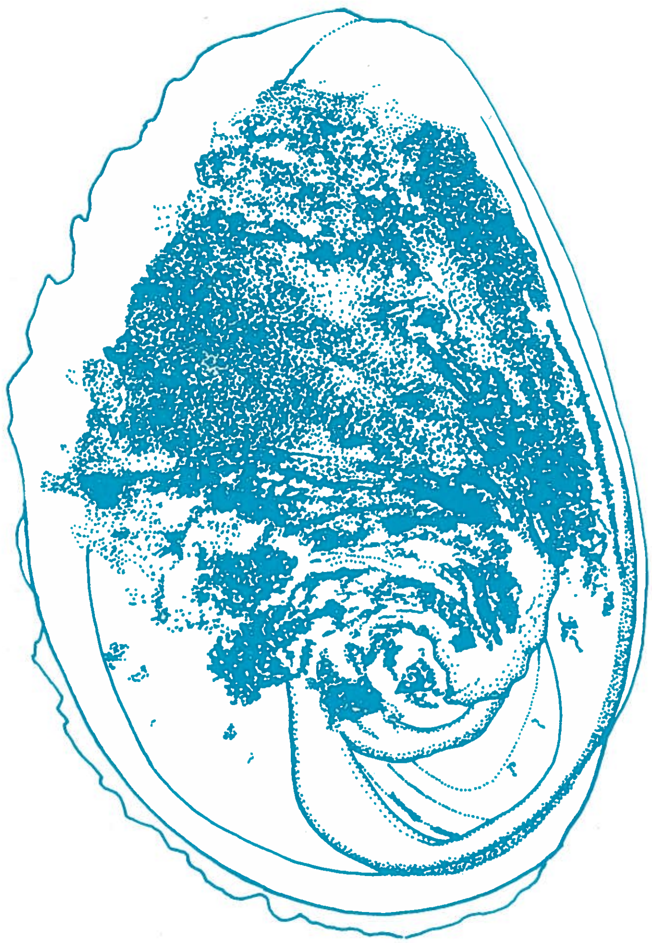
Fresh-water molluscs from New Mexico and vicinity

by Dwight W. Taylor



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Abstract—Nine new species are described from New Mexico, four from Arizona, two from Utah, and five from Texas, with redescriptions of two more from New Mexico and Texas. These 22 species are classified in Assimineidae (one species of *Assiminea),* Hydrobiidae (11 species of *Fontelicella* and two monotypic new genera, *Apachecoccus* and *Yaquicoccus),* Littoridinidae (seven species of *Tryonia),* and Sphaeriidae (one species of *Pisidium).* Virtually all are narrowly local forms, and have been considered actually or potentially endangered species. Geological significance of these species lies in the drainage history of the region. They conform to previous geological interpretations in showing that they evolved in separate drainages of Pliocene or older times, which have been united into the present stream systems.

Introduction

The species described herein were collected during studies supported by the New Mexico Department of Game and Fish, Santa Fe, through John P. Hubbard; and by the New Mexico Bureau of Mines and Mineral Resources, Socorro, through Frank E. Kottlowski, Director, and John W. Hawley. The studies have been carried out partly to assess potentially threatened and endangered species of the State fauna (New Mexico Department of Game and Fish, 1985), and partly in preparation of a regional manual of the fresh-water molluscan fauna of New Mexico and adjacent areas, including the Rio Grande drainage generally. Fieldwork in the Diamond Y Draw area of Texas was in part supported by the U.S. Fish and Wildlife Service, Office of Endangered Species, Albuquerque, New Mexico.

Field guidance, discussions of local geology, and possible collecting sites have been provided by John W. Hawley, David W. Love, and Robert H. Weber of the New Mexico Bureau of Mines and Mineral Resources. Permission for collection and advice on localities in the Bitter Lake National Wildlife Refuge was provided by L. B. Marlatt, Supervisor. Leslie Hubricht provided information concerning his earlier collecting in the vicinity of Socorro.

Publication costs of species in New Mexico listed as threatened or endangered have been in part defrayed by the New Mexico Department of Game and Fish Endangered Species Program, and by the U.S. Fish and Wildlife Service, Office of Endangered Species, Albuquerque, New Mexico.

Names of institutions in which specimens are housed are abbreviated as follows: ANSP, Academy of Natural Sciences of Philadelphia, Pennsylvania; LACM, Los Angeles County Museum of Natural History, Los Angeles, California; UCM, University of Colorado Museum, Boulder; UMMZ, University of Michigan Museum of Zoology, Ann Arbor; UTEP, University of Texas at El Paso. Thanks are due to the curators at these institutions for the opportunity to study specimens in their care.

Geological interpretations

One of the goals of study in New Mexico and adjacent areas has been to test the value of fresh-water molluscs in indicating past river drainages. New Mexico is particularly suitable, because history of the Rio Grande has been of interest to many geologists. A variety of geological data, including radiometric dates, is available. Previous interpretations provide alternatives with which to compare data from aquatic molluscs.

Application of the distribution of fresh-water snails and clams to interpretation of geologic history requires that the species be limited to perennial water at all stages of life; that range of habitat and dispersion be known at least generally; and that affinities of the species be understood. Among the small snails of the Hydrobiidae and Littoridinidae, forming so much of the Southwest fauna, shell features are usually no indication of relationships and the fossil record is unlikely to prove illuminating. From the broad-brush studies completed so far, it appears that the thermal-spring species are generally ancient, perhaps mid-Tertiary in age, and that differentiation in *Tryonia* is substantially slower than in most Hydrobiidae. Within the fauna described herein this contrast is evident in the upper Rio Grande and Pecos River. The species of *Fontelicella (davisi, neomexicana, pecosensis* groups) are sharply distinct. The species of *Tryonia (alamosae, brunei, kosteri* of the *alamosae* group) are related. As a rule of thumb, it may be that the Fontelicellas are Pliocene and the Tryonias Miocene. Whether this is due to intrinsically different rates of speciation, or is determined to some extent by *habitat—Fontelicella* is generally a grazer on exposed surfaces, whereas *Tryonia* is a sediment-dwelling particle selector—remains to be studied.

In New Mexico and adjacent areas, distribution of the small spring and spring-brook snails show a clear-cut dividing line. This line runs southeast along the Mogollon Highlands of Arizona and into Chihuahua, parallel to the Rio Grande between the New Mexico border and the Big Bend. All species of *Tryonia (Paupertryonia)* are northeast of this line. All Fontelicellas on the northeast are of the *Fontelicella californiensis* series, related to species of Utah west of the Colorado River. Southwest of this line, the Tryonias are *Tryonia* (s.s.) and Fontelicellas all are of the *Fontelicella stearnsiana* group within the *stearnsiana* series. This clear separation of so many species is evidently due to some geologic feature of mid-Tertiary or greater age, but the data are so generalized that any precise interpretation would be premature.

On a grand scale, evolution of the regional drainage has been a consequence of epiorogenic uplift of the southern Colorado Plateau-eastern Basin and Range region and differential movement on basin-range faults (Gable & Hatton, 1983). More rapid headward erosion by tributaries of master streams with lower base levels (Rio Grande, Gila River) has been at the expense of interior streams or of headwaters with higher base levels. Isolated populations of molluscs living today retain in their morphological characters the results of evolution in these separate drainages.

The more local and more detailed interpretations of the fauna are tied closely to methodology. Special attention has been devoted to *Fontelicella,* because it is diversified over so much of the western United States and provides a range of characters that permit detailed taxonomy and historical interpretations. The rich data provided by species of this genus proved applicable to geological history only when a hierarchy of specific relationships (species and subspecies, species-groups, series of groups, subgenera) was established. This in turn required what has not been worked out before: methodology for classifying the varied ornament and structure of the male reproductive organ, a symbolic notation, and working out homology of the various penial glands—sometimes bewilderingly varied.

In general, the relationships of species in *Fontelicella* have been based on structure and glands of the penis. The female reproductive system is far more conservative, almost stereotyped, and usually provides no useful clue to relationships. In the few cases where the female system shows distinctive characters *(Fontelicella kolobensis* group, and particularly the *neomexicana* group), the relationships are consistent with those based on the male system and are correlated also with geographic distribution.

In *Tryonia* no detailed hierarchy of classification has been achieved. Groups of species have been defined by various attributes of penial structure and glandular papillae that are correlated also with geographic distribution. In contrast to *Fontelicella,* the result has been often a series of monotypic species-groups with no evident mutual relationships. The new subgenus *Paupertryonia,* of New Mexico and southward at the southeast limit of range of *Tryonia,* has been exceptionally amenable to study in showing a diversity of characters and species-groups within the subgenus.

Data from geological sources and molluscan distribution are synthesized in the following sections. These data, including information from studies in progress, are incorporated in Fig. 1, inferred latest Tertiary drainage, modified from Hawley et al. (1976). In a general way, but not in most details of local drainage and chronology, these are in accord with interpretations based on fish distribution (Smith & Miller, 1986).

Upper Rio Grande

History of the upper Rio Grande has been studied by various geologists. The dominant view is that the river developed as a stream of interior drainage that gradually extended its course southward, finally by latest Pliocene–early Pleistocene time becoming tributary to internal basins of northern Mexico. Only in the mid-Pleistocene did the upper Rio Grande join the lower Rio Grande (Gile et al., 1981; Hawley & Kottlowski, 1969; Kottlowski, 1953; Seager et al., 1984; Strain, 1970; and references therein).

Molluscan evidence is fully consistent with this interpretation and does not support the inferred ancient history of a greater Rio Grande (Belcher, 1975). Only three living species of molluscs are restricted to the upper Rio Grande, two forming the *Fontelicella neomexicana* group (3, 7, 8 in Fig. 1) with no close relatives elsewhere, and *Tryonia alamosae* (6 in Fig. 1). The drainage seems always to have had only a sparse fauna, for even in the headwater region of southern Colorado, early Pleistocene fossils from the Alamosa Formation (1 in Fig. 1; Rogers et al., 1985) show no hint of a rich perennial-stream fauna.

Neither the mollusc distribution nor physical geology support the statement of Rogers et al. (1985: 537) that the Miocene (lower) Santa Fe Group was deposited by streams draining to the Pacific, whereas the Pliocene–early Pleistocene Alamosa Formation was deposited by a Rio Grande that drained to the Gulf of Mexico. Miocene depositional environments in the Rio Grande depression (rift) of the New Mexico region were characterized by closed depositional basins, with central playa lakes, rather than by through-going fluvial systems (Hawley, 1978).

Pecos River and lower Rio Grande

Localized gastropods of the Pecos and lower Rio Grande are restricted to southeastern New Mexico and Trans-Pecos Texas, and are heavily concentrated in drainage of the Roswell and Delaware basins, sites of the major springs of the region (9, 11, 14-17 in Fig. 1).

The implication of these local species is that their spring and spring-brook habitats are of late Tertiary age. Thus they are inconsistent with interpretation of the Ogallala Formation (Miocene) as an alluvial blanket that covered much of southeastern New Mexico, including the Pecos Valley (Frye, 1970; Frye, Leonard & Glass, 1982). Facies of the Ogallala Formation as interpreted by Seni (1980) include habitats (braided stream, flood basin, and lacustrine basin) that are consistent with fossil molluscs of the Ogallala Formation, but not with spring and spring-brook habitats of living local forms in the Pecos Valley. Neither do these alluvial-fan habitats provide a suitable mechanism for isolation of species. The conclusion is that the Roswell and Delaware basins were not part of the Ogallala alluvial-fan sequence; they were already in a different environment and drainage.

Reeves (1972: 110) already proposed such a different environment and drainage on purely geological grounds. He suggested that the head of the Pecos River valley extended northward through development of solution-subsidence depressions. Both Kelley (1980) and Reeves (1972) thought that the oldest Pecos Valley fill might be of early Ogallala or even pre-Ogallala age. This early fill includes the quartzose conglomerate (Fiedler & Nye, 1933: 35-38) that is the principal alluvial aquifer of the Roswell artesian basin, and some of the thick solution-basin fill in the Delaware basin (Maley & Huffington, 1953).

Northward progression of solution-subsidence basins provides suitable habitats and isolating mechanism for small snails restricted to the flowing water of springs, and accounts also for their local restriction at the level of species as well as species-group.

Gila River

Like the Rio Grande, the Gila has segments of its drainage characterized by sharply different fauna. Endemic forms of eastern Arizona *(Tryonia gilae* and *Apachecoccus)* are clearly or probably related to others in the Rio Santa Maria, Chihuahua; and the Fontelicellas downstream are all of the relatively simple *Fontelicella stearnsiana* group. Species of the upper Gila in New Mexico are sharply distinct from each other and from others in the region.

Near the Forks of the Gila River (5 in Fig. 1) are found *Fontelicella gilae* and *F. thermalis,* the latter being the most distinctive species *in* the genus. Inferred course of this part of the Gila is shown as tributary to the Mimbres River, following Hawley et al. (1976). Their geological interpretation is based on the fact that the watershed (10 in Fig. 1) between Sapillo Creek of the Gila drainage and the upper Mimbres is an alluvial divide. The canyon of lower Sapillo Creek is deeply incised in volcanic rocks and is suggestive of capture by a more rapidly eroding Gila River. Occurrence of these two distinctive species of *Fontelicella* in a former separate drainage, the Mimbres, provides a plausible isolating mechanism.

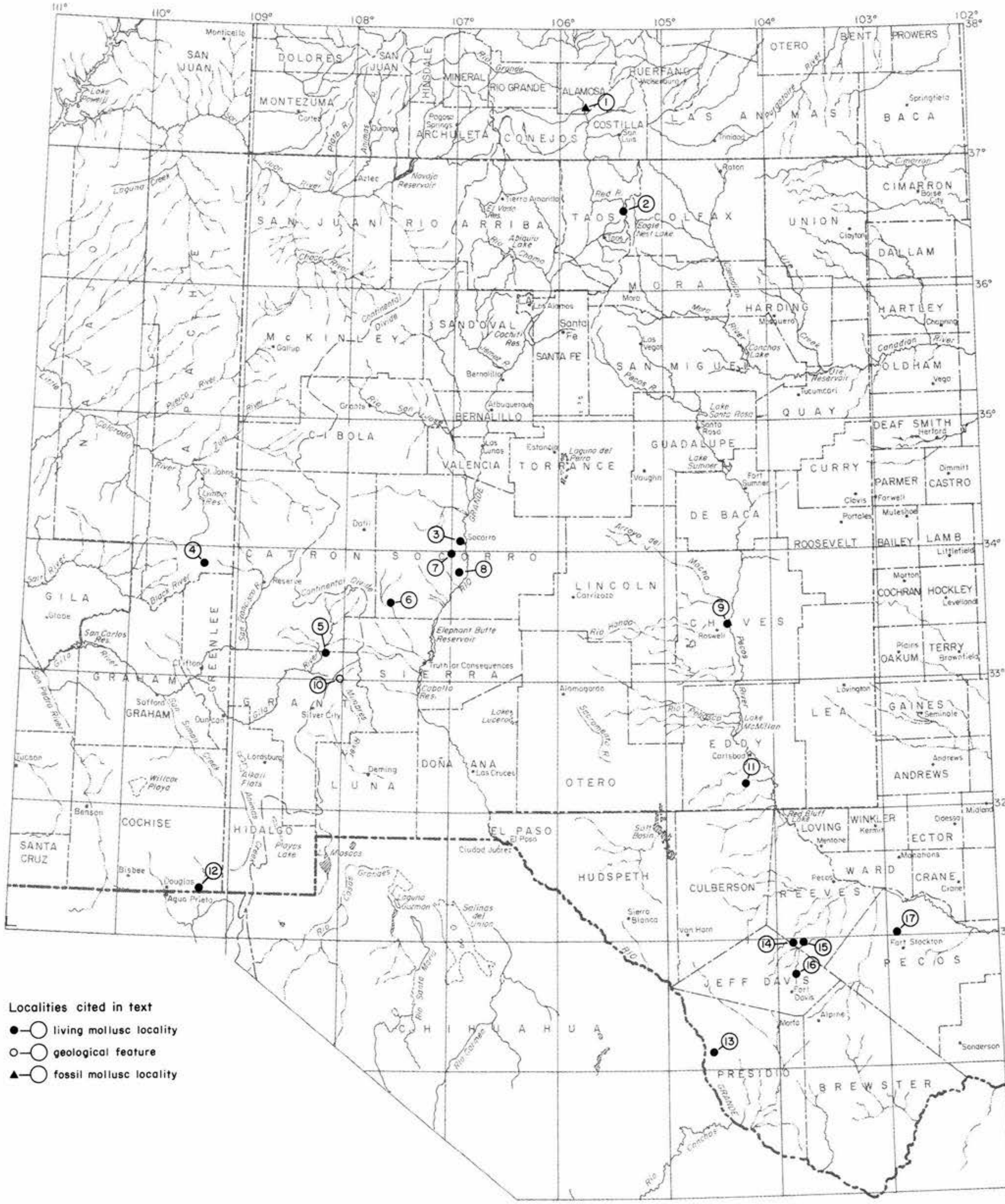

FIGURE 1—Inferred latest Tertiary drainage of New Mexico and adjacent areas, based on interpretations of geology and mollusc distribution. Numbered localities cited in text. **1,** Alamosa Formation, early Pleistocene, Hansen Bluff. **2,** *Pisidium sanguinichristi* n.sp., living, Middle Fork Lake, Sangre de Cristo Mountains. **3,** *Fontelicella neomexicana* (Pilsbry), modern but now extinct, Socorro. **4,** *Fontelicella trivialis* n.sp., living, Three Forks. **5,** *Fontelicella gilae* n.sp. and *F. thermalis* n.sp., living, Forks of Gila River. **6,** *Tryonia alamosae* n.sp., living, head of Alamosa Creek. **7,** *Fontelicella neomexicana* (Pilsbry), living, Torreon Spring. **8,** *Fontelicella chupaderae* n.sp., living, Willow Spring. **9,** *Assiminea pecos* n.sp., *Fontelicella roswellensis* n.sp., and *Tryonia kosteri* n.sp., living, Bitter Lake National Wildlife Refuge. **10,** Divide between Sapillo Creek of Gila River drainage and Mimbres River. **11,** *Fontelicella pecosensis* n.sp., living, Blue Spring and Castle Spring; and *Fontelicella* aff. *metcalfi* n.sp., Holocene, Black River Falls. **12,** *Yaquicoccus bernardinus* n.gen. et sp., living, San Bernardino Ranch. **13,** *Fontelicella metcalfi* n.sp., living, Naegele Springs. **14,** *Tryonia cheatumi* (Pilsbry) and *T. brunei* n.sp., living, Phantom Lake Spring. **15,** *Tryonia cheatumi* (Pilsbry), living, San Solomon Spring. **16,** *Fontelicella davisi* n.sp., living, Limpia Creek. **17,** *Assiminea pecos* n.sp., *Tryonia adamantina* n.sp., and *T. stocktonensis* n.sp., living, Diamond Y Draw.

Accounts of species

Family ASSIMINEIDAE

The genus *Assiminea* includes 50-60 species, mostly found in coastal brackish water or along the sea coast in tropical and temperate regions worldwide. Abbott (1958) reviewed classification of the group.The new species described here belongs to what he called the *nitida* complex, a "group of very small, nut-brown, translucent and thin-shelled species" of worldwide distribution. A peculiarity of the genus is that the tentacles have been almost completely lost, leaving the eyes within the tips of short ocular peduncles (Fig. 2d).

Inland species of *Assiminea* are known at other places in the world, but *Assiminea pecos* in New Mexico is more remote from the sea than any other occurrence.

ASSIMINEA PECOS, new species
Fig. 2

1966. *Assiminea* sp.: Taylor, p. 208; basin of Cuatro Cienegas, Coahuila, Mexico.
1982. *Assiminea taylori* [nomen nudum] Fullington, pp. 63-64; characteristic of Chihuahuan biotic province.
1984. *Assiminea* sp.: U.S. Fish & Wildlife Service, p. 21673; candidate endangered species.
1985. Pecos Assiminea: New Mexico Department of Game & Fish, account MOLL/AS/AS/AA; endangered species.
1985. *Assiminea:* Taylor, p. 319; Rio Grande drainage as far upstream as New Mexico.
1986. Pecos assiminea snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A small species with chestnut-brown shell; regularly conical spire with up to $4^1/2$ regularly rounded whorls separated by an incised suture; aperture nearly round, umbilicus contained about 9 times in the shell diameter and only slightly covered by columellar lip.

Types—Holotype LACM 2088, a dry shell from the largest female of the series measured, collected by D. W. Taylor, 5-V-1981. Paratypes UTEP 10,051.

Type locality—Seepage on Bitter Lake National Wildlife Refuge, 1,250 ft E, 2,100 ft S, sec. 21, T10S, R25E, Chaves County, New Mexico.

Etymology—Named for the Pecos River.

Description—The shell (Fig. 2a–c, Table 1) is minute, conical, with a spire angle of 55-60°, and with up to $4^1/2$ strongly convex and regularly rounded whorls that are separated by an incised suture. The shell wall is translucent, glossy chestnut brown when fresh, thin but firm. The aperture is broadly ovate, nearly circular. The thin parietal lip is appressed simply to the preceding whorl, and passes smoothly into the thicker columellar lip. This lip is not flared but simply rounded and only slightly encroaches on an umbilicus that is contained in the shell diameter about 9 times. The thicker columellar lip thins as it passes gradually into the outer lip, which meets the parietal lip at an obtuse angle. The protoconch of about one whorl is smooth, glossy, abruptly set off from the later shell with definitive sculpture of fine, close-set, axial threads. These have little relief over most of the shell, but on the base and especially around the umbilicus become stronger, forming delicate, dose rugae. Growth lines and plane of aperture are at an angle of about 10° to the axis of coil. Spiral sculpture consists of very fine, irregular, discontinuous striae that commonly interrupt the fine growth-threads.

Operculum corneous, paucispiral, pale amber, slightly concave externally, with no internal thickenings.

Variation—The shells are geometrically simple and show little variation. As is true of other species in the genus, females are slightly larger than males (Table 1). The two shells drawn are the largest female and male in the subsets measured.

In old shells the thickening of the columellar lip may become opaque white and spread even onto the parietal wall, contrasting with the translucent brown of the rest of the shell.

Comparisons—The geographically nearest coastal species of *Assiminea* is *A. succinea* (Pfeiffer) of the Caribbean and Gulf of Mexico. That species has more flat-sided whorls, a subsutural thread, and a columellar callus pad that occludes or fills the umbilicus. The species of the Pacific Coast, *A. californica* (Tryon), differs from *A. pecos* by more flat-sided whorls and the presence of a columellar callus pad, but is similar in lacking a subsutural thread.

The inland species of *Assiminea* in Nevada and California are like *A. pecos* in lacking a subsutural thread, but differ in size and form, and are more similar to the Pacific Coast species *A. californica*. The strongly rounded whorls, deep suture, nearly round aperture, lack of subsutural thread, and especially the umbilicus make *A. pecos* the most distinct of the five American species.

Localities and material examined—NEW MEXICO, CHAVES COUNTY: Spring at Roswell Country Club, northeast of clubhouse, 600 ft W, 850 ft N, sec. 22, T10S, R24E; D. W. Taylor, 28-X-1968; one empty shell representing an extinct population. Lost River, 2,150 ft E, 1,800 ft S, sec. 5, T1OS, R25E; D. W. Taylor, 6-XI-1984. Seepage 1,250 ft E, 2,100 ft S, sec. 21, T10S, R25E; D. W. Taylor, 1981; type locality; a large but

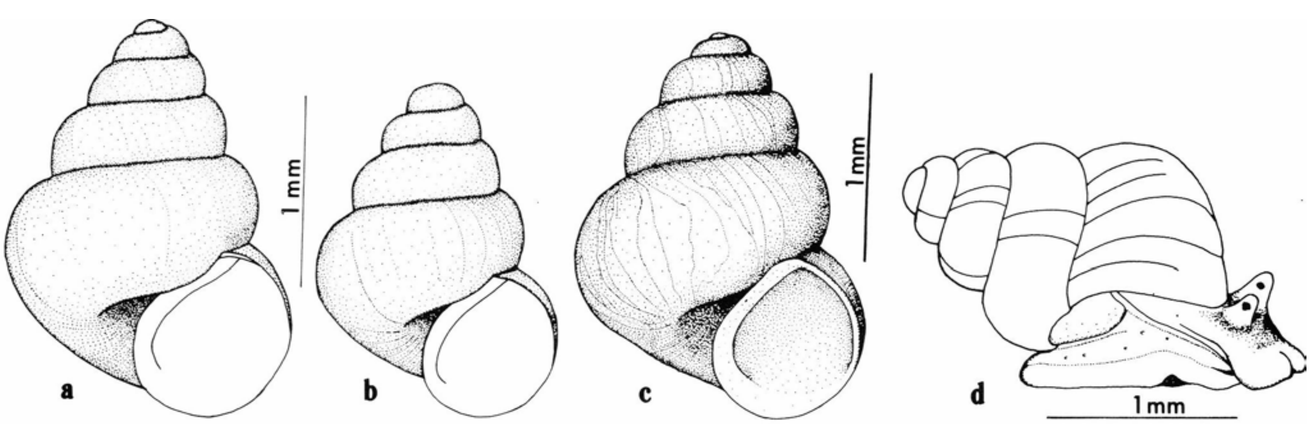

FIGURE 2—*Assiminea pecos* n.sp.: a, b, Shells from type locality, Bitter Lake National Wildlife Refuge, Chaves County, New Mexico; *a* female (holotype), *b* male; in each case the largest specimen in the subsets measured. **c**, Shell, Roswell Country Club, Chaves County, New Mexico. **d**, Living animal, Diamond Y Draw, Pecos County, Texas.

TABLE 1—Measurements and descriptive statistics of shells of *Assiminea pecos* n.sp. from type locality. N = 30 for both sexes.

	Males	Females
Whorls		
Mean	3.9	4.3
Range	3½–4¼	4–4½
Length		
Mean	1.55	1.87
Range	1.36–1.69	1.72–2.16
S. D.	0.082	0.112
S. E.	0.015	0.020
Length of peritreme		
Mean	0.70	0.79
Range	0.62–0.77	0.74–0.86
S. D.	0.033	0.034
S. E.	0.006	0.006
Length of peritreme/length		
Mean	0.450	0.422
Range	0.43–0.49	0.40–0.45
S. D.	0.014	0.016
S. E.	0.003	0.003
Width		
Mean	1.18	1.40
Range	1.05–1.29	1.32–1.51
S. D.	0.057	0.055
S. E.	0.010	0.010
Width/length		
Mean	0.762	0.749
Range	0.71–0.82	0.69–0.79
S. D.	0.024	0.027
S. E.	0.004	0.005

highly localized colony that became extinct between 1981 and 1984.

TEXAS, PECOS COUNTY: Diamond Y Draw, from Diamond Y Spring downstream for about 1 mi; D. W. Taylor, 19681984.

MEXICO, COAHUILA: Playa 3 km north of Las Delicias; Jose Lugo, Jr., 1966; one empty shell. Playa 21 km south of Rancho San Marcos; Jose Lugo, Jr., 1966; one empty shell.

In the basin of Cuatro Cienegas, both in internal drainages on the west and in the headwaters of the Rio Salado de los Nadadores of the Rio Grande drainage, numerous bottom samples indicate the species is widespread but sparse. Its local distribution is affected by the common practice of annually burning dry sedges. At only one locality was the species found alive: along the headwaters of Rio Churince immediately north of Laguna Churince; D. W. Taylor, 10VII-1975.

FOSSIL: Lowest terrace of Pecos River, south side, on east side of State Highway 18, $2^3/4$ mi (airline) southwest of Grandfalls, Pecos County, Texas; D. W. Taylor, 21-X-1984.

Alluvium along Rio Monclova, highway 57, 0.5 km north of San Juan Bautista, Coahuila, Mexico; D. W. Taylor, 3VIII-1968.

Habitat—The snails have been always found on moist earth beside seepages or spring-brooks, never beside standing water. They occur beneath salt grass or sedges, less often on exposed surfaces.

Family HYDROBIIDAE
FONTELICELLA Gregg & Taylor, 1965

Fontelicella is the most widespread and diversified genus of Hydrobiidae in the American West. Because of the number of species and their variation, definition of the genus and of groups within the genus is less precise than in most other genera.

The shell varies from globose to elongately oval or narrowly conical. In the female reproductive system a bursa copulatrix is present, variable in size and form, but consistently projecting posteriorly to the albumen gland. Bursa/albumen gland ratio has been calculated following Ponder (1982) as the mean of length and width of the bursa (not including its duct) divided by the length of the albumen gland. A receptaculum seminis is consistently present, ranging from club-shaped to narrowly elongate, entering the oviduct between the posterior apex of the distal bend and confluence of the bursal duct. The penis has glandular patches and generally an accessory process or lobe. Variation is great, providing the basis for grouping species but preventing ready characterization.

Terminology of ornament and structure of the penis is shown in Fig. 3, a composite of many species and populations. The basic ornament consists of a terminal strip (T) on the terminal lobe, a strip or patch on the ventral lobule (VL), and often a strip on the dorsal surface of the free portion of the penis (DP). Additional glandular areas and lobules are usually present, providing further characters. In general, the smaller glandular patches are less constant in presence, location, or fusion with others; and the ventral glands are less constant than those of the dorsal surface. A lobule is relatively common on the ventral surface and rare on the dorsal surface. The terminal strip is commonly uninterrupted; the penial gland (DP), when present, is rarely interrupted.

Nearly all species of *Fontelicella* belong to the typical subgenus, which is widespread in the western United States. The subgenus *Microamnicola* is monotypic, restricted to southwestern Nevada. *Natricola* includes a few species at the northern margin of the range, from south-central Oregon to westernmost Wyoming. Within *Fontelicella (s.s.)* two series of species can be distinguished. The *F. californiensis* series includes the type species of the genus, *F. californiensis*, and comprises species with a wider, more massive penis that has more glandular patches and usually a ventral lobule, dorsal strips, and a long, transverse terminal strip. This series of species occurs nearly throughout the range of the genus; it includes most of the species, and all those from the upper Gila drainage of eastern Arizona to the east and

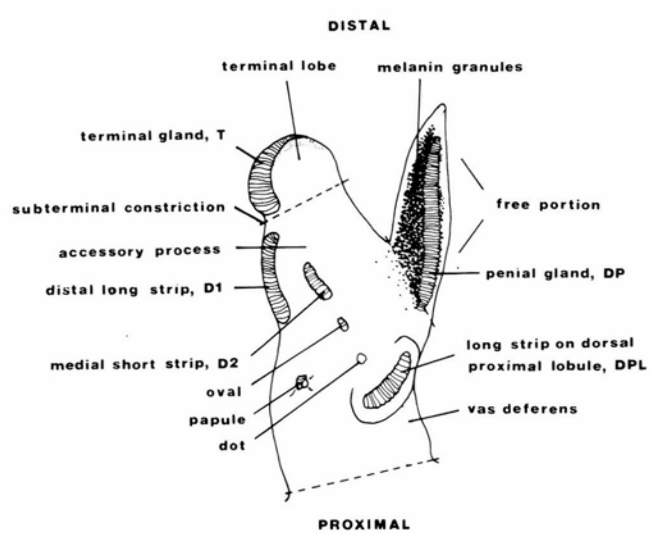

FIGURE 3—Terminology of ornament and structure of penis in *Fontelicella*. Diagrammatic, dorsal view. The penis bifurcates into an accessory process and a free portion containing the vas deferens. Characteristically the accessory process ends in a terminal lobe set off by a subterminal constriction. Glands and structures are designated topographically as dorsal, ventral, or terminal. Glands may or may not be raised on a lobule, and according to relative length are termed long or short strip, oval, or dot. A raised dot is a papule.

southeast. The *F. stearnsiana* series includes species with a slender penis that has few glandular patches and sometimes only a narrow terminal gland that is often oriented lengthwise. This series is widespread in California and Arizona, and occurs also in southeastern Idaho, Nevada, and Utah. Within this series the typical group, the *stearnsiana* group, occurs from central California south and southeast to Baja California, Sonora, and Arizona; it includes all the Fontelicellas of the lower Gila drainage.

Unexpectedly, the operculum has yielded markedly distinct characters in a few species, all described herein from New Mexico. Instead of being plane, in *Fontelicella pecosensis* the operculum has a raised spiral coiling; instead of being entirely corneous, in *F. roswellensis* it has internal calcareous material; and in *F. chupaderae* the operculum is intensely hued. None of these features is correlated with other characters of the animals, nor with unusual habitat.

Study of *Fontelicella* began years ago as a joint effort with W. **0.** Gregg. He is responsible principally for developing the terminology of the penis used herein (Fig. 3). Virtually all results of his work and of our joint studies were destroyed in vandalism of his collection not long before his death. Our work began in southern California, perhaps the worst place to start, where assessing the significance of characters is made difficult by presence of only two widely different species; consistently unispecific occurrences of the genus; and rarity or lack of males in many populations. Only with study of a variety of species over the range of the genus has a foundation for grouping and ranking the species been laid.

Most of the morphological differences between species are in size and proportions, providing little clue to relationships. Readily observable qualitative differences are present only in the penis, primarily in the arrangement of glandular patches. Similarities between species in penial ornamentation and in the bursa copulatrix are correlated with geographic proximity, providing support for the belief that these features indicate a relatively recent common ancestry.

The species described herein are allocated to the following informal species-groups: *davisi,* New Mexico-Texas; *gilae,* New Mexico; *kolobensis,* Utah; *neomexicana,* New Mexico; *pecosensis,* New Mexico; *thermalis,* New Mexico; and *trivialis,* Arizona.

FONTELICELLA DAVISI group

Penis with a long glandular strip (T) on the terminal lobe; a long penial gland (DP) single in its distal half but bifurcate proximad, with limbs of about equal length; ventral lobule with a long glandular strip (VL); other dorsal and ventral glandular patches and a dorsal distal lobule (DDL) variably present.

Bursa copulatrix a bulky sac as wide at anterior end as albumen gland and rounded at posterior end. Bursa/albumen gland ratio 0.38-0.78.

Three species, *F. davisi* n.sp., *F. metcalfi* n.sp., and *F. roswellensis* n.sp., from the lower Pecos Valley in southeastern New Mexico to the lower Rio Grande drainage in Trans-Pecos Texas.

The *Fontelicella davisi* group marks the southeastern limit of the genus. It is distinguished especially by the Y-shaped DP gland, a form otherwise unknown in *Fontelicella.*

FONTELICELLA DAVISI, new species
Fig. 4

1936. *Hydrobia palomasensis* (Pilsbry) [misidentified]: Cheatum, p. 22; tributary of Limpia Creek about 5 mi northeast of Fort Davis.

1982. *Fontelicella palomasensis* (Pilsbry) [misidentified]: Fullington, pp. 63-64; characteristic of Chihuahuan biotic province.

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a terminal long strip (T)

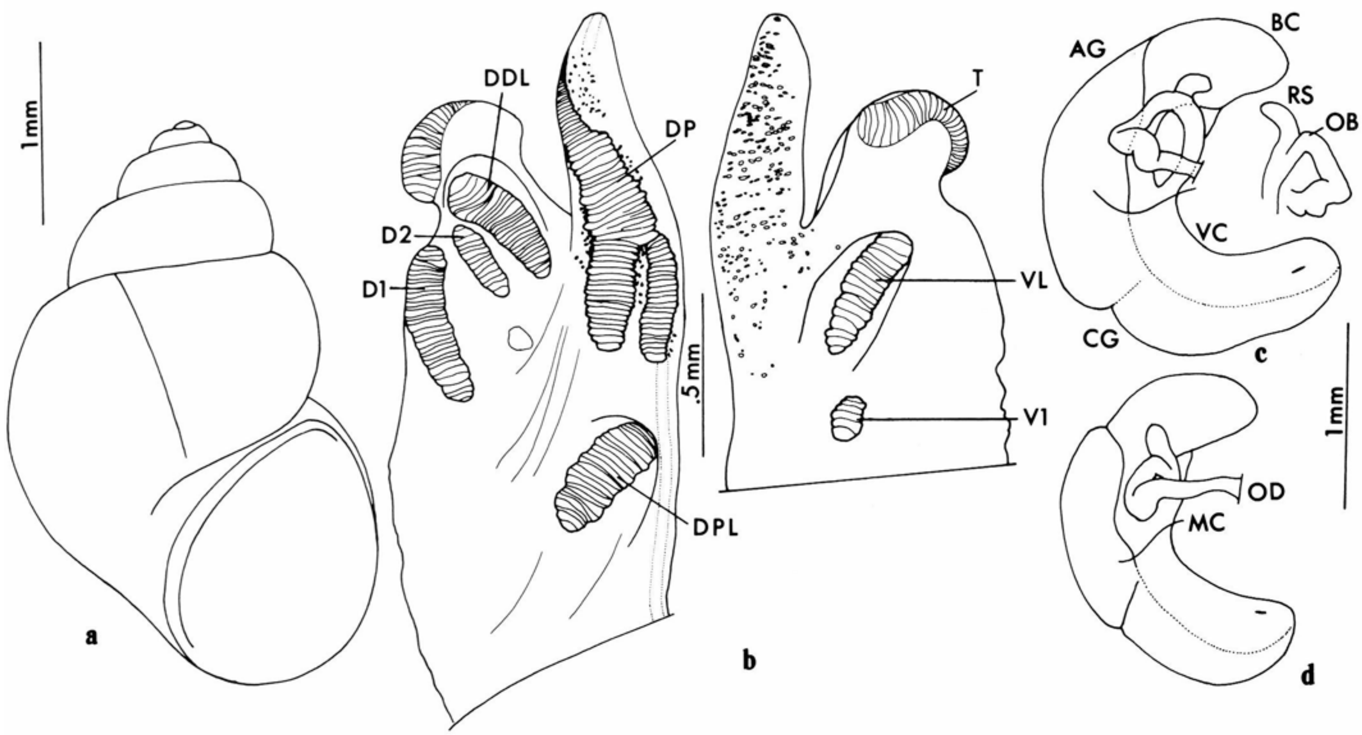

FIGURE 4—*Fontelicella davisi* n.sp.: **a,** Shell of larger female; **b,** penis, dorsal (left) and ventral (right) views of holotype; **c, d,** distal portion of female reproductive system; detail in *c* is of same specimen. Abbreviations: AG, albumen gland; BC, bursa copulatrix; CG, capsule gland; DDL, gland on dorsal distal lobule; DP, penial gland; DPL, gland on dorsal proximal lobule; D1, D2, dorsal glands; MC, wall of mantle cavity; OB, distal bend of oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL; gland on ventral lobule; V1, ventral gland.

on the end of the accessory process; on the dorsal surface a penial gland (DP) single in its distal half but bifurcate proximad, with limbs of about equal length; an oblique long strip on a strong dorsal proximal lobule (DPL); an oblique long strip on a dorsal distal lobule (DDL); a slightly oblique long strip on the left distal surface (Dl); on the ventral surface a diagonal long strip (VL) on the ventral lobule.

Types—Holotype LACM 2211, a male preserved in alcohol, collected by D. W. Taylor, 16-IV-1981. Paratypes UTEP 10,053.

Type locality—Tributary of Limpia Creek about 5 mi northeast of Fort Davis, Jeff Davis County, Texas.

Etymology—Named for Jefferson Davis, who is commemorated locally by Fort Davis, the Davis Mountains, and Jeff Davis County.

Description—Shell (Fig. 4a, Table 2) elongately ovate, with short spire. Whorls regularly convex to slightly shouldered, separated by a distinct or even incised suture forming a spire with gently convex outline. Peritreme simply adnate or free. Periostracum tan.

Operculum (Table 3) plane, amber. Attachment scar with a well-developed border all around, which leaves no spiral trace.

Penis (Fig. 4b, Table 4) usual in shape, distinguished by the pattern of glands. The free portion of the penis contains numerous melanin granules, but these do not form the dense black core found in many other species.

Distal female system (Fig. 4c, d): Bursa copulatrix a bulky sac as wide at anterior end as the albumen gland. Bursa/albumen gland ratio in five specimens ranged from 0.45 to 0.76, mean 0.60.

Loop of oviduct thickened, with a double bend. Receptaculum seminis club-shaped, usually curved, projecting behind the distal bend of the oviduct where it is appressed to the bursa.

Albumen gland extends anteriorly of the hind end of the mantle cavity by up to one-fourth the length of the gland. Ventral channel broad beneath both the capsule gland and albumen gland.

Variation—The major glandular patches on the penis are present uniformly in the sample studied (Table 4).

Comparisons—Fontelicella davisi is most like its geographically nearest neighbor, *F. metcalfi*, in characters of penial ornamentation. The features in common are the bifurcate penial gland (DP), dorsal proximal lobule bearing a glandular strip (DPL), a long strip on the left dorsal surface (D1), and a diagonal long strip on the ventral lobule (VL). Differences are that the dorsal distal lobule (DDL) of *F. davisi* is absent in *F. metcalfi*, although the corresponding glandular patch (D2) is present; in *F. davisi* Dl ordinarily consists of one strip, whereas in *F. metcalfi* it is compound; *F. davisi* often has a small gland on the ventral side in addition to that on the ventral lobule (VL); and T in *F. metcalfi* is ventroterminal.

In shell features, *Fontelicella davisi* is of the elongately ovoid form usual in the genus, whereas *F. metcalfi* is short and stout. These two Texas species form a pair that is most like *F. roswellensis* of eastern New Mexico, but are quite

TABLE 2—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella davisi* n.sp.

Whorls	
Mean	4.36
Range	4–4$^3/_4$
Length	
Mean	3.10
Range	2.76–3.84
S. D.	0.217
S. E.	0.040
Length of body whorl	
Mean	2.35
Range	1.92–2.70
S. D.	0.159
S. E.	0.029
Length of peritreme	
Mean	1.41
Range	1.26–1.56
S. D.	0.089
S. E.	0.016
Length of peritreme/length	
Mean	0.454
Range	0.42–0.50
S. D.	0.024
S. E.	0.004
Length of peritreme/length of body whorl	
Mean	0.599
Range	0.55–0.67
S. D.	0.030
S. E.	0.006
Width/length	
Mean	0.651
Range	0.58–0.71
S. D.	0.030
S. E.	0.006
Width/length of body whorl	
Mean	0.859
Range	0.79–1.00
S. D.	0.040
S. E.	0.007

TABLE 3—Measurements and descriptive statistics of 20 opercula of *Fontelicella davisi* n.sp. from larger females measured (Table 2).

Length	
Mean	1.24
Range	1.14–1.36
S. D.	0.053
S. E.	0.012
Width/length	
Mean	0.712
Range	0.66–0.76
S. D.	0.015
S. E.	0.003
Left end/length	
Mean	0.283
Range	0.26–0.31
S. D.	0.025
S. E.	0.006

TABLE 4—Penial glands in *Fontelicella davisi* n.sp. N = 30.

Terminal gland (T)	
Long strip	30
Dorsal glands	
Penial gland (DP) bifurcate	30
Dorsal proximal lobule (DPL)	30
Dorsal distal lobule (DDL)	30
Left distal strip (D1)	30
Additional dot or oval	10
Additional 2 dots or ovals	3
Additional 3 dots or ovals	3
Additional strip	1
Additional strip and 2 dots	1
Ventral glands	
Diagonal long strip on lobule (VL)	30
Additional posterior strip or oval	3
Additional posterior dot or papule	7
Additional posterior 2 dots	1

distinct from the geographically intermediate *F. pecosensis.*

Localities and material examined—TExAs, JEFF DAVIS COUNTY: Tributary of Limpia Creek about 5 mi northeast of Fort Davis; Ottys Sanders, IV-1936, E. P. Cheatum, IX-1936 (Cheatum, 1936: 22); D. W. Taylor, 16-IV-1981. Spring, south slope of Spring Mountain; C. Thompson & M. M. Sampson, 1914 (UMMZ 66309). Trough, Big Spring, foot of Spring Mountain, C. Thompson & M. M. Sampson, 1914 (UMMZ 66308).

Local inquiry did not enable relocation of "Big Spring" or "Spring Mountain," but there seems to be at least one population in addition to that at the type locality.

Habitat—The rivulet in which the snails live is perennial in its upper course, but ordinarily does not flow as far as Limpia Creek. It is a pool-falls sequence tumbling among boulders, only a few inches wide at the falls and forming pools a few inches deep. Bottom is soft mud over gravel and rock with patches of watercress. *Fontelicella* was abundant among the vegetation, in and on mud and rock, associated with *Pisidium casertanum* (Poli).

FONTELICELLA METCALFI, new species
Fig. 5

1986. *Fontelicella* sp.: Ashbaugh & Metcalf, pp. 7-8; Naegele Springs, Texas, living and Holocene.

Diagnosis—A short, plump species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a terminal long strip (T) on the ventroterminal surface of the accessory process; on the dorsal surface a penial gland (DP) single in its distal half but bifurcate proximad, with limbs of about equal length; a robust, oblique gland on a swelling of the proximal right surface (DPL); a strip or oval (D2) on the right side of the accessory process distad of the base of the free portion of the penis; and beginning near the left distal margin a diagonal, very long strip or a series of smaller glandular patches (D1); on the ventral surface a diagonal long strip (VL) on the ventral lobule.

Types—Holotype LACM 2212, a male preserved in alcohol, collected by D. W. Taylor, 15-IV-1981. Paratypes UTEP 10,055.

Type locality—Naegele Springs, 5.3 mi north-north-west of Ruidosa, Presidio County, Texas.

Etymology—Named for A. L. Metcalf of the University of Texas (El Paso), who discovered the population and provided data.

Description—Shell (Fig. 5a, Table 5) subconical to elongately ovate, with short to moderately long spire. Whorls regularly convex to slightly shouldered, separated by a distinct suture, forming a spire with broadly convex outline. Peritreme simply adnate or free. Periostracum pale tan.

Operculum (Table 6) similar in form to that of *F. chupaderae* but pale amber, darker amber in the callus, plane. The attachment scar has a distinct border all around, but leaves no conspicuous spiral trace.

Penis (Fig. 5c, Table 7) of the form usual in the group, distinguished by the pattern of glands and by having T ventroterminal in location. The free portion of the penis

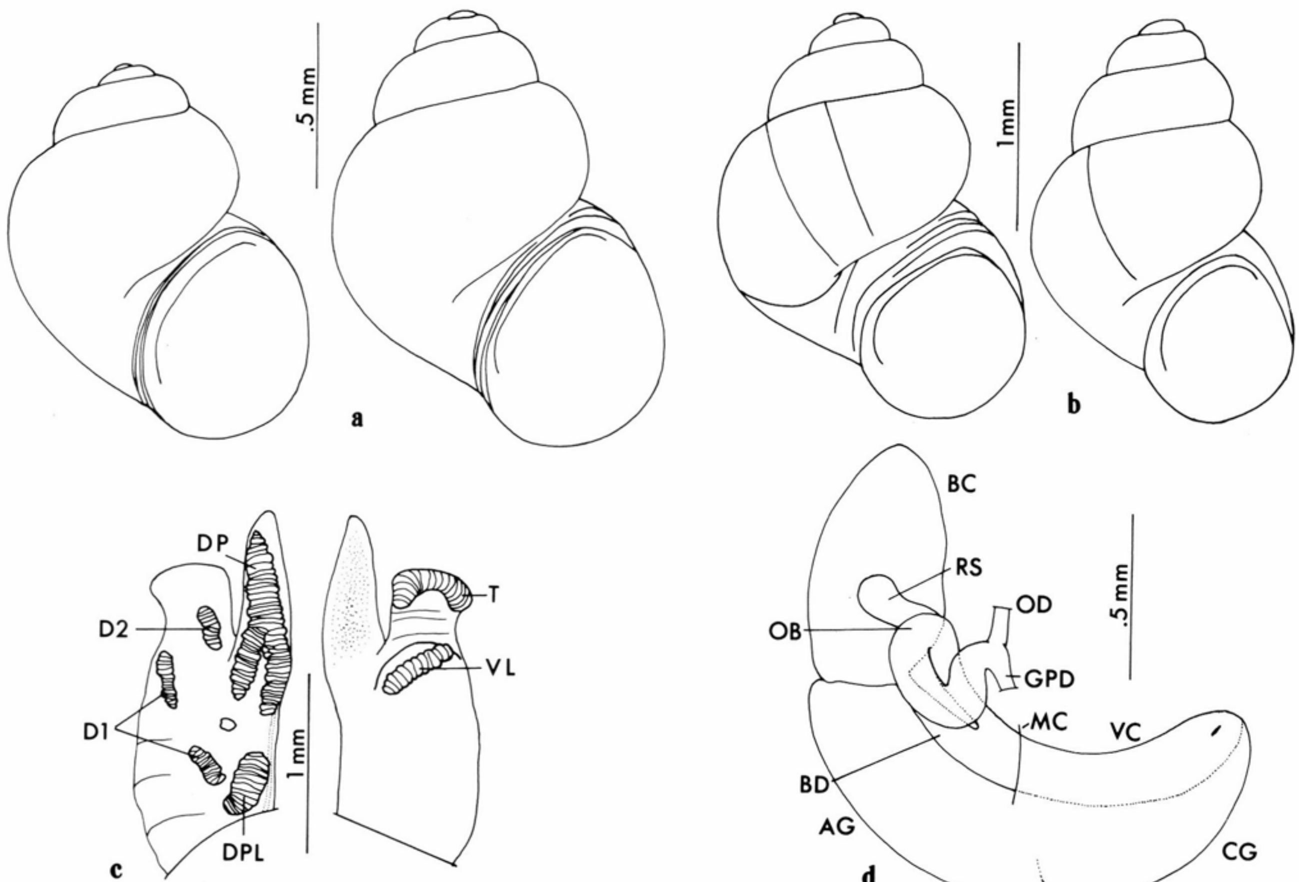

FIGURE 5—*Fontelicella metcalfi* n.sp.: **a,** Two larger female shells from type locality; **b,** *Fontelicella* aff. *metcalfi*, representative shells, Holocene, Black River Falls, Eddy County, New Mexico; **c,** penis, dorsal (left) and ventral (right) views of holotype; **d,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix, BD, duct of bursa copulatrix; CG, capsule gland; DP, penial gland; DPL, gland on dorsal proximal swelling; D1, D2, dorsal glands; GPD, gonopericardial duct; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, gland on ventral lobule.

contains a concentration of melanin granules, but these do not form a dense, black core.

Distal female system (Fig. 5d): Bursa copulatrix a bulky sac as wide at anterior end as the albumen gland and tapered posteriorly to a narrowly rounded tip. Bursa/albumen gland ratio in seven specimens ranged from 0.46 to 0.78, mean 0.59.

Loop of oviduct thickened, with a double bend, the segment between nearly straight. Receptaculum seminis club-shaped, straight or, more frequently, slightly curved to the right, projecting behind the distal bend of the oviduct. It is appressed to the bursa, reaching to (or slightly less or more) the mid-length of that structure.

Albumen gland projects into the mantle cavity by one-third to less than one-fourth of its length. Duct of bursa copulatrix is half-immersed in the albumen gland and widens gradually as it runs forward, becoming $1^1/2$-3 times as wide as the oviduct. Ventral channel poorly defined.

Variation—Most conspicuous variation is in the number and arrangement of penal glands (Table 7). In two specimens of the sample tabulated DP was angular and not bifurcate, without the usual posterior right limb. This supports the interpretation that DP in this instance is not the simple strip of most species to which an accessory dorsal strip has been added.

Comparisons—Fontelicella metcalfi is most like its geographically nearest neighbor, *F. davisi*, in features of the penis, although the shells are quite different. Patterns of glands are compared in the text under *F. davisi*. Both species share weak pigmentation of the free portion of the penis, in addition to similar glands.

Observations on living animals—Overall pigmentation is relatively pale. As usual, the rostrum is the area most heavily dusted with melanin; it may be nearly black, but sometimes is so pale that the buccal mass can be seen readily in dorsal view. White granules form a patch behind the eye across the width of the tentacle, roughly square with a diffuse posterior edge. There may also be a few scattered white granules in the tentacle distad to the eye. In the mantle collar and operculigerous lobe sugary hyaline granules and melanin combine to give a salt-and-pepper appearance. Less conspicuous are subepithelial hyaline granules within the sides of the head-foot.

The penis is weakly pigmented also, its general aspect translucent and slightly cloudy. In the accessory process are a few scattered white granules, in the free portion of the penis a salt-and-pepper sheath of melanin and hyaline granules around the vas deferens.

Localities and material examined—TEXAS, PRESIDIO COUNTY: Naegele Springs, 5.3 mi north-north-west of Rui-

TABLE 5—Measurements and descriptive statistics of shells of *Fontelicella metcalfi* n.sp. and *F.* aff. *F. metcalfi*. N = 30 in all cases. Samples from Black River Falls and Independence Creek are fossil, selected for larger size. Sample from Naegele Springs is of larger females.

	Black River Falls	Independence Creek	Naegele Springs
Whorls			
Mean	3.8	3.8	3.8
Range	$3^1/_4$–4	$3^1/_2$–$4^1/_4$	$3^1/_2$–$4^1/_4$
Length			
Mean	2.01	1.94	2.37
Range	1.66–2.35	1.63–2.32	2.15–2.66
S. D.	0.190	0.163	0.141
S. E.	0.035	0.030	0.026
Length of body whorl			
Mean	1.57	1.54	1.94
Range	1.34–1.80	1.34–1.80	1.80–2.15
S. D.	0.135	0.097	0.096
S. E.	0.025	0.018	0.018
Length of peritreme			
Mean	0.92	0.89	1.19
Range	0.80–1.09	0.77–1.00	1.06–1.34
S. D.	0.082	0.072	0.065
S. E.	0.015	0.013	0.012
Length of peritreme/length			
Mean	0.457	0.458	0.506
Range	0.40–0.52	0.37–0.52	0.44–0.55
S. D.	0.031	0.032	0.027
S. E.	0.006	0.006	0.005
Length of peritreme/length of body whorl			
Mean	0.585	0.577	0.615
Range	0.51–0.63	0.52–0.63	0.55–0.67
S. D.	0.030	0.031	0.027
S. E.	0.006	0.006	0.005
Width/length			
Mean	0.708	0.712	0.725
Range	0.64–0.82	0.61–0.82	0.64–0.79
S. D.	0.049	0.053	0.038
S. E.	0.009	0.010	0.007
Width/length of body whorl			
Mean	0.905	0.896	0.879
Range	0.82–1.02	0.81–1.00	0.83–0.94
S. D.	0.049	0.043	0.035
S. E.	0.009	0.008	0.006

TABLE 6—Measurements and descriptive statistics of 20 opercula of *Fontelicella metcalfi* n.sp. from larger females measured (Table 5).

Length	
Mean	1.15
Range	1.08–1.32
S. D.	0.050
S. E.	0.011
Width/length	
Mean	0.681
Range	0.65–0.73
S. D.	0.019
S. E.	0.004
Left end/length	
Mean	0.288
Range	0.27–0.32
S. D.	0.014
S. E.	0.003

TABLE 7—Penial glands in *Fontelicella metcalfi* n.sp. N = 30.

Terminal gland (T)	
Long strip	30
Dorsal glands	
Penial gland	
Bifurcate	28
Left limb only	2
Dorsal proximal lobule (DPL)	30
Dorsal gland 1 (D1)	30
Diagonal long strip only	12
Two diagonal strips in line	3
Diagonal strip and dot in line	13
Diagonal strip, 2 dots in line	2
Additional dot, medial	8
Additional 2 dots, medial	1
Dorsal gland 2 (D2)	30
Ventral gland on lobule (VL)	
Diagonal long strip	29
No gland or lobule	1

dosa; A. L. Metcalf and K. M. Ashbaugh, 10-X1-1979 (UTEP 7802, 7804); D. W. Taylor, 15-IV-1981.

Fossils from the following two localities in the Pecos River valley, New Mexico and Texas, are so similar (Table 5) that they are probably the same species and are grouped as *Fontelicella* aff. *metcalfi.* NEW MEXICO, EDDY COUNTY: Black River Falls, center NW 1/4 sec. 35, T24S, R26E; D. W. Taylor, 30-VII-1968. TEXAS, TERRELL COUNTY: lowest terrace of Pecos River, 1/4 mi north of mouth of Independence Creek; D. W. Taylor, 28-VI-1968.

Habitat—At Naegele Springs the snails were common in the outflow (source 24°C) among dense watercress and in fine mud. Associated species were *Physa mexicana* Philippi and *Pisidium casertanum* (Poli). A previous collection by A. L. Metcalf, 3-1-1978, yielded also *Musculium transversum* (Say) and *Pisidium insigne* Gabb. Ashbaugh & Metcalf (1986) recorded living and Holocene molluscs from and near the springs, documenting the richer fossil assemblage. Henry (1979: 25) published analyses of water from the springs and showed their location relative to the alluvial fill of Presidio Bolson.

The two fossil occurrences in the Pecos Valley are from river-deposited sediments, but in both cases might be derived from tributary spring-fed streams.

FONTELICELLA ROSWELLENSIS, new species

Fig. 6

1899. *Amnicola* sp.: Pilsbry, p. 79; South Spring River near Roswell, New Mexico, Pleistocene; J. D. Tinsley, collector, 1899.

1954. *Amnicola neomexicana* Pilsbry [misidentified]: Noel, pp. 126-127, 132; Lander spring-brook near Roswell; life history and ecology.

1984. *Fontelicella* sp.: U.S. Fish & Wildlife Service, p. 21673; candidate endangered species.

1985. Roswell spring snail: New Mexico Department of Game & Fish, account MOLL/HY/FO/DD; endangered species. 1986. Roswell spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella (s.s.)* with glandular patches on the penis as follows: a terminal long strip (T); a Y-shaped penial gland (DP) with two posterior limbs, the anterior limb extending onto the left side of the free portion of the penis; a dorsal distal lobule (DDL) often bearing a

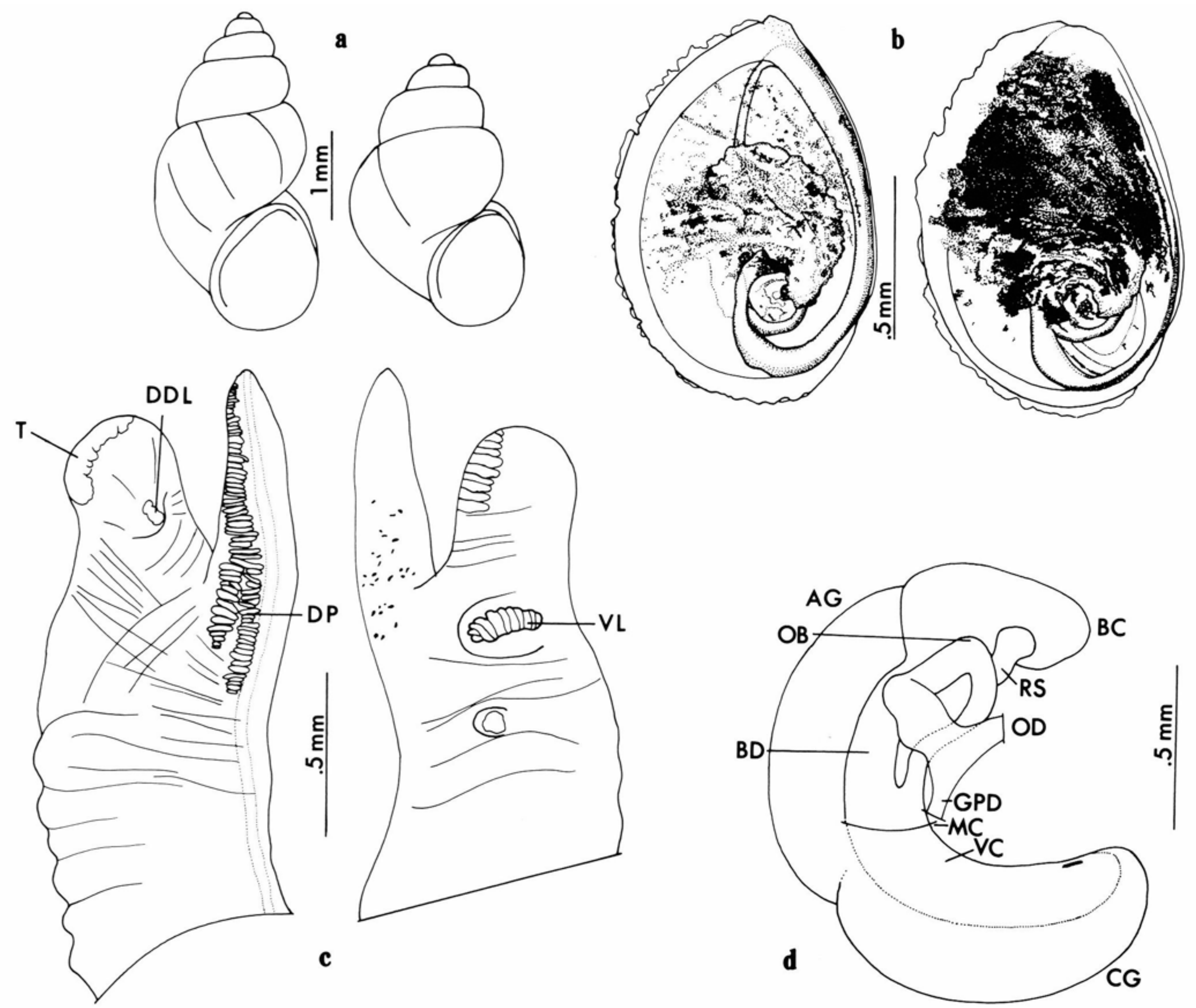

FIGURE 6—*Fontelicella roswellensis* n.sp.: **a,** Larger female shells from Roswell County Club; **b,** operculum, inner face, from Roswell Country Club, composite sketches showing some surface relief and, in transmitted light, distribution of calcareous material within as well as on surface; **c,** penis, dorsal (left) and ventral (right) views of holotype; **d,** distal portion of female reproductive system, from type locality. Abbreviations: AG, albumen gland; BC, bursa copulatrix, BD, duct of bursa copulatrix; CG, capsule gland; DDL, gland on dorsal distal lobule; DP, penial gland; GPD, gonopericardial duct; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, gland on ventral lobule.

small patch; often a gland (Dl) on the dorsal left medial surface; and a ventral lobule with a strip (VL) that is usually transverse. Operculum unique in the genus, with internal calcareous thickening.

Types—Holotype LACM 2213, a male preserved in alcohol, collected by D. W. Taylor, 28-X-1981. Paratypes UTEP **10,057.**

Type locality—Seepage 1,250 ft E, 2,100 ft S, sec. 21, T10S, R25E, Chaves County, New Mexico.

Etymology—Named after the nearby town of Roswell.

Description—Shell (Fig. 6a, Table 8) elongately ovoid, with long spire. Whorls regularly convex to shouldered, separated by an incised suture, forming a spire with a gently convex outline. Peritreme simply adnate or free. Periostracum tan.

Operculum (Fig. 6b, Table 9) plane, corneous portion pale amber. Internal calcareous thickening occurs as irregular white streaks, flecks, or a suffusion within most of the operculum. Attachment scar bordered by a discrete thickening leaving a spiral trace. The internal comeous callus over white calcareous material may be evident as a dark-amber patch. Distribution of the calcareous material indicates that it is added along the growing edge of the operculum at the columellar margin, irregularly mixed with corneous material, and to a lesser extent as part of the internal callus. The calcareous component is not an internal callus, but is incorporated within the body of the operculum. In addition to calcareous material in the operculum, the following features are distinctive: columellar margin and border of the attachment scar are thicker than in other species of the genus; and the narrow end of the internal callus, at which lengthwise growth takes place, is broader and blunter than in other species of the genus.

Incidence of calcareous material within the operculum varies between populations. In a sample of 30 specimens from Sago Spring, 15 contained some—from a trace to less than 10% in nine specimens and from 10 to 25% in six specimens. Specimens with no lime show other characteristics of *F. roswellensis:* a thick border around the attachment scar, leaving a spiral trace; a thick internal callus; and a blunt, narrow end of the callus. Hue varies from pale amber to amber, with the internal callus darker. Of 30 specimens from the type locality, 12 had calcareous material through 50-75%, seven in 25-50%, two in 10-25%, and eight between a trace and 10% of the operculum; one specimen had none. Corresponding figures for 21 specimens from Roswell Country Club are over 75% in four specimens, 50-75% in three specimens, 25-50% in seven specimens, and 10-25% in seven specimens.

Penis (Fig. 6c, Table 10) of the form usual in the group,

TABLE 8—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella roswellensis* n.sp. from Roswell Country Club.

Whorls	
Mean	4.5
Range	4–5
Length	
Mean	3.01
Range	2.4–3.8
S. D.	0.315
S. E.	0.058
Length of body whorl	
Mean	2.21
Range	1.8–2.6
S. D.	0.188
S. E.	0.034
Length of peritreme	
Mean	1.29
Range	1.1–1.5
S. D.	0.107
S. E.	0.019
Length of peritreme/length	
Mean	0.432
Range	0.39–0.47
S. D.	0.020
S. E.	0.004
Length of peritreme/length of body whorl	
Mean	0.585
Range	0.55–0.62
S. D.	0.017
S. E.	0.003
Width/length	
Mean	0.610
Range	0.52–0.67
S. D.	0.039
S. E.	0.007
Width/length of body whorl	
Mean	0.826
Range	0.72–0.92
S. D.	0.043
S. E.	0.008

TABLE 9—Measurements and descriptive statistics of 20 opercula of *Fontelicella roswellensis* n.sp. Opercula from larger females measured (Table 8).

Length	
Mean	1.076
Range	0.98–1.16
S. D.	0.059
S. E.	0.013
Width/length	
Mean	0.714
Range	0.657–0.761
S. D.	0.028
S. E.	0.006
Left end/length	
Mean	0.286
Range	0.239–0.318
S. D.	0.020
S. E.	0.004

TABLE 10—Penial glands in *Fontelicella roswellensis* n.sp. N = 30 for both samples.

	Type Locality	Roswell Country Club
Terminal gland (T)		
Interrupted into two short strips	2	4
One long strip	28	26
Dorsal glands		
Penial (DP)		
One Y-shaped strip	26	29
One straight long strip	4	
Left posterior limb slightly disjunct		1
Dorsal distal lobule (DDL)		
Absent, no gland	3	12
Present, no gland		7
Present, with glandular papilla	12	3
Present, with oval or short strip	15	8
Dorsal left medial gland (D1)		
Absent	30	9
Oval or papilla		3
Strip		18
Ventral glands		
Lobule with strip (VL)	30	30
Papilla behind lobule	2	

distinguished by the pattern of glands, but otherwise as in *F. davisi.*

Distal female system (Fig. 6d): Bursa copulatrix a bulky sac that may be as wide at anterior end as the albumen gland. Bursa/albumen ratio in six specimens ranged from 0.38 to 0.67, mean 0.50.

Loop of oviduct thickened, with a double bend. Part of the loop, often as much as the posterior half, rests against the anterior end of the bursa. Receptaculum seminis club-shaped, straight or, more frequently, curved to the right; projects behind the distal bend of the oviduct, where it is appressed to the bursa.

Albumen gland projects into the mantle cavity by up to one-fourth of its length. Duct of bursa copulatrix is half immersed in the albumen gland; it widens conspicuously after leaving the bursa and is two or three times as wide as the oviduct distad of the loop. Ventral channel broad, poorly defined externally.

Variation—From inspection of shell samples, sexual dimorphism is inconspicuous. Glandular patches on the penis are quite similar in the two samples studied (Table 10). The terminal gland (T), one of the less variable glands in *Fontelicella,* shows similar variation in both samples. Variation in calcareous additions to the operculum has been described above.

Comparisons—Fontelicella *roswellensis* differs from *F. davisi* and *F. metcalfi* in having fewer, weaker dorsal glands and no dorsal proximal lobule (DPL). In having a dorsal distal lobule (DDL), *F. roswellensis* is more like *F. davisi* than *F. metcalfi,* which lacks this structure; but the latter two are closer to each other than to *F. roswellensis* in features of the glands and in having a plain, amber operculum as usual in the genus, not the distinctive whitish-streaked operculum with calcareous thickening as *F. roswellensis.* In shell features *F. davisi* and *F. roswellensis* are similar in the elongately ovoid form usual in the genus, whereas *F. metcalfi* is distinctive by its short, stout shape.

Distribution—Springs in the Pecos River valley in vicinity of Roswell, Chaves County, New Mexico.

Localities and material examined—All localities are on U.S. Geological Survey Bitter Lake quadrangle, 1:24,000 (1962). The westernmost occurrence is a spring northeast of the clubhouse of Roswell Country Club, 600 ft W, 850 ft N, sec. 22, T1OS, R24E, sampled at various times from 1968 to 1981. All other localities are within Bitter Lake National Wildlife Refuge, as follows: Sago Spring, tributary to Bitter Lake. Seepage into drainage ditch along west side of Refuge unit 6, in NE1/4 sec. 16, T10S, R25E. Seepage on west side of Refuge unit 7, 1,250 ft E, 2,100 ft S, sec. 21, T1OS, R25E (type locality), where the species became extinct before 1984. Localities within the Refuge were sampled in May and October 1981, and November 1984.

The largest series available are from the Roswell Country Club, where the future of the population is doubtful. The most suitably preserved specimens are from the type locality, but shells are so heavily encrusted that standard measurements could not be taken.

Location of "Lander Springbrook," where Noel (1954) carried out her life history studies, could not be traced, but it is doubtful that the habitat and population survive. Description by Noel of the site as "4.7 km northeast" of Roswell, and also as tributary to South Spring River, is irreconcilable.

The following Pleistocene fossils are referred to *Fontelicella roswellensis.* All of them have been found in vicinity of the modern populations:

SSB 5437, UMMZ 119175: Berrendo River, 4 mi northeast of Roswell; from B. Walker collection.

UMMZ 67846: Pecos River northeast of Roswell, no collector or date recorded.

Habitat—See under *Tryonia kosteri,* hereafter. Both *T. kosteri* and *F. roswellensis* are commonly associated, in both fresh and gypsum-rich waters. The differential occurrence of the two might be explained partly by the ability of *F. roswellensis* to live in even tiny perennial seepages (as at the type locality, where *T. kosteri* was absent). Yet, in Lost River only T. *kosteri* was found, although neither substratum, gypsum content, or current seemed unsuitable for *F. roswellensis.*

Remarks—Shells of *Fontelicella roswellensis* and *Tryonia kosteri* look much alike and the two may be difficult to separate when bodies are withdrawn into the shell. However, the amber operculum of *F. roswellensis,* even when without whitish streaks, contrasts conspicuously with the transparent operculum of *T. kosteri.*

FONTELICELLA GILAE group

Penis with the usual long glandular strip on the terminal lobe divided into two portions, a long strip (Tl) representing left and central portions, and a papule on the right (Tr) representing its right end; a long penial gland (DP) and a second long strip (DP1) on dorsal and left distal surfaces of the free portion of the penis; a long strip (DDL) on a prominent dorsal distal lobule; a long strip (Dl) on left distal margin of the accessory process; ventral lobule with a long glandular strip (VL).

Bursa copulatrix a bulky sac as wide at anterior end as albumen gland and blunt at posterior end. Bursa/albumen gland ratio 0.54-0.65.

One species, *F. gilae* n.sp., from forks of the Gila River, west-central New Mexico.

FONTELICELLA GILAE, new species
Fig. 7

1985. Gila spring snail: New Mexico Department of Game & Fish, account MOLL/HY/FO/BB; endangered species.
1986. Gila spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a terminal long strip (Tl) representing the left and central portions of the usual T, and a papule (Tr) representing its right end; on the dorsal surface a long strip on the free portion of the penis (DP); a second long strip (DP1) extending from left dorsal surface of the free portion onto its left side; on a prominent dorsal distal lobule an arcuate or semicircular long strip (DDL); a long strip (D1) on the left distal margin of the accessory process; on the ventral surface a long strip (VL) on the ventral lobule.

Types—Holotype LACM 2214, a male preserved in alcohol, collected by D. W. Taylor, 11-IV-1981. Paratypes UTEP 10,054.

Type locality—Springs on north side of East Fork of Gila River, center of sec. 3, T13S, R13W, unsurveyed, Grant County, New Mexico.

Etymology—Named for the Gila River.

Description—Shell (Fig. 7a, Table 11) elongately ovoid, with long spire. Whorls regularly convex to slightly shouldered, separated by a distinct or even incised suture, forming a spire with convex outline. Peritreme simply adnate or free. Periostracum tan.

Operculum (Table 12) plane, amber, more intensely hued in the callus. The attachment scar has a distinct border all around, but leaves no conspicuous spiral trace.

Penis (Fig. 7b, c, Table 13) unique in the genus in having two glands on the free portion (DP and DP1). Terminal strip (T) usually divided unequally or reduced; rare individuals with the usual T (Fig. 6c) permit identification of the sep-

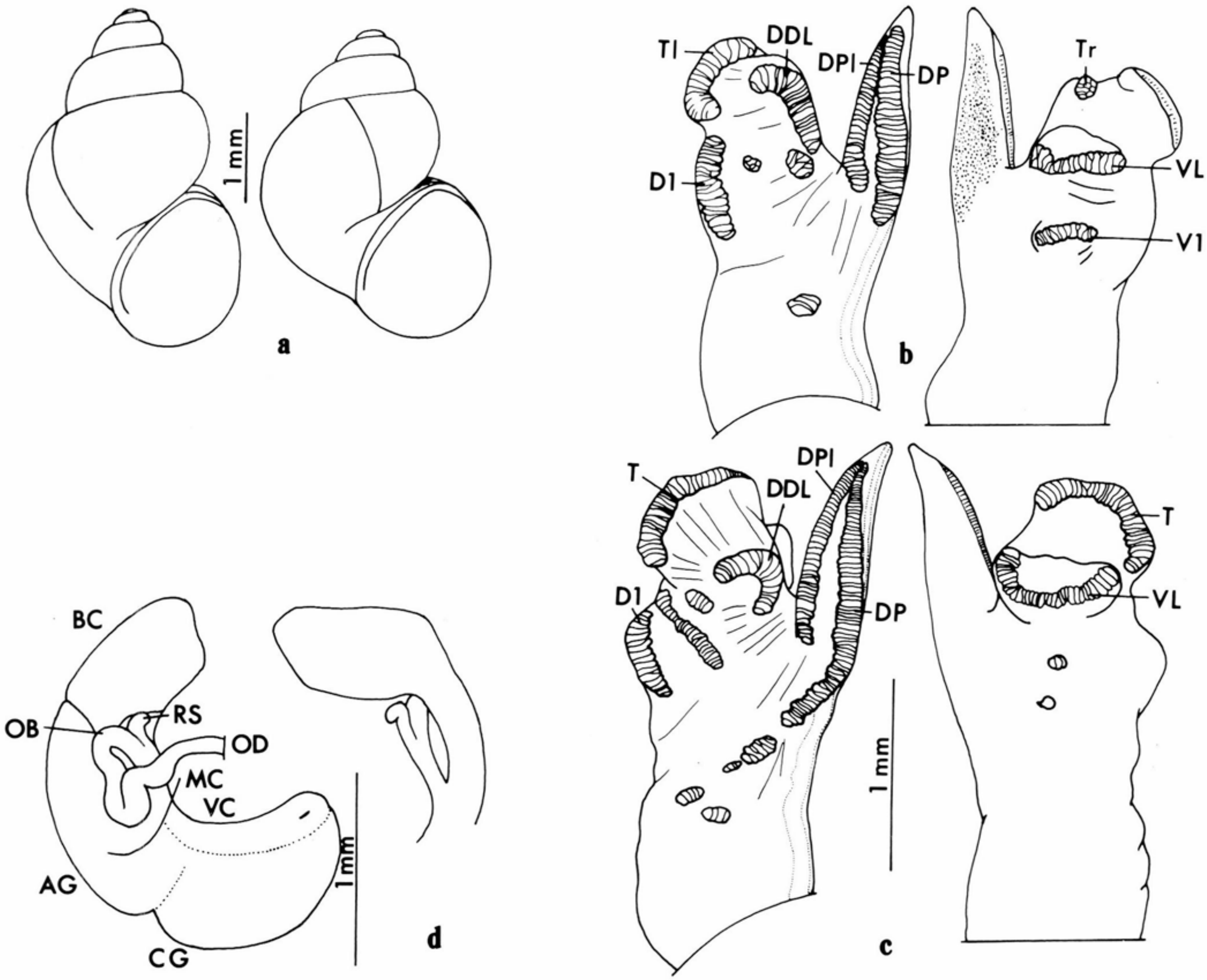

FIGURE 7—*Fontelicella gilae* n.sp.: **a,** Shells of larger females; **b, c,** penis, dorsal (left) and ventral (right) views, *b* holotype; **d, e,** distal portion of female reproductive system, detail in *e* is of specimen in *d*. Abbreviations: AG, albumen gland; BC, bursa copulatrix, CG, capsule gland; DDL, gland on dorsal distal lobule; DP, penial gland; DPl, left penial gland; D1, dorsal gland; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; Tl, left portion of terminal gland; Tr, right portion of terminal gland; VC, ventral channel; VL, gland on ventral lobule; V1, ventral gland.

arate components Tl and Tr as segments of T. Glands consistently present are DP and DP1; a long strip on a right distal lobule (DDL); and a long strip on the left lateral surface (Dl). Numerous minor glands are inconstant in occurrence or position (Table 12).

In life, the free portion of the penis shows a diffuse melanin core; elsewhere, the penis is colorless and translucent, with scattered hyaline granules.

Distal female system (Fig. 7d–e): Bursa copulatrix a bulky sac as wide at anterior end as the albumen gland. Bursa/albumen gland ratio in six specimens ranged from 0.54 to 0.65, mean 0.59.

Loop of oviduct thickened, with a double bend. Receptaculum seminis dub-shaped, curved, projecting behind the distal bend of the oviduct, appressed to the albumen gland in front of the bursa.

Albumen gland projects into the mantle cavity by less than one-fourth of its **length.** Ventral channel broad and poorly defined externally beneath capsule gland and albumen gland.

Variation—Most conspicuous variation is in the penial glands (Table 13). The shell is ordinary for the group, with no corollary to the unusual penis.

Observations on living animals—Overall color is gray, darker on dorsal and lateral sides of rostrum and head. Above and behind the eye is a patch of sugary-white granules as wide as the tentacle, one-half to twice as long as wide, with a diffuse posterior border. Scattered white granules are visible also in the operculigerous lobe, mantle collar, and less commonly in the back of the head, tentacles in front of the eyes, and sides of the head foot. In darker individuals the sides of the body have a salt-and-pepper appearance caused by melanin and hyaline granules scattered in the tissue. The buccal mass is commonly dull red to pink.

Only four specimens were found at the second locality (noted below). They were nearly unpigmented, with only a faint dusting of melanin on rostrum, tentacles, and sides of head-foot. The buccal mass was pink, in contrast to that of the associated *F. thermalis.*

TABLE 11—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella gilae* n.sp. from type locality.

Whorls	
Mean	4.4
Range	4¼–4¾
Length	
Mean	3.47
Range	3.1–4.0
S. D.	0.212
S. E.	0.039
Length of body whorl	
Mean	2.71
Range	2.4–3.0
S. D.	0.153
S. E.	0.028
Length of peritreme	
Mean	1.64
Range	1.5–1.8
S. D.	0.093
S. E.	0.017
Length of peritreme/length	
Mean	0.475
Range	0.42–0.51
S. D.	0.022
S. E.	0.004
Length of peritreme/length of body whorl	
Mean	0.607
Range	0.55–0.64
S. D.	0.019
S. E.	0.004
Width/length	
Mean	0.682
Range	0.62–0.74
S. D.	0.035
S. E.	0.006
Width/length of body whorl	
Mean	0.871
Range	0.78–0.94
S. D.	0.032
S. E.	0.006

TABLE 12—Measurements and descriptive statistics of 20 opercula from larger females of *Fontelicella gilae* n.sp. from type locality.

Length	
Mean	1.402
Range	1.13–1.54
S. D.	0.087
S. E.	0.020
Width/length	
Mean	0.672
Range	0.64–0.76
S. D.	0.029
S. E.	0.007
Left end/length	
Mean	0.267
Range	0.23–0.30
S. D.	0.016
S. E.	0.004

Localities and material examined—The two localities are in Grant County, New Mexico, within, but close to the border of, the Gila Wilderness Area. The type locality is listed as "No Name Spring, East Fork Gila River (13S. 13W.10.200)" by Summers (1976: 14) in part. Qualification is necessary because cool springs (with *F. gilae* only) are directly associated with thermal springs (with both *F. gilae and F. thermalis),* and data on flow and water chemistry published by Summers apply only to the thermal sources. The second locality is listed as "No Name Spring (13S.

TABLE 13—Penial glands in *Fontelicella gilae* n.sp. from type locality. N = 30.

Terminal glands	
One long strip (T)	1
Tl only, about ⅔–¾ as long as T	9
Tl and a papule (Tr)	16
Tl and a short strip (Tr)	2
Tl divided, and a papule (Tr)	2
Dorsal glands	
Two penial glands (DP and DPl)	30
Dorsal distal lobule	30
Left distal strip	30
0 additional glands	3
1 additional gland	7
2 additional glands	6
3 additional glands	7
4 additional glands	5
5 additional glands	0
6 additional glands	1
7 additional glands	1
Ventral glands	
Long strip on ventral lobule (VL)	27
0 additional glands	1
1 additional posterior dot or papule	6
1 additional posterior strip or oval	14
1 additional posterior strip and dot	1
2 additional posterior dots or papules	4
4 additional posterior dots	1
Two long strips or ovals on VL	3
1 additional posterior oval	2
3 additional posterior dots	1

13W.20.430)" by Summers, whose report should be consulted for data on flow and water chemistry.

Habitat—At the type locality cool waters issue from fissures in alcoves of spectacular vertical rhyolite cliffs. Water appears in the cliff face as high as 75 ft above the canyon floor, with progressively more at lower levels. These high sources are inaccessible to the collector; whether snails live in them is speculative. At the highest point where temperature could be measured (on a talus pile at the base of the cliff), the water was 14°C (contrast the 40°C of the nearby thermal sources). Combined outflow of these hanging springs formed a watercress-grown rivulet about 2 ft wide (20°C); this is a habitat typical of *Fontelicella* throughout the West. Associated species were *Physa mexicana* Philippi, *Pisidium casertanum* (Poli), and *P. insigne* Gabb; these species are likewise typical of this kind of habitat throughout many states.

In the nearby thermal sources were both *Fontelicella gilae* and *F. thermalis,* but no other molluscs. As field identification of *F. gilae* was not feasible, temperature range was not determined.

The second locality (type locality of *F. thermalis)* yielded only four specimens of *F. gilae.* It remains possible that the species occurs there in larger numbers, in cooler water and among clumps of grass where sampling is difficult. Although both species may occur directly associated, *F. gilae* was not found in the extreme *thermalis* habitat, on vertical rock in warm water.

FONTELICELLA KOLOBENSIS group

Penis with no dorsal glands except a short penial (DP); ventral lobule and glands present or absent; terminal gland (T) a long transverse strip, or reduced to an oval, or subdivided and with accessory process also divided into two lobes with glands (T1, Tr).

Bursa copulatrix consistently narrower than albumen gland, sometimes much narrower, with rounded posterior end. Bursa/albumen gland ratio 0.20-0.38. Duct of bursa, and

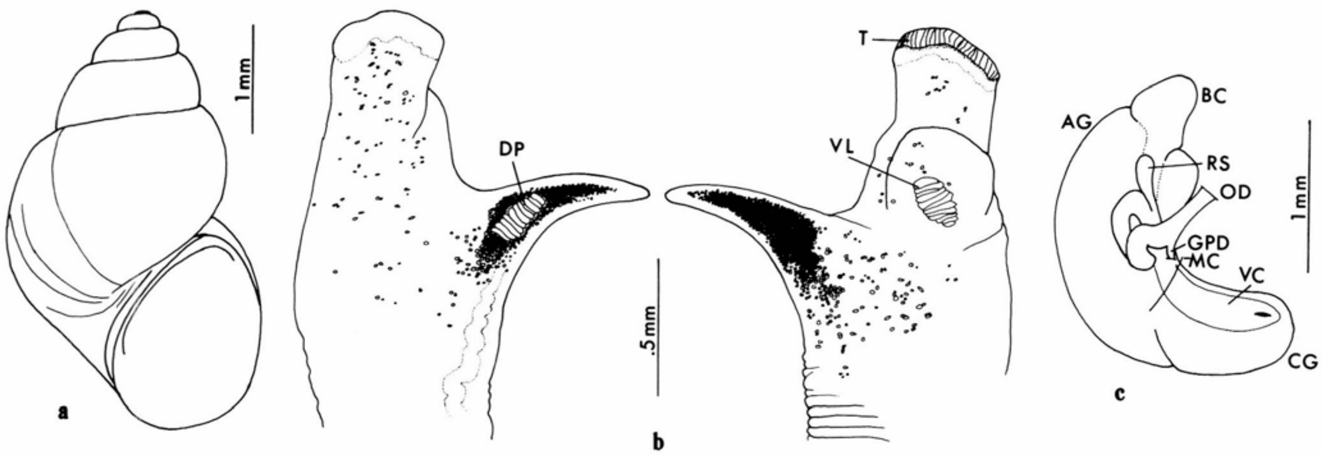

FIGURE 8—*Fontelicella kolobensis* n.sp.: **a,** Shell; **b,** penis; **c,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; CG, capsule gland; DP, penial gland; GPD, gonopericardial duct; MC, posterior end of mantle cavity; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, gland on ventral lobule.

sometimes anterior end of bursa, embedded in albumen gland.

Two species, in the upper Virgin River drainage, southwestern Utah: *F. kolobensis* n.sp. in drainage from Kolob Plateau, on the east side of the river; and *F. pinetorum* n.sp. in drainage from Pine Grove Mountains, on the west side of the river. One of these may be *Amnicola deserta* Pilsbry (1916-17), described from "Washington Co., Utah" without locality data that would allow collection for redefinition. Consequently, no allocation is possible and the form should be treated as unrecognizable, contrary to the listing by U.S. Fish & Wildlife Service (1984).

FONTELICELLA KOLOBENSIS, new species
Fig. 8

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a short penial (DP) on proximal half of the free portion; accessory process with a long transverse terminal strip (T); a ventral lobule with gland (VL) of variable size, and sometimes a papule on the ventral surface in front of VL.

Holotype—LACM 2216, a male preserved in alcohol, collected by D. W. Taylor, 13-XI-1984.

Type locality—Toquerville Springs, sec. 35, T40S, R13W, Washington County, Utah.

Etymology—Named for nearby Kolob Plateau.

Description—Shell (Fig. 8a, Table 14) elongately ovoid. Whorls regularly convex, separated by an incised suture, forming a spire with a slightly convex outline. Peritreme simply adnate or free; when adnate, largely or completely covering a narrow umbilicus. Periostracum tan.

Operculum (Table 15) plane, amber, with a darker internal callus. Attachment scar has a discrete border all around that leaves no conspicuous spiral trace.

Penis (Fig. 8b, Table 16) as usual in the *californiensis* series, distinguished by pattern of glands. The penial (DP) is usually a short strip on proximal half of the free portion. A terminal gland (T) and a strong ventral lobule consistently present. Ventral glands variable; a gland (VL) is consistently present on the ventral lobule, and sometimes there is a papule anterior to VL also. The free portion of the penis has a core of melanin granules, but they do not form the conspicuous black mass found in many species.

Distal female system (Fig. 8c): Bursa copulatrix a sac projecting behind the albumen gland. It is consistently rounded at the posterior end, but varies in width from a slender sac, not clearly separate from its duct, to a structure two-thirds as wide as the albumen gland. The full length of the bursal

TABLE 14—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella kolobensis* n.sp. from type locality.

Whorls	
Mean	4.0
Range	$3^3/_4$–$4^1/_2$
Length	
Mean	3.14
Range	2.85–3.70
S. D.	0.228
S. E.	0.042
Length of body whorl	
Mean	2.55
Range	2.30–2.85
S. D.	0.152
S. E.	0.028
Length of peritreme	
Mean	1.57
Range	1.39–1.76
S. D.	0.090
S. E.	0.016
Length of peritreme/length	
Mean	0.503
Range	0.45–0.56
S. D.	0.027
S. E.	0.005
Length of peritreme/length of body whorl	
Mean	0.618
Range	0.57–0.66
S. D.	0.024
S. E.	0.004
Width/length	
Mean	0.701
Range	0.62–0.76
S. D.	0.033
S. E.	0.006
Width/length of body whorl	
Mean	0.862
Range	0.78–0.91
S. D.	0.030
S. E.	0.005

TABLE 15—Measurements and descriptive statistics of 20 opercula from larger female *Fontelicella kolobensis* n.sp. from type locality.

Length	
Mean	1.45
Range	1.34–1.60
S. D.	0.069
S. E.	0.015
Width/length	
Mean	0.706
Range	0.68–0.74
S. D.	0.019
S. E.	0.004
Left end/length	
Mean	0.287
Range	0.26–0.31
S. D.	0.016
S. E.	0.004

TABLE 16—Penial glands in *Fontelicella kolobensis* n.sp. from type locality. N = 30.

Terminal gland (T)	
Long strip	29
Oval	1
Penial gland (DP)	
Long strip	4
Short strip	22
Oval	4
Ventral glands	
Ventral lobule (VL)	
Long strip	14
Short strip	9
Oval	6
Dot	1
Additional anterior papule	7

straight or slightly curved to the right, projects well behind the distal bend and is appressed to the albumen gland at one side of the bursal duct or directly above the duct. Duct of the receptaculum enters the oviduct distad of the distal bend.

Albumen gland may extend scarcely beyond the end of the mantle cavity or as far as one-fourth of its length. Bursal duct, of width equal to the oviduct, joins with it to enter a broad ventral channel.

Variation—Penial glands vary as shown in Table 16. As usual, glands on the ventral surface are more variable than dorsal glands. The ventral lobule is consistently well developed regardless of size of its gland.

Comparisons—The most similar species is *Fontelicella pinetorum* n.sp. on the other side of the Virgin River drainage, in which the dorsal surface of the penis is similar, with no glands except the penial (DP). *F. pinetorum* shows a great variation in size and form of the terminal lobe and size of the gland (T). By contrast, *F. kolobensis* shows much less variation, but in the sample tabulated (Table 16) one specimen showed a shortened T, reduced to an oval, as in some *F. pinetorum.* Ventral glands and a lobule are consistently present in *F. kolobensis* and absent in *F. pinetorum.* Even in the incidence of minor glands the two species are different: A ventral anterior papule was found in seven specimens (23%) of *F. kolobensis* tabulated; and a minor dorsal gland was found in one specimen (1%) of the *F. pinetorum* tabulated.

The distal female system is more conservative than the penial glands in degree of variation, but even here the species differ. The bursa copulatrix of *F. kolobensis* may be larger than any found in *F. pinetorum,* and the anterior extent of the albumen gland is generally less in *F. kolobensis.*

Localities and material examined—In addition to the type locality, the species was collected in small numbers at Berry Springs, sec. 1, T42S, R14W. No other molluscs were associated. At Toquerville Springs the habitat has recently been affected by flooding, and at Berry Springs artificial improvement has eliminated nearly all of the spring-brook.

FONTELICELLA PINETORUM, new species

Fig. 9

1940. *Paludestrina longinqua* (Gould) [misidentified]: Jones, p. 42, in part; Danish Ranch, Washington County, Utah.

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a short penial (DP) on the proximal half of the free portion; accessory process with a terminal gland variable from an oval to long strip, or divided into segments, or divided into two glands on two separate lobes. No ventral glands.

Holotype—LACM 2217, a male preserved in alcohol, collected by D. W. Taylor, 13-XI-1984.

Type locality—Spring tributary to Leeds Creek, 2,400 ft W, 2,300 ft N, sec. 16, T40S, R14W, Washington County, Utah.

Etymology—Latin *pinus,* pine, and *-etum,* signifying place or location, thus a pine forest or pine grove. Named for occurrence in the Pine Grove Mountains.

Description—Shell (Fig. 9a, Table 17) elongately ovoid. Whorls regularly convex, separated by an incised suture, forming a spire with slightly convex outline. Peritreme usually free, sometimes simply adnate; narrow umbilicus consistently present. Periostracum tan.

Operculum (Table 18) plane, amber, with a darker internal callus. The attachment scar has a discrete border that leaves no conspicuous spiral trace.

Penis (Fig. 9b–d, Table 19) as usual in general proportions, but with the rare condition of bifurcate terminal lobe as a common occurrence. Specimens with the standard T gland as a long strip have a terminal lobe set off by a subterminal constriction. The free portion of the penis has a core of melanin granules, partly masked by DP, not forming the dense mass of some species.

Distal female system (Fig. 9e): Bursa copulatrix a slender sac indistinctly separate from its duct, projecting behind the albumen gland to a rounded tip. The full length of the bursal duct, and sometimes even the anterior part of the bursa, immersed in the albumen gland. Bursa/albumen gland ratio in six specimens ranged from 0.20 to 0.34, mean 0.27.

Loop of oviduct thickened and glandular, with an anterior double kink and simple posterior distal bend. Receptaculum seminis club-shaped, slightly curved to the right, projects well behind the distal bend, and is appressed to the albumen gland over the bursal duct or anterior end of the bursa. Duct of the receptaculum enters the oviduct distad of the distal bend.

Albumen gland extends beyond the end of the mantle cavity by one-third to less than one-fourth of its length. Bursal duct, of width equal to the oviduct, joins with it to enter a broad ventral channel.

Variation—Most conspicuous variation is in the glands on the penis and in shape of the accessory process (Table 19). The two populations sampled are similar in frequency of occurrence of T as a single long strip. At the type locality the next most common variant is a bilobed accessory process with two glands. At Danish Ranch the next common variation has an accessory process reduced in width, with T a short strip or oval.

Comparisons—See under *Fontelicella kolobensis* n. sp.

Localities and material examined—Besides the type lo-

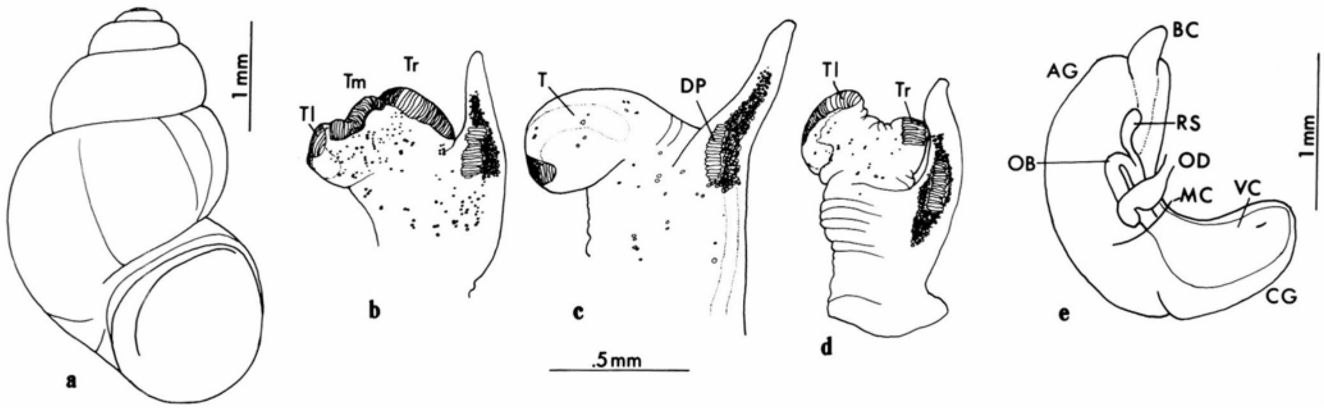

FIGURE 9—*Fontelicella pinetorum* n.sp. from type locality: **a,** Shell; **b–d,** dorsal view of three penises showing variation in glands and terminal lobe; **e,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; CG, capsule gland; DP, penial gland; MC, posterior end of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; Tl, Tm, Tr, left, middle, and right segments of terminal gland; VC, ventral channel.

cality, the species was collected only from a spring outflow at Danish Ranch, sec. 33, T40S, R14W, Washington County, Utah. Both localities are on the southeast slope of the Pine Grove Mountains and are tributary to Leeds Creek.

Habitat—The type locality is a cold spring source (9°C) rising as multiple outflows among boulders and mosses with marginal grasses. Associated species were *Lymnaea parva* Lea, *Pisidium casertanum* (Poli), and *P. insigne* Gabb. At Danish Ranch, associated species were *Physa mexicana* Philippi and *Pisidium casertanum* (Poli).

Remarks—In *Fontelicella* the terminal gland (T) is usually one of the less variable features. In *F. pinetorum* the gland is variable and shows two unusual traits. One is occurrence of a bifurcate accessory process, with T in two segments on two lobes; the other is narrowing of the terminal lobe with T shortened even to an oval.

TABLE 17—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella pinetorum* n.sp. from type locality.

Whorls	
Mean	4.2
Range	4–4½
Length	
Mean	3.15
Range	2.79–3.64
S. D.	0.197
S. E.	0.036
Length of body whorl	
Mean	2.48
Range	2.27–2.76
S. D.	0.120
S. E.	0.022
Length of peritreme	
Mean	1.43
Range	1.27–1.73
S. D.	0.091
S. E.	0.017
Length of peritreme/length	
Mean	0.456
Range	0.40–0.54
S. D.	0.033
S. E.	0.006
Length of peritreme/length of body whorl	
Mean	0.577
Range	0.52–0.68
S. D.	0.033
S. E.	0.006
Width/length	
Mean	0.680
Range	0.61–0.78
S. D.	0.039
S. E.	0.007
Width/length of body whorl	
Mean	0.864
Range	0.80–0.96
S. D.	0.040
S. E.	0.007

TABLE 18—Measurements and descriptive statistics of 20 opercula from larger female *Fontelicella pinetorum* n.sp. from type locality.

Length	
Mean	1.31
Range	1.20–1.40
S. D.	0.055
S. E.	0.012
Width/length	
Mean	0.732
Range	0.69–0.79
S. D.	0.024
S. E.	0.005
Left end/length	
Mean	0.297
Range	0.26–0.35
S. D.	0.021
S. E.	0.005

TABLE 19—Penial glands in *Fontelicella pinetorum* n.sp. N = 50 for both samples.

	Type Locality	Danish Ranch
Terminal gland (T)		
One long strip	20	20
Two segments, one lobe	9	1
Two segments, two lobes	19	1
Three segments	2	
One short strip		11
One oval		17
Dorsal glands		
One distal oval		1
Penial gland (DP)		
One long strip	11	42
One long strip and one oval		1
Two short strips	1	2
One short strip	34	5
Absent	4	

FONTELICELLA NEOMEXICANA group

Penis with a long glandular strip (T) on the terminal lobe; a long penial gland (DP); and three shorter dorsal glandular strips—one diagonal on the right distal surface of the accessory process (D1), one diagonal on the right proximal surface (D3), and one diagonal on the left medial surface (D2); ventral lobule with a long glandular strip (VL); other ventral glandular patches variably present.

Bursa copulatrix relatively large, as wide at anterior end as albumen gland, pointed posteriorly. Bursa/albumen gland ratio 0.55-1.01.

Two species, *F. neomexicana* (Pilsbry, 1916) and *F. chupaderae* n.sp., both from the upper Rio Grande drainage in south-central New Mexico.

The species of the *neomexicana* group are no more similar to those of the Pecos and lower Rio Grande than to those of the upper Gila River, despite present drainage patterns. Thus, they suggest a history of isolation of the upper Rio Grande from the lower Rio Grande, an interpretation fully consistent with geological data.

FONTELICELLA NEOMEXICANA (Pilsbry, 1916)
Fig. 10

1916. *Amnicola neomexicana* Pilsbry, 1916-1917, p. 111, pl. 5, fig. 4; Socorro, New Mexico, in warm springs.

1976. *Amnicola neomexicana* Pilsbry: U.S. Fish & Wildlife Service, p. 17742; candidate endangered species.

1982. *Fontelicella neomexicana* (Pilsbry): Burch, p. 26, fig. 239.

1984. *Fontelicella neomexicana* (Pilsbry): U.S. Fish & Wildlife Service, p. 21673; candidate endangered species.

1985. *Fontelicella neomexicana:* New Mexico Department of Game & Fish, account MOLL/HY/FO/NE; endangered species.

1986. *Fontelicella neomexicana:* U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a terminal long strip (T) on the terminal lobe; on the dorsal surface a long penial gland (DP), and three smaller strips—one diagonal on the right distal surface (D1), one diagonal on the right proximal surface (D3), and one diagonal on the left medial surface (D2); on the ventral lobule a long diagonal glandular strip (VL), and posteriorly commonly a short transverse glandular patch (V1) on the right side of the accessory lobe.

Syntypes—ANSP 121113, a series of dry shells, collector and date unknown.

Type locality—"Socorro, in warm springs" (Pilsbry, 1916: 111), Socorro County, New Mexico.

Etymology—New Mexico had yielded only one hydrobiid when this species was named, so *"neomexicana"* was appropriate.

Description—Shell (Fig. 10a, Table 20) elongately ovoid, with moderate spire. Whorls regularly convex to slightly shouldered, separated by a distinct but not strongly incised suture, forming a spire with gently to strongly convex out-

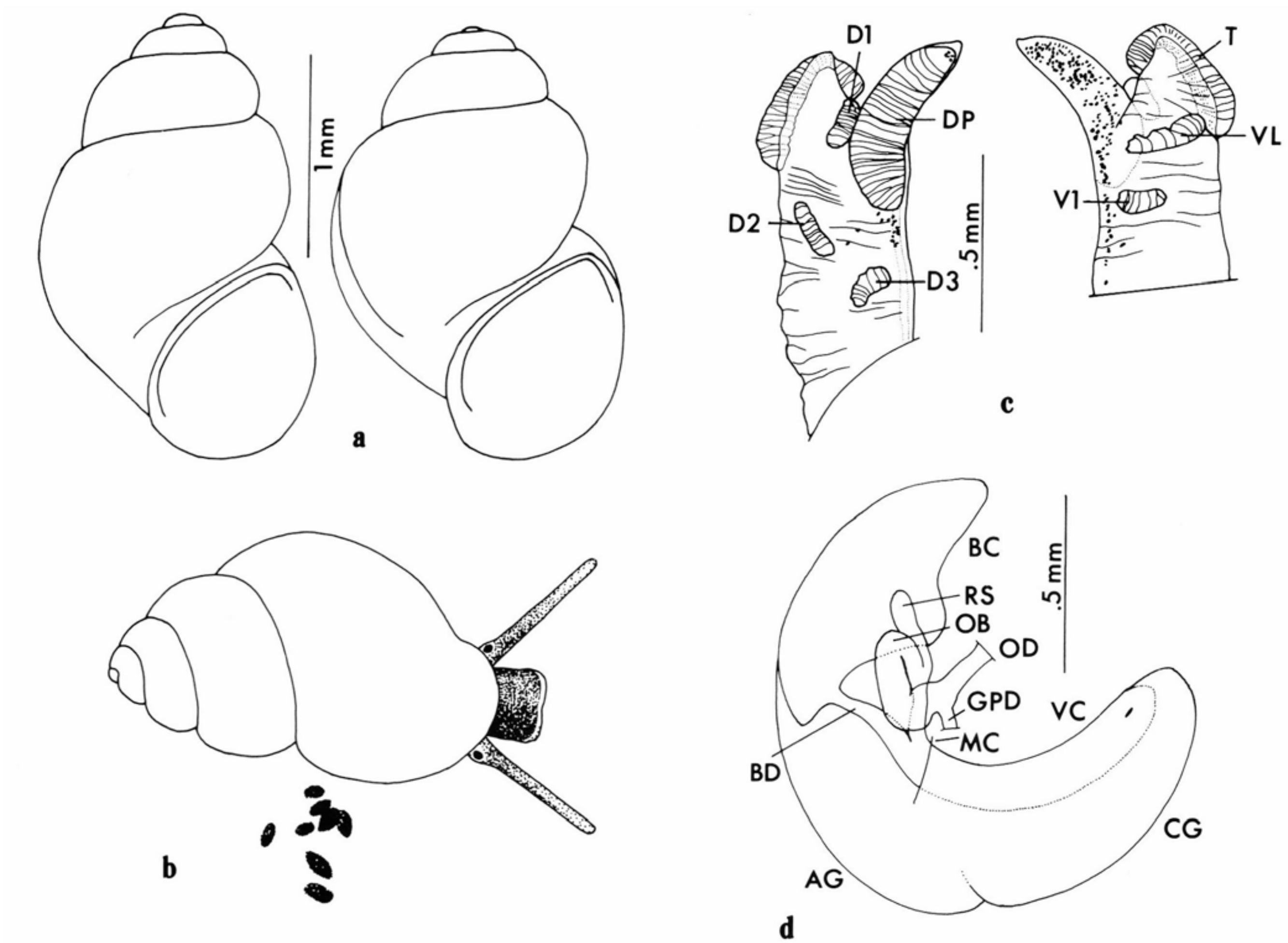

FIGURE 10—*Fontelicella neomexicana* (Pilsbry), Torreon Springs: **a,** Shells of larger females; **b,** living specimen; **c,** penis, dorsal (left) and ventral (right) views; **d,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; BD, duct of bursa copulatrix; CG, capsule gland; DP, penial gland; D1, D2, D3, dorsal glands; GPD, gonopericardial duct; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, gland on ventral lobule; V1, ventral gland.

line. Peritreme usually adnate, sometimes free. Periostracum light tan.

Operculum (Table 21) similar in form to that of *Fontelicella chupaderae.* The internal callus is reddish brown to amber, but otherwise the operculum is pale.

Penis (Fig. 10c, Table 22) as in *Fontelicella chupaderae* except for small differences in glands. The dorsal central gland (D2) is as strongly developed as the others, not distinctly weaker as in *F. chupaderae;* and a ventral gland (V1) is commonly present posteriorly of the ventral lobule.

Distal female system (Fig. 10d): Bursa copulatrix relatively large, as wide as the albumen gland and pointed posteriorly where its tip is wedged between intestine and shell. The anterior end is subrounded or also pointed, and origin of the bursal duct is over the midline of the albumen gland, or even laterad. Thus, the posterior end of the duct lies laterad to the oviducal loop rather than being concealed beneath it as usual. Bursa/albumen gland ratio in six specimens ranged from 0.55 to 1.01, mean 0.80.

Loop of oviduct thickened, with a double bend, less tightly coiled than in *F. chupaderae.* The posterior tip overlies the bursa. Receptaculum seminis narrowly club-shaped, straight or slightly curved to left or right. It projects behind the distal bend of the oviduct nearly to, or beyond, midlength of the bursa to which it is appressed. Duct of the receptaculum enters the oviduct just anteriorly of the bursa.

Albumen gland projects into the mantle cavity by about one-half its length. Duct of bursa copulatrix, half-immersed in the albumen gland, runs in a diagonal curve or at a conspicuous angle forward to the oviduct. Bursal duct and oviduct are of equal width and merge to form an indistinct ventral channel.

Variation—As usual, females attain a larger size than males. Number and arrangement of penal glands vary, with T, DP, D1, D2, and VL uniformly present. The dorsal proximal gland (D3) found uniformly in *Fontelicella chupaderae* is nearly always present, and a ventral posterior gland (V1) is common.

Comparisons—See under *Fontelicella chupaderae.*

Observations on living animals—The mantle is so densely pigmented with melanin that the body seen through the shell appears black. External form of the snails (Fig. 10b) is as usual in the genus. The deeply pigmented rostrum appears black and is bordered anteriorly by pale lip-pads. The tentacles are dusted heavily with melanin proximad and less so distad, and thus appear black to dark gray at the

TABLE 20—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella neomexicana* (Pilsbry) from Torreon Springs.

Whorls	
Mean	3.8
Range	$3^{1/2}$–$4^{1/4}$
Length	
Mean	2.01
Range	1.77–2.26
S. D.	0.122
S. E.	0.022
Length of body whorl	
Mean	1.60
Range	1.46–1.77
S. D.	0.075
S. E.	0.014
Length of peritreme	
Mean	0.95
Range	0.86–1.03
S. D.	0.050
S. E.	0.009
Length of peritreme/length	
Mean	0.476
Range	0.43–0.53
S. D.	0.025
S. E.	0.005
Length of peritreme/length of body whorl	
Mean	0.597
Range	0.55–0.66
S. D.	0.028
S. E.	0.005
Width/length	
Mean	0.671
Range	0.62–0.72
S. D.	0.027
S. E.	0.005
Width/length of body whorl	
Mean	0.841
Range	0.79–0.88
S. D.	0.023
S. E.	0.004

TABLE 21—Measurements and descriptive statistics of 20 opercula of *Fontelicella neomexicana* (Pilsbry) from larger females measured (Table 20).

Length	
Mean	0.89
Range	0.81–0.97
S. D.	0.042
S. E.	0.009
Width/length	
Mean	0.645
Range	0.60–0.69
S. D.	0.024
S. E.	0.005
Left end/length	
Mean	0.254
Range	0.24–0.28
S. D.	0.008
S. E.	0.002

TABLE 22—Penial glands in *Fontelicella neomexicana* (Pilsbry) from Torreon Springs. N = 30.

Terminal gland (T)	
Long strip	23
Two ovals	7
Dorsal glands	
Long penial (DP)	30
Proximal (D3)	
Diagonal	22
Transverse	2
Longitudinal	1
Dot	2
Absent	3
Central (D2)	30
Distal (D1)	
Diagonal	26
Longitudinal	1
Dot	3
Additional medial dot	1
D2 confluent with T	1
Ventral glands	
Gland on lobule (VL)	
Long diagonal	29
Three short ovals	1
Additional anterior papule	2
Posterior gland (V1)	
Transverse	10
Short oval	3
One dot	5
Two dots	1
Absent	11

base, grading to pale gray at the tips. A ventral ciliated tract runs along each tentacle.

Heaviest pigmentation is on the rostrum, back and sides of the head, less on the dorsal anterior surface of the foot and operculigerous lobes and still less elsewhere on the foot. The sole is pale gray, the heavier pigmentation of the dorsal and lateral surfaces of the head-foot ending abruptly at the margin of the sole. Intensity of pigmentation varies so that some individuals are nearly black all over except for the sole and ventral surfaces of tentacles and rostrum; others are paler.

Above and behind the eyes is a patch of pale hyaline granules masked by epithelial melanin; it is relatively inconspicuous in comparison with other species of the genus.

The penis as usual has melanin in the core of its free portion and scattered hyaline granules elsewhere.

Localities and material examined—The original specimens of *Fontelicella neomexicana* evidently came from one of the thermal springs about 3 mi west of Socorro (for map and details of flow and chemistry see Summers, 1976). The species is now extinct at the type locality, but the date and cause of the extinction remain uncertain.

Prior to recent development of the springs, Leslie Hubricht collected in both Evergreen (Sedillo) Spring and City (Socorro) Spring, finding the endemic Socorro isopod *Thermosphaeroma thermophilum,* but no snails. In June 1968 I visited the area and collected in Cook Spring, obtaining only the common *Physa mexicana* Philippi and the introduced *Planorbella duryi* (Wetherby). Socorro Spring was fully developed, with no surface water remaining; Sedillo Spring was inaccessible. I visited Sedillo Spring on 10-IV-1979 with Robert H. Weber, but found no snails in the flowing water at the source. An artificial reservoir about 50 ft downstream yielded only *Physa mexicana.*

According to the U.S. Fish & Wildlife Service (1976), the species was present in Sedillo and Socorro Springs as recently as 1971. Based on my experience and the information given above, I do not believe the snail was living in the area in 1971; whether it ever occurred in more than one of the springs near **Socorro** is speculative.

Description and illustrations of *Fontelicella neomexicana* provided herewith are all based on a sample from Torreon Springs, about 8 km southwest of the type locality. As no morphological details can be obtained from topotypes, it is not certain that this population is indeed conspecific. Yet the shells are similar and the only basis for naming a new species would be geographic prejudice.

Habitat—Torreon Springs, where I collected with Robert H. Weber on 10-IV-1979, is in the SW^1/4 NE^1/4 sec. 8, T5S, R2W, Socorro County, New Mexico. The principal spring source has been impounded, leaving virtually none of the flowing-water habitat so critical for most hydrobiids. One tiny spring source remained, with an improved source-pool less than 1 m^2 in area (17°C). *Fontelicella* was abundant on rootlets in this pool, but was not found in the ditches and ponds irrigating the area. Other molluscs found in the vicinity were *Physa mexicana* Philippi, *Lymnaea modicella* **Say, and** *Pisidium casertanum* (Poli).

On a subsequent visit (24-IV-1981) the colony was found to occupy not only the source but also the outflow tributary (about 8 ft long) to an irrigation ditch. No snails were in the irrigation flow; the total population was then estimated at about 5,000 individuals.

FONTELICELLA CHUPADERAE, new species

Fig. 11

1984. *Fontelicella* sp.: U.S. Fish & Wildlife Service, p. 21673; candidate endangered species.

1985. Chupadera spring snail: New Mexico Department of Game & Fish, account MOLL/HY/FO/AA; endangered species.

1986. Chupadera spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella (s.s.)* with heavy melanin pigmentation making the eyes inconspicuous and obscuring the usual patch of granules above and behind the eyes. Operculum a conspicuous deep reddish brown. Glandular patches on the penis consist of a terminal long strip (T) on the terminal lobe; on the dorsal surface a long penial gland; and three smaller strips—one diagonal on the right distal surface of the accessory process **(Dl),** one diagonal on the right proximal surface (D3), and one weaker diagonal on the left medial surface (D2); on the ventral surface a transverse lobule bearing a long glandular strip (VL) and sometimes a tiny papule anteriorly.

Types—Holotype LACM 2218, a male preserved in alcohol, collected by D. W. Taylor and Robert H. Weber, 231V-1979. Paratypes UTEP 10,052.

Type locality—Willow Spring, on Cienaga Ranch at south end of Chupadera Mountains, about 5 mi west of Bosque del Apache National Wildlife Refuge headquarters, Socorro County, New Mexico.

Etymology—Named for the Chupadera Mountains.

Description—Shell (Fig. 11a, Table 23) elongately ovoid, with moderate spire. Whorls regularly convex to slightly shouldered, separated by a distinct but not strongly incised suture, forming a spire with gently to strongly convex outline. Peritreme usually adnate, sometimes free. Periostracum tan to brown.

Operculum (Fig. 11c, Table 24) plane, reddish brown. The attachment scar has a distinct border all around, but leaves no conspicuous spiral trace.

Penis (Fig. 11d, Table 25) with a free portion containing conspicuous melanin granules, but not the dense core found in many other *Fontelicella* species.

Distal female system (Fig. 11e): Bursa copulatrix an exceptionally large sac as wide as the albumen gland at anterior end and pointed at posterior end, where it is wedged between the intestine and shell. Bursa/albumen gland ratio in six specimens ranged from 0.67 to 0.91, mean 0.76.

Loop of oviduct tightly coiled, commonly elongate lengthwise, and parallel-sided; its posterior one-fourth to one-half overlies the bursa. Receptaculum seminis narrowly club-shaped, straight or slightly curved to left or right; projects behind the distal bend of the oviduct to varying degree,

TABLE 23—Measurements and descriptive statistics of shells of 30 larger females of *Fontelicella chupaderae* n.sp. Erosion prevented some standard measurements.

Length of body whorl	
Mean	1.60
Range	1.43–1.74
S. D.	0.091
S. E.	0.017
Length of peritreme	
Mean	1.02
Range	0.92–1.12
S. D.	0.057
S. E.	0.010
Length of peritreme/length of body whorl	
Mean	0.639
Range	0.59–0.71
S. D.	0.024
S. E.	0.004
Width/length of body whorl	
Mean	0.826
Range	0.78–0.90
S. D.	0.034
S. E.	0.006

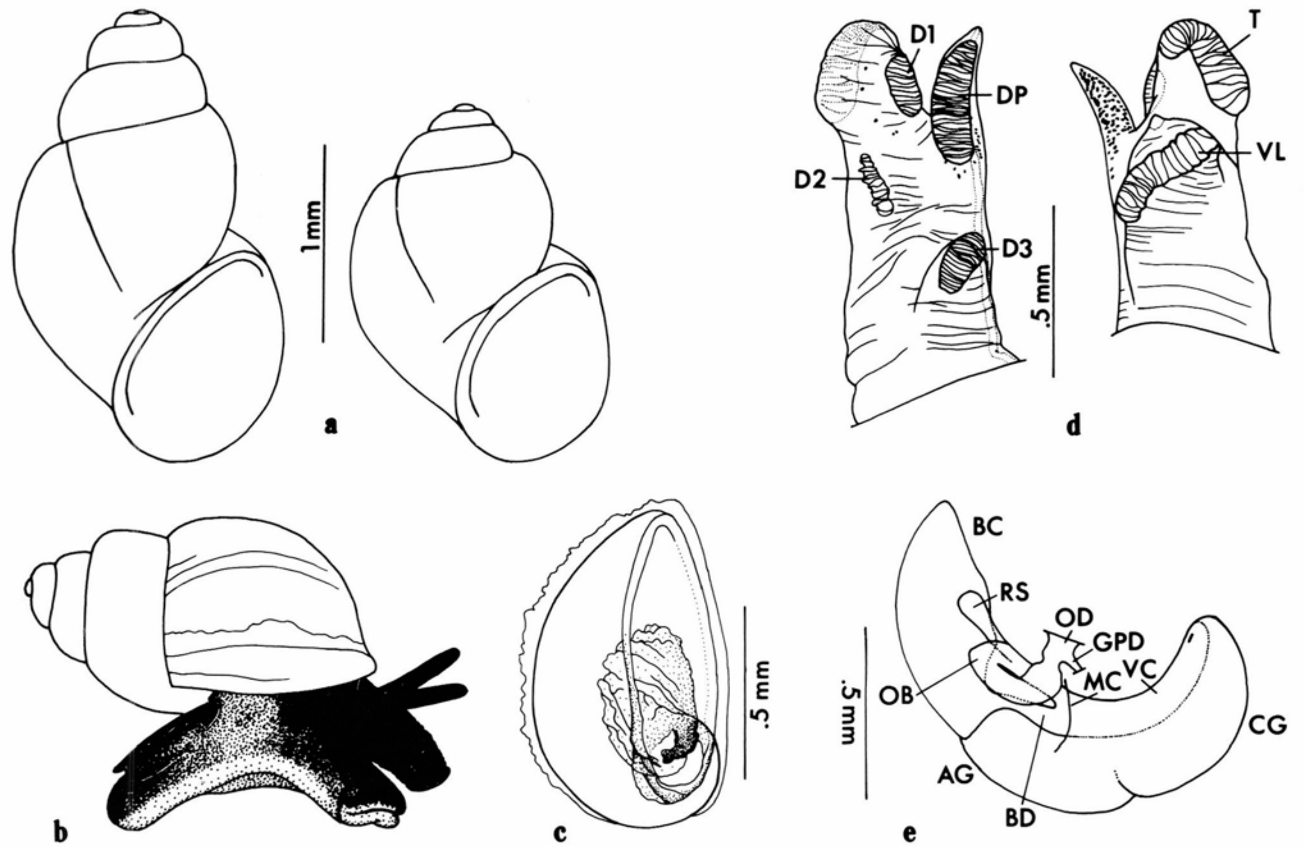

FIGURE 11—*Fontelicella chupaderae* n.sp.: **a,** Shells of larger females; **b,** living specimen; **c,** operculum, inner face; **d,** penis, dorsal (left) and ventral (right) views; **e,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; BD, duct of bursa copulatrix; CG, capsule gland; DP, penial gland; D1, D2, D3, dorsal glands; GPD, gonopericardial duct; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, gland on ventral lobule.

usually to just behind the mid-length of the bursa to which it is appressed.

Albumen gland relatively small compared to the bursa, projects into the mantle cavity by about one-half its length. Duct of bursa copulatrix is half embedded within the albumen gland and of width equal to the oviduct. Ventral channel indistinct.

Variation—As usual, females attain a larger size than males. Number and arrangement of penial glands vary, with T, DP, and D3 consistently present. D2, nearly always present, is uniformly weaker than the corresponding gland in *Fontelicella neomexicana.*

TABLE 24—Measurements and descriptive statistics of 20 opercula of *Fontelicella chupaderae* n.sp. from larger females measured (Table 23).

Length	
Mean	0.91
Range	0.85–0.98
S. D.	0.042
S. E.	0.009
Width/length	
Mean	0.639
Range	0.60–0.69
S. D.	0.030
S. E.	0.007
Left end/length	
Mean	0.254
Range	0.23–0.28
S. D.	0.013
S. E.	0.003

TABLE 25—Penial glands in *Fontelicella chupaderae* n.sp. N = 30.

Terminal gland (T)	
Long strip	22
Incomplete	2
Two ovals	5
One oval	1
Dorsal glands	
Long penial (DP)	30
Proximal (D3)	
Present	29
Absent	1
Central (D2)	
Present	29
Absent	1
Additional posterior dot	1
Distal (D1)	
Present	29
Absent	1
Ventral glands	
Gland on lobule (VL)	
Transverse	25
Diagonal	1
Longitudinal	1
Reduced	1
Divided	1
Absent	1
Anterior papule (V1)	
Present	8
Absent	22

Comparisons—In structure of the penis *Fontelicella chupaderae is* most like its geographically nearest neighbor, *F. neomexicana,* agreeing in number and arrangement of penial glands, even in the occurrence of an interrupted or incomplete terminal gland (T). Distinctive features of *F. chupaderae* are that D2 is weaker than that of *F. neomexicana,* and that on the ventral side *F. chupaderae* lacks the posterior gland (V1) often present in *F. neomexicana.*

The distal female systems of *F. chupaderae* and *F. neomexicana* are much alike in the relatively large, posteriorly pointed bursa copulatrix. Within the genus they are unique in this feature. *F. neomexicana* differs in the subrounded or pointed anterior end of the bursa, more loosely coiled loop of the oviduct, and especially in the bursal duct that leaves the bursa more laterad and is curved or angled diagonally across the albumen gland.

Pigmentation of the body and operculum is far more intense in *F. chupaderae* than in other species of the genus.

Observations on living animals—The deep reddish-brown operculum is unique in the genus. Even in pale-gray juveniles of 1-2 whorls, whose internal organs are visible, the operculum is distinctively dark.

The animals (Fig. 11b) are the most heavily pigmented of any in the genus. Within the shell no organs can be seen; a pale area in the region of the pericardium is present as usual. Mantle and dorsolateral surfaces of the head-foot are so heavily coated with melanin that they often appear uniformly black; there is no contrast between eye and surrounding area, no evident granules behind the eye, and no change in intensity of pigmentation from back of head to tip of tentacle. Less heavily pigmented individuals are dark gray, with a patch of hyaline granules behind the eye and tentacles grading from darker gray at the base to lighter at the tip; hyaline granules are visible through the sides of the head-foot and the lip-pads are correspondingly paler. In the usual heavily pigmented individuals the sole is pale gray, with the dense melanin coat ending sharply at its upper border; hyaline granules can be seen within, as usual.

Habitat—Willow Spring issues from multiple sources (22°C) and flows through a disturbed area among rhyolitic pebbles and cobbles with sand, mud, and aquatic plants. *Fontelicella* was abundant on stones, dead wood, and among vegetation, in current where there was an organic film on a firm surface.

Below the source the spring outflow is dammed, forming two artificial ponds. In the ponds or slow current below them were found *Physa mexicana* Philippi, *Lymnaea modicella* Say, and *Pisidium casertanum* (Poli), but no *Fontelicella.*

FONTELICELLA PECOSENSIS group

Penis with a long glandular strip (T) on the terminal lobe; a long penial gland (DP) partly on the free portion of the penis and partly behind it; a dorsal distal lobule (DDL) often

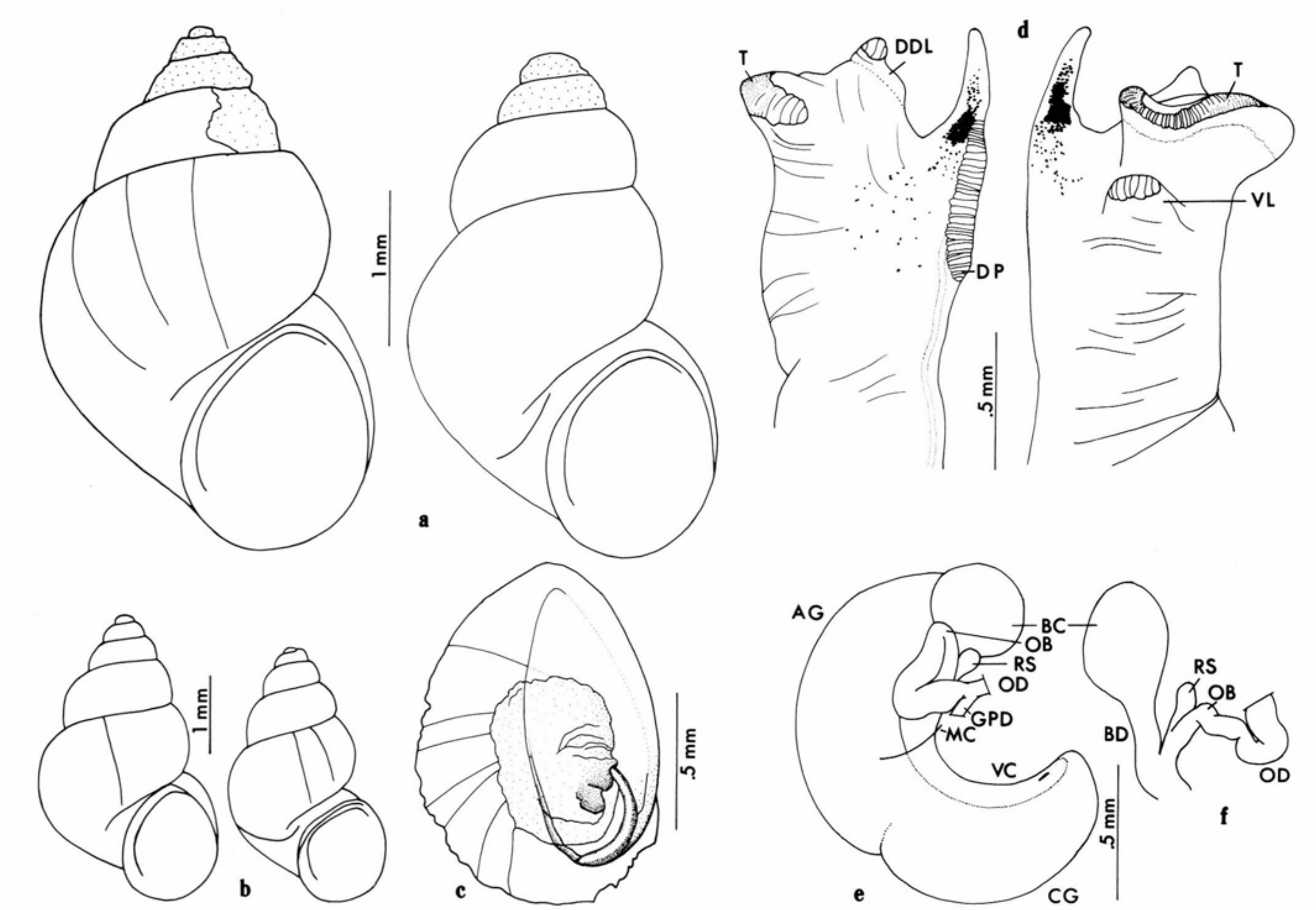

FIGURE 12—*Fontelicella pecosensis* n.sp.: **a,** Larger male shells from Blue Spring; **b,** representative shells, Holocene, Black River Falls; **c,** operculum, inner face; **d,** penis, dorsal (left) and ventral (right) views, from Blue Spring (the specimen has more glands than usual, characteristically the gland on DDL and VL and its gland are not present); **e, f,** distal portion of female reproductive system, *f* is detail of specimen in *e.* Abbreviations: AG, albumen gland; BC, bursa copulatrix; BD, duct of bursa copulatrix; CG, capsule gland; DDL, dorsal distal lobule; DP, penial gland; GPD, gonopericardial duct; MC, wall of mantle cavity; OB, distal bend of oviduct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; VC, ventral channel; VL, ventral lobule.

bearing a tiny gland; and frequently a ventral glandular patch (V), sometimes on a lobule (VL).

Bursa copulatrix a bulky sac one-half to nearly as wide as the albumen gland, with posterior end broadly rounded. Bursa/albumen gland ratio 0.28-0.40.

One species, *Fontelicella pecosensis* n.sp., in springs tributary to Black River, southeastern New Mexico, part of the Pecos River drainage.

FONTELICELLA PECOSENSIS, new species
Fig. 12

1985. Pecos spring snail: New Mexico Department of Game & Fish, account MOLL/HY/FO/CC; endangered species. 1986. Pecos spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a terminal long strip (T); a long strip on the right side of dorsal distal surface, extending onto the free portion of the penis (DP); a dorsal distal lobule (DDL); sometimes small glands that may be on or off the lobule; and often a small ventral glandular patch (V) that may be on a reduced lobule. Operculum unique in the genus, not plane but with earlier whorls projecting on the external face.

Types—Holotype LACM 2220, a male preserved in alcohol, collected by D. W. Taylor, 20-IV-1981. Paratypes UTEP 10,056.

Type locality—Blue Spring, center SW$^{1}/4$ sec. 27, T24S, R26E, Eddy County, New Mexico.

Etymology—Named for the Pecos River.

Description—Shell (Fig. 12a–b, Tables 26-27) narrowly elongate, with a relatively long spire. Whorls separated by an incised suture, forming a spire with conical outline. Peritreme usually adnate, sometimes free. Periostracum tan.

Operculum (Fig. 12c, Table 28) amber, more intensely hued in the callus. On the external face the earliest whorls project with an overlap. On the internal face the most conspicuous feature is a prominent thickening along the left anterior border of the attachment scar. This thickening leaves a spiral trace separating the edge of the opercular whorls and fades out abruptly at its left end. Except for the left anterior border, edges of the attachment scar are inconspicuous.

Penis (Fig. 12d, Table 29) distinguished by number and arrangement of glands, and by the dorsal distal lobule. The core of the free penis has a dense aggregation of melanin granules; elsewhere in the penis there are few.

Distal female system (Fig. 12e–f): Bursa copulatrix a bulky sac at anterior end one-half to nearly as wide as the albumen gland. Bursa/albumen gland ratio in six specimens ranged from 0.28 to 0.40, mean 0.32.

Loop of oviduct thickened, with a double bend. Relation to the bursa varies, so that the distal bend may overlie the bursal duct just in front of the bursa or the anterior end of the bursa. Receptaculum seminis club-shaped, straight or curved to the right, may or may not project well behind the distal bend, and may overlie the albumen gland next to the bursal duct or extend onto the bursa.

TABLE 26—Measurements and descriptive statistics of larger male and female shells of *Fontelicella pecosensis* n.sp. from source of Blue Spring. Erosion prevented some standard measurements. N = 30 for both samples.

	Male	Female
Length of body whorl		
Mean	2.29	2.23
Range	2.06–2.49	2.09–2.46
S. D.	0.099	0.116
S. E.	0.018	0.021
Length of peritreme		
Mean	1.30	1.31
Range	1.17–1.49	1.20–1.43
S. D.	0.077	0.064
S. E.	0.014	0.012
Length of peritreme/length of body whorl		
Mean	0.568	0.585
Range	0.51–0.62	0.52–0.63
S. D.	0.024	0.030
S. E.	0.004	0.005
Width/length of body whorl		
Mean	0.839	0.887
Range	0.79–0.88	0.77–0.96
S. D.	0.027	0.036
S. E.	0.005	0.007

TABLE 27—Measurements and descriptive statistics of shells of *Fontelicella pecosensis* n.sp. N = 30 for both samples. Specimens from Black River Falls are fossil, selected by size; those from Blue Spring are larger males from the first irrigation weir.

	Black River Falls	Blue Spring
Whorls		
Mean	4.7	4.9
Range	4¼–5¼	4½–5¼
Length		
Mean	2.85	2.38
Range	2.43–3.58	2.15–2.83
S. D.	0.304	0.170
S. E.	0.056	0.031
Length of body whorl		
Mean	2.02	1.66
Range	1.63–2.46	1.52–1.97
S. D.	0.213	0.116
S. E.	0.038	0.021
Length of peritreme		
Mean	1.15	0.914
Range	0.94–1.46	0.80–1.06
S. D.	0.125	0.052
S. E.	0.023	0.009
Length of peritreme/length		
Mean	0.404	0.385
Range	0.36–0.46	0.35–0.41
S. D.	0.021	0.018
S. E.	0.004	0.003
Length of peritreme/length of body whorl		
Mean	0.569	0.551
Range	0.51–0.62	0.49–0.58
S. D.	0.025	0.019
S. E.	0.005	0.004
Width/length		
Mean	0.616	0.587
Range	0.56–0.67	0.56–0.62
S. D.	0.033	0.019
S. E.	0.006	0.004
Width/length of body whorl		
Mean	0.868	0.842
Range	0.81–0.94	0.79–0.89
S. D.	0.034	0.026
S. E.	0.006	0.005

TABLE 28—Measurements and descriptive statistics of 20 opercula of *Fontelicella pecosensis* n.sp. from larger males measured (Table 26) from Blue Spring.

Length	
Mean	1.19
Range	1.09–1.33
S. D.	0.062
S. E.	0.014
Width/length	
Mean	0.718
Range	0.69–0.76
S. D.	0.020
S. E.	0.004
Left end/length	
Mean	0.305
Range	0.26–0.35
S. D.	0.018
S. E.	0.004

TABLE 29—Penial glands in *Fontelicella pecosensis* n.sp. N = 30 for both samples.

	Blue Spring	Castle Spring
Terminal gland (T)		
One long strip	29	30
Strip interrupted	1	
Dorsal glands		
Long penial (DP)	30	30
Dorsal distal lobule	30	30
Present, no glands	26	30
Present, with dot	4	
One gland off DDL	5	1
Two glands off DDL		1
Ventral glands		
Lobule (VL) present	13	
Strip	12	
Oval	1	
Lobule absent	17	30
No glands	6	
Papule or dot	9	3
One strip	1	
Two strips	1	

Albumen gland projects into the mantle cavity consistently by about one-fourth its length. Duct of bursa copulatrix half-embedded within the albumen gland and as wide as the distal end of the oviduct or up to one and half times as wide. Ventral channel broad and poorly defined.

Variation—Ordinarily, in *Fontelicella* the females attain a larger size. In *F. pecosensis* the sexes do not differ substantially in size (Table 26). Length of spire and relative size of peritreme are the principal shell variants.

Distribution—Two springs tributary to Black River, a tributary of Pecos River, in southeastern New Mexico.

Localities and material examined—NEW MEXICO, EDDY COUNTY: Castle Spring, 1,000 ft W, 900 ft N, sec. 23, T24S, R26E. Blue Spring, center SW1/4 sec. 27, T24S, R26E. Pleistocene or Holocene, Black River Falls, center NW'/4 sec. 35, T24S, R26E. All collected by D. W. Taylor, 1968-1981.

Habitat—In Blue Spring, *Fontelicella pecosensis* was abundant at the source on pebbles and mud. Associated molluscs were scarce, only *Lymnaea modicella* Say and *Pisidium casertanum* (Poli). About 1 1/4 mi below the source at the first irrigation weir *Fontelicella* was common, but less so than at the source. The natural channel has vertical banks and the stream is 6-8 ft wide and 4-5 ft deep, with dense masses of *Chara.* Found along the sides of the stream with *Fontelicella* were *Lymnaea modicella* Say, *Gyraulus parvus* (Say), *Physa mexicana* Philippi, *Pisidium casertanum* (Poli), *P. compressum* Prime, and *P. singleyi* Sterki.

FONTELICELLA THERMALIS group

Penis with a long glandular strip (T) on a small terminal lobe; a long penial gland (DP) continuous with a narrower curved strip (Dp) extending to the left distal margin, the combined strip forming a long "fishhook" that encloses several oblique glandular strips; no ventral lobule but a transverse strip (V) close behind the terminal lobe.

Bursa copulatrix narrower than albumen gland, posterior end broadly rounded. Bursa/albumen gland ratio 0.52-0.78.

One species, *F. thermalis* n.sp., from thermal springs near forks of the Gila River, west-central New Mexico.

FONTELICELLA THERMALIS, new species
Fig. 13

1985. New Mexico hot spring snail: New Mexico Department of Game & Fish, account MOLL/HY/FO/EE; endangered species.

1986. New Mexico hot spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species of *Fontelicella* (s.s.) with relatively small, broadly conical shell and oblique plane of aperture. Glandular patches on the penis consist of a dorsad-open semicircular or horseshoe-shaped strip on a small terminal lobe (T); on the dorsal surface a long fishhook-shaped gland composed of a wider penial portion (DP) continuous with a long, narrower curved strip (Dp) extending to the left distal margin and enclosing a few (commonly three) strips oblique to the long axis of the penis; on the ventral surface no lobule, but a transverse strip (V) close behind the terminal lobe.

Types—Holotype LACM 2224, a male preserved in alcohol, collected by D. W. Taylor, 10-IV-1981. Paratypes UTEP 10,058.

Type locality—Hot spring on east side of Gila River, NEI/4 SW1/4 sec. 17 T13S, R13W, unsurveyed, Grant County, New Mexico.

Etymology—Named for the habitat in thermal springs.

Description—Shell (Fig. 13a, Table 30) globose, with very short spire. Whorls strongly convex to weakly shouldered, separated by an incised suture, forming a spire with gently concave to gently convex outline. Peritreme simply adnate. Columellar margin broad, flat, with numerous coarse traces of earlier peritreme edges. Plane of aperture oblique to axis of coil at about 30°. Periostracum tan.

Operculum (Fig. 13b, Table 31) plane, pale orangish-brown, with a dark orangish-brown internal callus. The attachment scar has a distinct border all around, but leaves no conspicuous spiral trace.

Penis (Fig. 13c, Table 32) has the basic features of *Fontelicella,* but proportions as well as glands are unusual. The terminal lobe is relatively small compared to the free portion of the penis; and the ventral gland (V) is not on a lobule and is situated farther distad than usual. The terminal gland (T) is a long strip that is semicircular or horseshoe-shaped when viewed end-on, and open dorsad; it is thus markedly different from the arcuate or even straight T in other species. The dorsal surface bears a long hook-shaped gland composed of the usual penial (DP) confluent with a long, narrower, curved strip (Dp) that extends to the left distal margin. Within the area so enclosed are several (commonly three) short glandular strips generally oblique to the long axis of the penis. The principal variation in the penis is in the number and arrangement of these minor dorsal glands (Table 31).

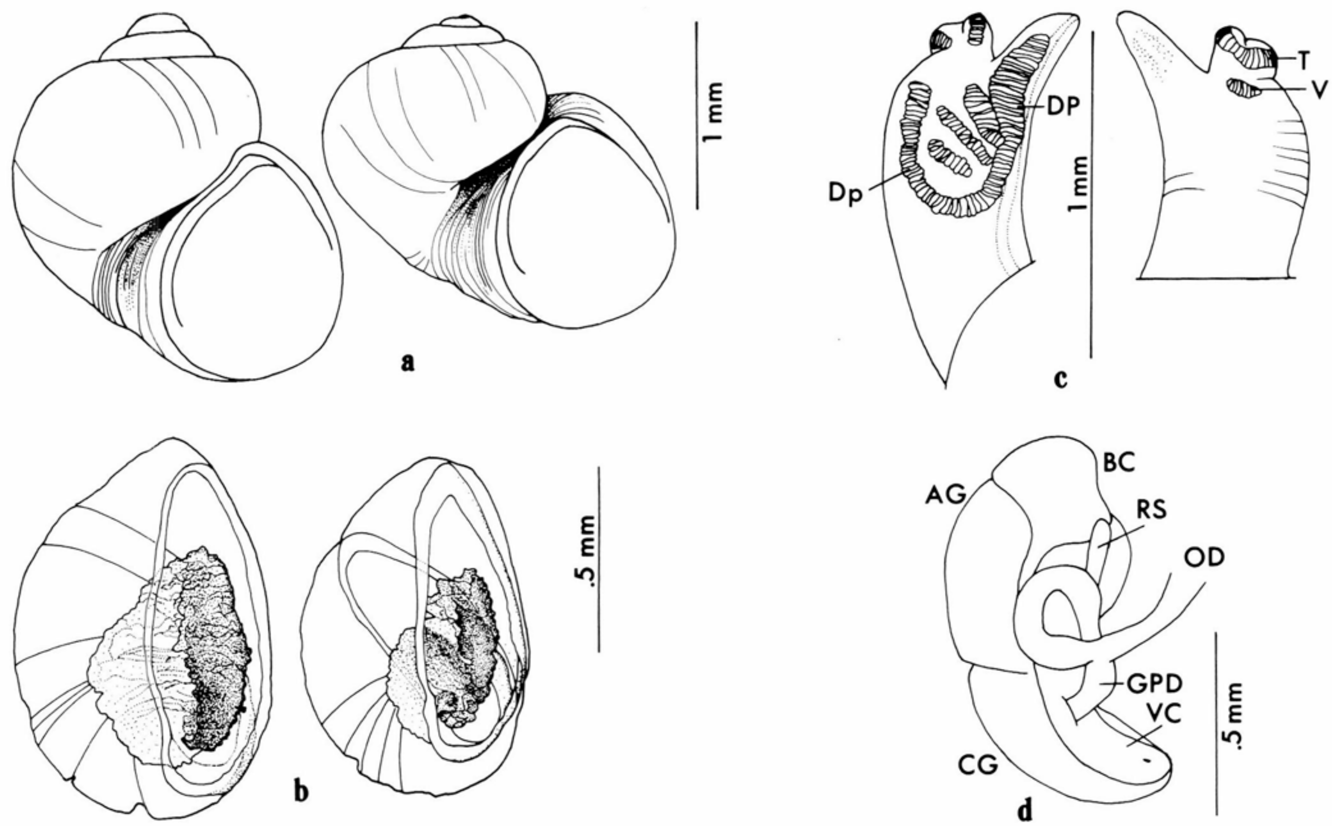

FIGURE 13—*Fontelicella thermalis* n.sp.: **a,** Two larger female shells; **b,** operculum, inner face; **c,** penis, dorsal (left) and ventral (right) views of holotype; **d,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; CG, capsule gland; DP, penial gland; Dp, dorsal posterior gland; GPD, gonopericardial duct; OD, oviduct; RS, receptaculum seminis; T, terminal gland; V, ventral gland; VC, ventral channel.

Distal female system (Fig. 13d): Bursa copulatrix a flaccid sac draped over the posterior end of the plump albumen gland, not as wide as that gland, and extending behind it as usual. The bursa may be wider than long, or the reverse. Bursa/albumen gland ratio in seven specimens ranged from 0.52 to 0.78, mean 0.61.

Loop of oviduct simple and open, unlike the tight coil or double-looped bend in most species of the genus; the oviduct becomes thicker and glandular in the loop. According to variation in the size and shape of the bursa, the posterior edge of the loop may overlie or touch the anterior margin of the bursa, or be remote. Receptaculum seminis tubular, straight or curved, greatly variable in length. It may extend well posterior of the distal bend of the oviduct, or only to its posterior edge. In six specimens the receptaculum extended onto the bursa, in one only to its anterior edge.

Albumen gland extends to posterior wall of mantle cavity. Duct of bursa copulatrix half-immersed in the albumen gland. Ventral channel broad.

Variation—Shell form varies considerably (Table 30), with some shells being even wider than high, the most extreme condition known in the genus. Larger shells may grow more laterad than lengthwise, with progressive development of a flat or concave columellar plate built up by successive peritremes.

Comparisons—This is the most distinctive species of the genus. Features unique in *Fontelicella* are: (1) the distal location of V; (2) buccal mass lacking the usual pink color; (3) absence of a patch of granules above and behind the eyes; (4) the shell W/L ratio may exceed 1.0; (5) lateral growth of the peritreme produces a plate-like area adjacent to the umbilicus and columellar margin; (6) the habitat is restricted to springs substantially warmer than those inhabited by any other species, although both *F. thermalis* and *F. gilae* may occur together; and (7) the average size (of a sample of large specimens) is the smallest known in the genus.

Observations on living animals—Overall body color is dark gray to black, with the heaviest melanin wash on rostrum and head. The eyes are encircled by a clear halo; no granular patch is present behind them (this patch is found in all other species of the genus). Overall pigmentation is more nearly uniform than in most species, i.e. contrast between head plus rostrum and the rest of the body is less marked than usual. The penis relatively lacking in pigment, with few or no granules, and sometimes no melanin in the free portion. The buccal mass as viewed through the relatively clear ventral surface of the rostrum is brown, not the usual pink.

Localities and material examined—The two localities are in Grant County, New Mexico, within the Gila Wilderness Area. The type locality is listed as "No Name Spring (13S.13W.20.430)" by Summers (1976: 14). The second locality is a group of thermal springs on the north side of East Fork of Gila River, center sec. 3, T13S, R13W, unsurveyed, sampled 11-IV-1981. This second locality is listed as "No Name Spring, East Fork Gila River (13S.13W.10.200)" by Summers (1976: 14), whose report should be consulted for data on flow and water chemistry.

Habitat—The spring at the type locality issues from multiple sources about 25 ft above the main stem of the Gila River on a steep slope of rock at the base of rhyolite cliffs. The water flows to the river over a roughly semicircular area, densely grown with grasses, that is about 60 ft long at river level. Snails were abundant in minor flows from

TABLE 30—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella thermalis* n.sp. from type locality.

Whorls	
Mean	3.1
Range	3–3½
Length	
Mean	1.68
Range	1.49–1.97
S. D.	0.128
S. E.	0.023
Length of body whorl	
Mean	1.49
Range	1.34–1.74
S. D.	0.107
S. E.	0.020
Length of peritreme	
Mean	1.06
Range	0.92–1.23
S. D.	0.081
S. E.	0.015
Length of peritreme/length	
Mean	0.630
Range	0.56–0.70
S. D.	0.032
S. E.	0.006
Length of peritreme/length of body whorl	
Mean	0.711
Range	0.63–0.78
S. D.	0.032
S. E.	0.006
Width/length	
Mean	0.950
Range	0.85–1.08
S. D.	0.049
S. E.	0.009
Width/length of body whorl	
Mean	1.033
Range	0.98–1.15
S. D.	0.184
S. E.	0.034

TABLE 31—Measurements and descriptive statistics of opercula from *Fontelicella thermalis* n.sp. from type locality. Opercula from larger females measured (Table 30). N = 20.

Length	
Mean	0.988
Range	0.91–1.09
S. D.	0.052
S. E.	0.012
Width/length	
Mean	0.683
Range	0.662–0.717
S. D.	0.015
S. E.	0.003
Left end/length	
Mean	0.281
Range	0.250–0.308
S. D.	0.015
S. E.	0.003

the spring on algal film and crusts of lime-depositing algae, on stones, and presumbly in dense grass where sampling was difficult. Next to the Gila River they were abundant even on vertical rock faces covered with a film of water. The principal outflows of the spring are too hot for the snails; their upper temperature limit was 38°C, and most individuals were probably in sheets or trickles at 33°-35°C. Precise measurement of temperature was not possible, as the thin flow of water was too shallow for immersion of the thermometer bulb.

TABLE 32—Penial glands in *Fontelicella thermalis* n.sp. from type locality. N = 30.

Terminal gland (T)	
Semicircular or horseshoe-shaped	30
Dorsal glands	
DP–Dp fused	29
DP and Dp separate	1
Within DP–Dp	
5 strips	1
4 strips	1
3 strips	10
2 strips	5
1 strip	1
3 strips and dot or oval	4
2 strips and 2 dots or ovals	1
2 strips and 1 dot or oval	4
1 strip and 2 dots or ovals	1
4 dots or ovals	1
5 dots or ovals	1
Ventral glands	
Transverse strip	15
Oblique or lengthwise strip	3
Dot or papule	12
Additional posterior dot or papule	2

The second locality is a group of thermal springs at the edge of East Fork Gila River. Here too the species was found abundant on steep or even vertical rock faces, but not in the hottest water close to the main sources. Snails were present at 38°-39°C, but most occurred at lower temperatures, as at the type locality. Cool springs here (type locality of *Fontelicella gilae,* q.v.) did not yield any specimens of *Fontelicella thermalis.*

At both localities, *F. gilae* n.sp. was the only mollusc associated with *Fontelicella thermalis.*

The narrow gorges of the upper Gila River drainage provide little of the usual *Fontelicella* habitat. Snails that could survive in thermal water flowing over steep rock faces may have been the only ones spared by the floods of past ages. Thus, selection could account for the unusual features of shell form and size. Even now at the type locality a moderate fraction of the population is probably washed away annually, when the river rises in the spring. Yet, other unusual features cannot be accounted for so readily, and a long independent history of the species seems to be implied.

FONTELICELLA TRIVIALIS group

Penis with accessory process tapered distad, with indistinct terminal lobe, and oval terminal gland (T) to left of midline. Penial gland (DP) short; two dorsal distal glands (Dl, D2) on right and left sides of accessory process. Ventral lobule with gland (VL).

One species, *F. trivialis* n.sp., from headwaters of the Black River on the southern slopes of the White Mountains, eastern Arizona.

In the distinctive distad tapering of the accessory process and in location of Dl and D2, *Fontelicella trivialis* is clearly allied with a species in the Sevier River drainage, Utah, on the far side of the Colorado River.

FONTELICELLA TRIVIALIS, new species

Fig. 14

Diagnosis—A species of *Fontelicella* (s.s.) with glandular patches on the penis as follows: a short strip or oval on an indistinct terminal lobe (T); a short penial gland (DP); on

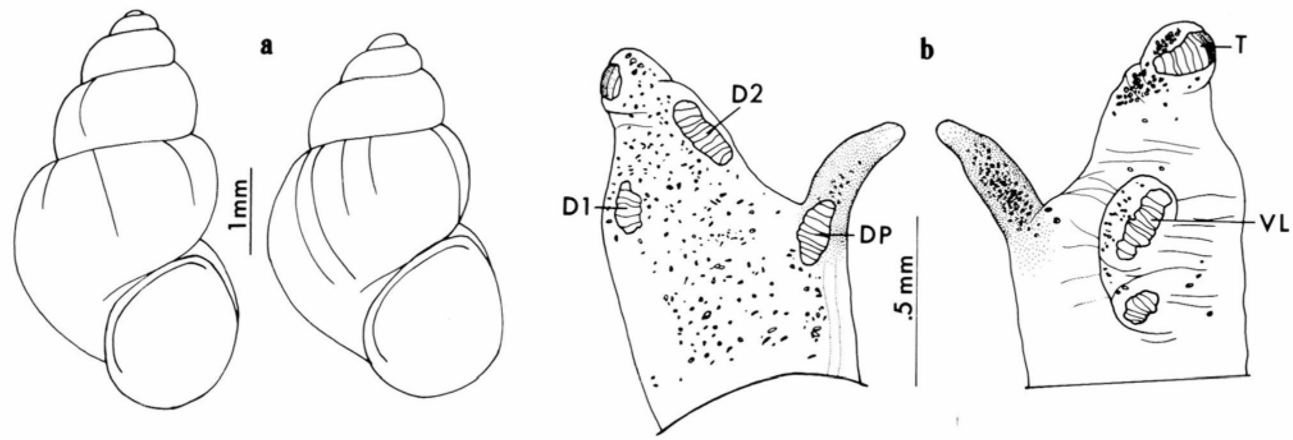

FIGURE 14—*Fontelicella trivialis* n.sp.: **a,** Two larger female shells; **b,** penis, dorsal (left) and ventral (right) views of holotype. Abbreviations: DP, penial gland; D1, D2, dorsal glands; T, terminal gland; VL, gland on ventral lobule.

the dorsal surface of the accessory process a short strip (D2) on the right and an oval or dot (D1) on the left; and on the ventral lobule a short strip or oval (VL).

Types—Holotype LACM 2225, a male preserved in alcohol, collected by D. W. Taylor, 5-XI-1980. Paratypes UTEP 10,059.

Type locality—Spring-fed pond 1,000 ft N of SW corner sec. 5, T5N, R29E, Apache County, Arizona.

Etymology—Latin *trivialis,* pertaining to three roads or paths, in reference to the adjacent locality Three Forks.

Description—Shell (Fig. 14a, Table 33) narrowly elongate, with a relatively long spire. Whorls separated by an incised suture, forming a spire with weakly convex outline. Periostracum tan.

Operculum (Table 34) plane, amber, with a darker-amber internal callus. Attachment scar with a well-developed border all around, but leaving no conspicuous trace.

Penis (Fig. 14b, Table 35) as usual in proportions, distinguished by the pattern of glands and especially the reduced T gland.

Exceptionally heavy parasitism precluded observation of details of the female system.

Variation—Two samples from different habitats were tabulated (Table 35) to show variation in penial glands. They came from the pond and spring mentioned below (see Habitat), for which associated species are listed. As usual, they show the relative constancy of major glands (T, DP, Dl, D2, VL) and variability in presence or number of minor glands.

Comparisons—The broad penis, transverse T gland, strong VL, and additional dorsal glands Dl and D2 besides DP links the species with the *F. californiensis* series. Thus, it agrees with all the species of New Mexico, Texas, and Chihuahua that have been examined so far. All others in Arizona and Sonora, including various populations in the Gila drainage, belong to the *F. stearnsiana* group within the *stearnsiana* series. The other New Mexico species of the upper Gila drainage, *F. gilae* and *F. thermalis,* are sharply distinct from each other as well as from *F. trivialis.*

Observations on living animals—Pigmentation is as usual in the genus: heaviest on dorsolateral surfaces of the rostrum, dorsal anterior surface of the foot, and operculigerous lobes. Overall intensity varies greatly. In less pigmented individuals, lacking nearly all melanin on external surfaces, the body is transparent and abundant hyaline granules can be seen throughout the head and foot. Animals with dense melanin wash appear nearly black. A cluster of white hyaline granules above and behind the eyes is uniformly present.

Habitat—The species was found in abundance in springs and spring-fed creeks over an area of about 0.1 km', with variation in associated mollusc species. The entire area is at an elevation of about 8,240 ft, the highest at which *Fontelicella* has yet been found.

Tributaries of the North Fork of the East Fork of Black River descend from the west and enter a flat-floored valley covered with tall grasses, through which the streams meander. Springs of various size arise in the floor of the valley as well as several feet higher, on its north flank next to the road where the two larger spring sources have been im-

TABLE 33—Measurements and descriptive statistics of 30 larger female shells of *Fontelicella trivialis* n.sp.

Whorls	
Mean	4.8
Range	$4^{1}/_{4}$–5
Length	
Mean	4.16
Range	3.9–4.5
S. D.	0.163
S. E.	0.030
Length of body whorl	
Mean	2.97
Range	2.8–3.3
S. D.	0.125
S. E.	0.023
Length of peritreme	
Mean	1.69
Range	1.5–2.0
S. D.	0.117
S. E.	0.021
Length of peritreme/length	
Mean	0.406
Range	0.37–0.45
S. D.	0.025
S. E.	0.005
Length of peritreme/length of body whorl	
Mean	0.569
Range	0.53–0.62
S. D.	0.023
S. E.	0.004
Width/length	
Mean	0.595
Range	0.53–0.68
S. D.	0.035
S. E.	0.006
Width/length body whorl	
Mean	0.833
Range	0.77–0.90
S. D.	0.033
S. E.	0.006

TABLE 34—Measurements and descriptive statistics of 20 opercula of *Fontelicella trivialis* n.sp. from larger females measured (Table 33).

Length	
Mean	1.50
Range	1.40–1.61
S. D.	0.059
S. E.	0.014
Width/length	
Mean	0.723
Range	0.70–0.74
S. D.	0.023
S. E.	0.005
Left end/length	
Mean	0.286
Range	0.28–0.31
S. D.	0.017
S. E.	0.004

TABLE 35—Penial glands in two samples of *Fontelicella trivialis* n.sp. N = 30 for both.

	Spring	Pond
Terminal gland (T)		
Short strip or oval	30	30
Dorsal glands		
Penial (DP)		
Short strip	27	30
Long strip	3	
Right (D2)		
Short strip	28	30
Dot	1	
2 dots	1	
Left (D1)		
Oval		25
Dot	26	4
Absent	4	1
Ventral glands		
Lobule (VL)		
Long strip	2	1
Short strip	17	27
2 ovals	1	1
Oval	8	
Oval and dot		1
2 dots	1	
Absent	1	
Additional glands		
Anterior dot or oval		2
Medial dot		1
Lateral dot		1
Posterior oval or strip		4
2 posterior dots	1	
Posterior dot	2	11

proved with construction of cement enclosures. All sources measured were 15°C.

Above the spring area the creek is about 5 ft wide, 13°C, and flows over cobbles and mud with sparse growth of *Ranunculus* at the margins. Below inflow of the springs the creek is a degree warmer (14°C) and acquires broad belts of *Ranunculus* and semi-emergent vegetation along its sides, with corresponding amounts of mud.

Numerous springs issue also on the south side of the lower end of the valley. The largest, several feet above the valley floor, has been improved by construction of a cement enclosure. The springs flow into a pond about 200 ft long; both the pond and spring sources are 17°C. Outflow of the pond is a stream about 6 ft wide, with flow estimated at about 100 gal/min. The pond is up to 2 ft deep, with bottom of firm sand and gravel at the center overlain by a layer of flocculent mud thicker toward the sides; cobbles and boulders are scattered throughout. *Ranunculus* forms dense patches around the borders with emergent grasses at the margin; locally there are mats of filamentous green algae.

Flow from the pond is entirely to the northeast, and not as shown on the topographic map also to the southeast. After a few hundred feet it joins the main stream of the valley, and shortly thereafter the tributary enters the North Fork of East Fork of Black River. The latter stream is a torrent with smooth cobble bottom in which no molluscs were found. *Fontelicella trivialis* is apparently limited to this spring-rich meadow perched above the steep canyon of Black River.

Physa gyrina Say was the only mollusc found above the spring sources in the main tributary creek. *Fontelicella* and *Valvata* occurred sparsely in the marginal vegetation below and along the springs and seepages. *Anodonta californiensis* was found in pools at depth of four inches and more, the highest elevation recorded for the species.

The eastern of the two larger springs on the north side of the valley was sieved along its course about 100 ft below the source. This spring is marked on the U.S. Geological Survey Big Lake quadrangle, 1:62,500, at 150 ft east, 1,600 ft north of the southwest corner of section 5. *Fontelicella trivialis* was abundant, with lesser numbers of *Physa gyrina* (of small size), *Pisidium casertanum* (Poli), and a few *P. insigne* Gabb.

The spring-fed pond at the lower end of the valley has the highest diversity of species. *Fontelicella* was abundant in the flocculent mud, as well as climbing on vegetation. Associated molluscs were *Valvata humeralis* Say, *Physa gyrina* Say (of larger size), *Radix auricularia* (Linnaeus), *Gyraulus parvus* (Say), *Pisidium casertanum* (Poli), *P. compressum* Prime, and *P. variabile* Prime.

APACHECOCCUS, new genus

Diagnosis—Shell elongately ovate, up to 2 mm long, with 3 whorls. Penis with a large, bluntly rounded accessory process that bears an oval glandular patch on both dorsal and ventral sides. Free portion of penis at right angle to accessory lobe. Coiled renal portion of oviduct with three narrow loops, distal part greatly enlarged. No receptaculum seminis.

Type *species—Apachecoccus arizonae* n.sp.

Distribution—Known only from a group of mildly thermal springs in the valley of the Gila River on the San Carlos Indian Reservation, southeastern Arizona.

Etymology—From Apache, and Greek *coccus* (m.), grain or seed.

Remarks—As is so often the case with thermal-spring Hydrobiidae in the American West, this is an endemic genus with no evident close relatives. Especially distinctive features are the free portion of the penis, borne at right angle to the long axis of the penis, so that the vas deferens curves through 90°. A massive accessory lobe bears glandular patches, but not on the distal end of the lobe or even at the margin, as is more commonly the case. Rare, but not unique, features are the distal enlargement of the renal oviduct and lack of a receptaculum seminis.

APACHECOCCUS ARIZONAE, new species

Fig. 15

Diagnosis—Shell elongately ovate, 1.5-2 mm long, with 3-3 1/2 whorls. Penis with large accessory lobe bearing an oval glandular patch on dorsal and ventral surfaces, and free portion at right angle to long axis of penis.

Types—Holotype LACM 2203, a male preserved in alcohol, collected by D. W. Taylor, 20-IV-1971. Paratypes UTEP 10,050.

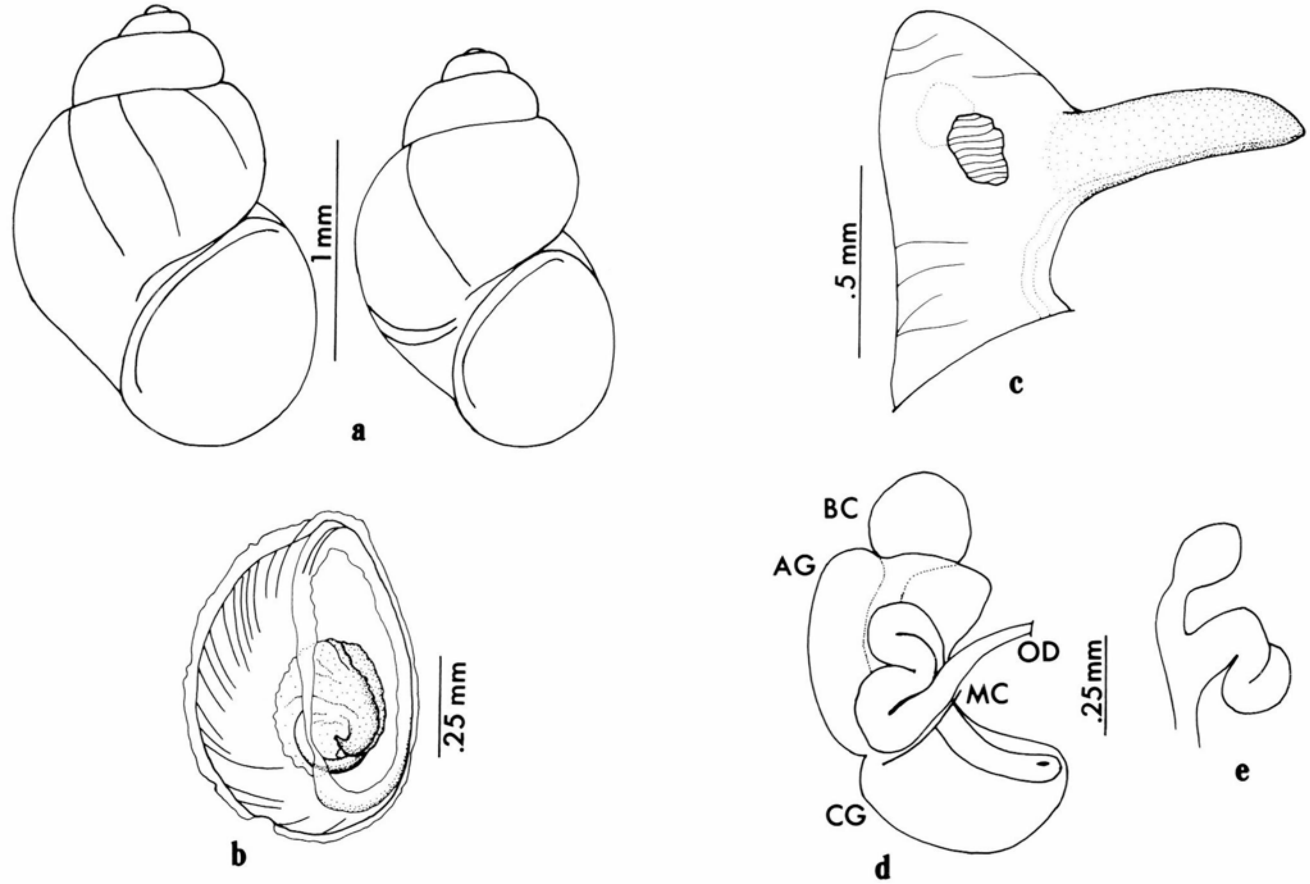

FIGURE 15—*Apachecoccus arizonae* n. gen. et sp.: **a,** Two larger female shells; **b,** operculum, inner face; **c,** penis, dorsal view; **d,** distal female reproductive system, ventral view; **e,** part of another specimen, with most of coiled portion of oviduct removed. Abbreviations: AG, albumen gland; BC, bursa copulatrix; CG, capsule gland; MC, wall of mantle cavity; OD, oviduct.

Type locality—Unnamed spring on north side of Gila River about 2 mi north of Bylas, in T3S, R22E, 25,000 ft W and 15,500 ft N of the township line, Graham County, Arizona.

Etymology—Named for the State of Arizona.

Description—Shell (Fig. 15a, Table 36) elongately ovoid with blunt apex, spire with convex outline. Whorls convex, separated by a well-impressed suture; last 1/4 to 1/10 whorl commonly disjunct from preceding whorl. Aperture ovate to subcircular. Plane of aperture and growth lines oblique to axis of coil. Sculpture of fine growth lines only. Periostracum pale tan.

Operculum (Fig. 15b, Table 37) plane, ovate, pale amber, with an amber internal callus. Attachment scar bordered by a narrow but discrete thickening that leaves no conspicuous trace.

Penis (Fig. 15c) made up of a massive accessory lobe with bluntly rounded end and a free portion directed at right angle. The melanin core in the free portion renders that structure opaque, but is not conspicuously jet black as is often the case in other genera. The accessory lobe bears oval glandular patches on dorsal and ventral surfaces, but not directly opposite.

Distal female system (Fig. 15d–e) with relatively small bursa copulatrix. In six specimens the bursa/albumen gland ratio ranged from 0.29 to 0.55, mean 0.42. The bursal duct and adjacent border of the bursa are slightly immersed in the albumen gland. The coiled renal portion of the oviduct is thickened and glandular, convoluted into three narrow loops. Distad of the coiled portion, proximad of junction with the bursal duct, the oviduct is dilated to 1.5-2 times its width in the coiled portion. Possibly this segment func-

TABLE 36—Measurements and descriptive statistics of shells of *Apachecoccus arizonae* n.gen. et sp. from type locality. N = 30 for both sexes.

	Males	Females
Whorls		
Mean	3.19	3.33
Range	3–3½	3–3¾
Length		
Mean	1.59	1.73
Range	1.43–1.80	1.49–2.09
S. D.	0.105	0.147
S. E.	0.019	0.027
Length of peritreme/length		
Mean	0.551	0.525
Range	0.45–0.59	0.41–0.56
S. D.	0.030	0.035
S. E.	0.005	0.006
Width		
Mean	1.17	1.24
Range	1.09–1.29	1.14–1.46
S. D.	0.067	0.072
S. E.	0.012	0.013
Width/length		
Mean	0.736	0.720
Range	0.66–0.80	0.63–0.78
S. D.	0.033	0.035
S. E.	0.006	0.006

TABLE 37—Measurements and descriptive statistics of 20 opercula of *Apachecoccus arizonae* n.gen. et sp. from type locality. Opercula from larger males measured (Table 36).

Length	
Mean	0.860
Range	0.78–0.97
S. D.	0.048
S. E.	0.011
Width/length	
Mean	0.698
Range	0.67–0.75
S. D.	0.018
S. E.	0.004
Left end/length	
Mean	0.310
Range	0.29–0.34
S. D.	0.013
S. E.	0.003

tions as a receptaculum seminis, which is not present as a discrete structure.

Localities and material examined—In addition to the type locality, the species was found at two other nearby springs also on the north bank of the Gila River, about 0.5 and 2 mi to the south. Both localities are in the same unsectionized township as the type locality: 3,100 ft W and 3,100 ft N in sec. 20, T3S, R22E; and in sec. 33, 3,800 ft N and 19,500 ft W of the township line.

Habitat—The spring sources in which the species lives are all mildly thermal, ranging from 26 to 32°C. The most abundant submergent vegetation is *Chara*, with marginal sedges and *Distichlis*. *Apachecoccus is* most common on firm substratum in the springbrooks, on dead wood, gravel, and pebbles. *Tyronia gilae* n.sp. is also abundant in all three springs but, as usual for the genus, it lives predominantly in mud and prefers a slower current than the associated hydrobiid. The only other mollusc found is the widespread snail *Physa mexicana* Philippi. These springs are home to two of the last surviving populations of the fish *Poeciliopsis occidentalis* (Johnson & Kobetich, 1970).

YAQUICOCCUS, new genus

Diagnosis—Hydrobiinae having a simple penis, with no accessory lobe, bearing a large, long-oval glandular patch on a prominent lobule on both dorsal and ventral surfaces. Bursa copulatrix relatively small, about one-sixth the volume of the albumen gland, with a duct longer than the bursa. A narrowly club-shaped receptaculum seminis projects posteriorly to the distal bend of the oviduct, and is diagonal to the long axis of the albumen gland.

Type *species—Yaquicoccus bernardinus* n.sp.

Distribution—So far known from a single population in Cochise County, Arizona, in drainage of Rio San Bernardino, tributary to the Rio **Yaqui.**

Etymology—From Rio Yaqui and Greek *coccus* (m.), grain or seed.

Comparisons—Yaquicoccus differs from the geographically nearest hydrobiid genus, *Fontelicella*, **in having the duct of the bursa** copulatrix immersed entirely in the albumen gland, and especially in the penial glands and lack of accessory lobe of the penis. Large size and lengthwise orientation of the two penial glands differ from those features in *Fontelicella*, so that *Yaquicoccus* is not merely a *Fontelicella* without an accessory lobe.

YAQUICOCCUS BERNARDINUS, new species
Fig. 16

Diagnosis—Shell narrowly conical with obtuse apex, 1.5–2 mm long, with $3^1/2$-4 whorls. Penis simple, with no accessory lobe, bearing a large, long-oval glandular patch on a prominent lobule on both left dorsal and ventral surfaces.

Types—Holotype LACM 2186, a male preserved in alcohol, collected by D. W. Taylor, 27-Vll-1968. Paratypes UTEP 10,066.

Type locality—Spring 2,300 ft E, 4,600 ft S of NW corner, sec. 15, T24S, R30E, Cochise County, Arizona.

Etymology—The name is in reference to the San Bernardino River.

Description—Shell (Fig. 16a, Table 38) narrowly conical, with an obtusely blunt apex. Spire with convex outline. Whorls convex, separated by well-incised suture. Aperture ovate; peritreme simply adnate to preceding whorl, or slightly disjunct. Plane of aperture and growth lines oblique to axis of coil. Sculpture of fine growth lines only. Periostracum pale tan.

Operculum (Fig. 16b, Table 39) pale amber, plane, with an amber central callus. Attachment scar has a narrow discrete thickening all around, but leaves no conspicuous trace.

Penis (Fig. 16c–d) simple, with no accessory process. Tip with a melanin-pigmented core, opaque. On both left dorsal and ventral surfaces prominent long-oval lobule, oriented lengthwise, bearing a similarly oriented glandular patch.

Distal female system (Fig. 16e): Bursa copulatrix relatively small. In six specimens the bursa/albumen gland ratio averaged 0.33 (range 0.28-0.41). The duct of the bursa is long and slender, conspicuously longer than the bursa, and entirely embedded within the albumen gland. The loop of the

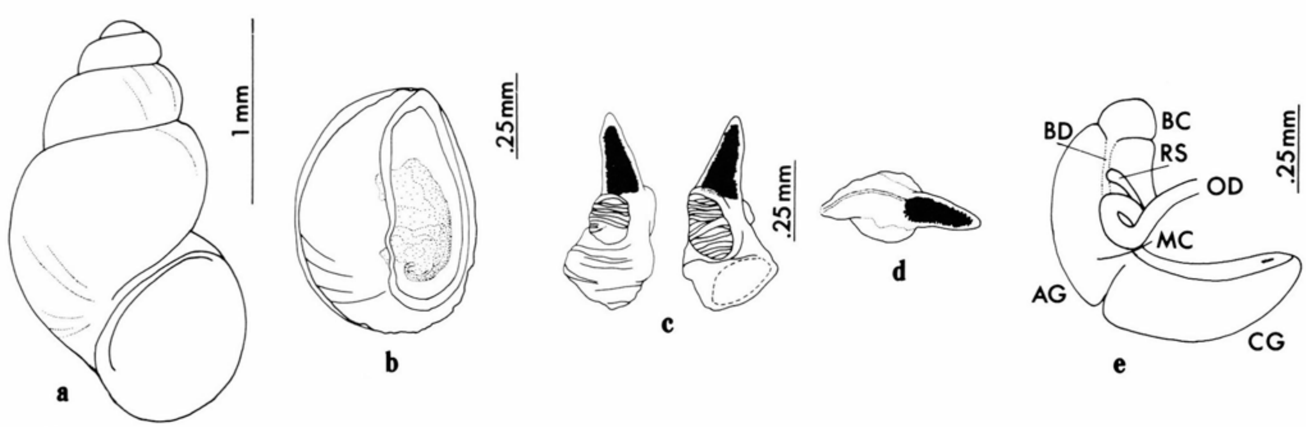

FIGURE 16—*Yaquicoccus bernardinus* n. gen. et sp.: **a,** Shell, the largest in the subsample of females measured; **b,** operculum, inner face; **c, d,** penis, *c* dorsal (left) and ventral (right) views, *d* right lateral view of another specimen; **e,** distal portion of female reproductive system. Abbreviations: AG, albumen gland; BC, bursa copulatrix; BD, duct of bursa copulatrix; CG, capsule gland; MC, wall of mantle cavity; OD, oviduct; RS, receptaculum seminis.

TABLE 38—Measurements and descriptive statistics of shells of *Yaquicoccus bernardinus* n.gen. et sp. N = 30 for both sexes.

	Males	Females
Whorls		
Mean	3.38	3.51
Range	3 1/4–3 3/4	3 1/4–4
Length		
Mean	1.58	1.82
Range	1.43–1.83	1.66–2.12
S. D.	0.104	0.105
S. E.	0.004	0.004
Length of peritreme/length		
Mean	0.458	0.455
Range	0.42–0.48	0.42–0.48
S. D.	0.018	0.019
S. E.	0.001	0.001
Width		
Mean	1.00	1.12
Range	0.86–1.14	1.03–1.23
S. D.	0.061	0.054
S. E.	0.002	0.002
Width/length		
Mean	0.633	0.615
Range	0.59–0.68	0.58–0.66
S. D.	0.027	0.020
S. E.	0.001	0.001

oviduct may be double-looped as in most west American Hydrobiinae, or more nearly in a tight coil. The slender, club-shaped, nearly straight receptaculum seminis is oriented diagonal to the length of the albumen gland, appressed simply to it, and commnly projects posteriorly to meet or overlap the immersed bursal duct.

Localities and material examined—Only one series, formalin-fixed, was available for study. The type locality is in the drainage of the San Bernardino River, tributary to the Rio Yaqui; it is the only place from which hydrobiids are known in this large river system of northwestern Mexico and adjacent Arizona.

TABLE 39—Measurements and descriptive statistics of 20 opercula from female *Yaquicoccus bernardinus* n.gen. et sp.

Length	
Mean	0.754
Range	0.71–0.81
S. D.	0.032
S. E.	0.007
Width/length	
Mean	0.695
Range	0.65–0.75
S. D.	0.021
S. E.	0.005
Left end/length	
Mean	0.305
Range	0.27–0.33
S. D.	0.017
S. E.	0.004

Habitat—The spring is about 100 ft southeast of an artificial pond, and is probably fed in part by lateral underflow from that pond. The spring-brook was a watercress-choked stream about 1 ft wide, trickling over gravel, mud, and dead wood and leaves. *Yaquicoccus* was abundant on dead wood, leaves, or stones. *Physa mexicana* Philippi was rare in vegetation or on wood. In fine silt and mud were *Pisidium casertanum* (Poli) and *P. singleyi* Sterki.

Family LITTORIDINIDAE
TRYONIA Stimpson, 1865

Diagnosis (new)—Shell conical to aciculate, thin or solid, smooth, lirate, costate, or with reticulate sculpture, but not spinose; no color bands; imperforate or with narrow umbilicus; adult length about 2-6 mm; sexual dimorphism variably pronounced, with females in some species attaining twice the size of males.

Operculum plane, paucispiral, colorless to pale amber, with no internal projections and only a thin internal callus.

Penis with a distal melanin-pigmented bulb bearing a terminal stylet. One to eight glands, each with a distal pore,

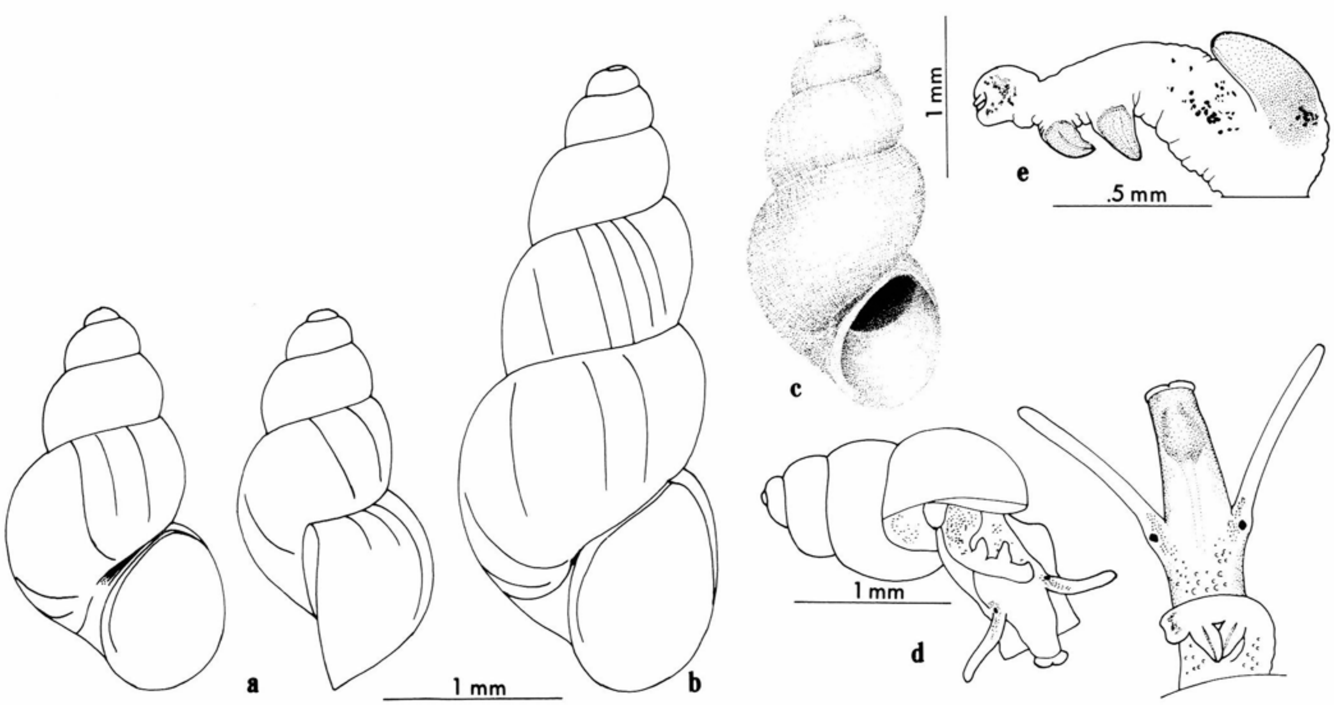

FIGURE 17—*Tryonia gilae* n.sp.: **a–c,** Shells, *a* larger male, *b* larger female, both from type locality, and *c* unsexed, from spring in sec. 33, T3S, R22E (drawn by A. D'Attilio); **d,** living animal from spring in sec. 20, T3S, R22E; **e,** penis, dorsal view, from type locality.

are borne directly on one or both sides of the penial blade, rarely also on the dorsal surface of the base. Usually one (rarely two) basal papilla, but none in subgenus *Paupertryonia*. Each glandular papilla broadly conical to roughly cylindrical; length of a papilla may be less or slightly more than width of penial blade.

Type species (by original designation)—Tryonia *clathrata* Stimpson, **1865.**

Etymology—Named for conchologist George Washington Tryon (1838-1888).

Distribution—Western United States and northern Mexico, the southern limit uncertain.

As an aid in diagnosis of species and tabulating number and location of papillae, a penial formula has been useful. The formula designates glands by left (L) and right (R) sides; a basal gland may be of usual **(B) or** reduced (b) size, or substantially larger than the distal papillae(^{B}). The distal papillae are ordinarily of almost equal size and only their total number is indicated; they are usually separated from the basal papilla by an interval (-).

TRYONIA GILAE group

Shell smooth, elongate. Penial formula L0-2 R^B-0. Head of penis not set off from blade, with no lateral projection; terminal stylet retractile into a depression. Distal papillae elongate, tapering, not constricted at base. Basal papilla roughly twice the size of distal papillae, elongate, tapering, not constricted at base.

Two species, *Tryonia gilae* n.sp. in Gila River drainage of eastern Arizona and an undescribed form in Rio Santa Maria drainage, Chihuahua.

TRYONIA GILAE, new species
Fig. 17

Diagnosis—An elongate species attaining a shell length of 3.4 mm. The penis bears a large basal glandular papilla on the right side that is more than twice as large as the distal papillae, and two distal papillae of equal size on the left side.

Types—Holotype LACM 2187, a male preserved in alcohol, collected by D. W. Taylor, 20-IV-1971. Paratypes UTEP 10,063.

Type locality—Unnamed spring on north side of Gila River about 2 mi north of Bylas, in T3S, R22E, 25,000 ft W and 15,500 ft N of the township line, Graham County, Arizona.

Etymology—Named for Gila River.

Description—Shell (Fig. 17a-c, Table 40) narrowly conical, with obtuse apex and broadly rounded anterior end. Whorls 4-5 in larger males and 5-6 in larger females, regularly convex and separated by an incised suture. Aperture ovate, broadly rounded anteriorly, subangular posteriorly. Parietal part of peritreme simply adnate to preceding whorl, leaving a narrow umbilical chink. Profile of aperture weakly sinuous, slightly oblique to axis of coil, posterior end in advance. Sculpture of fine, irregular collabral growth lines and discontinuous fine, irregular spiral striae that may cut the growth lines. Periostracum tan.

Penis (Fig. 17e, Table 41) a flattened blade with base about 2-3 times as wide as the isthmus behind the head. Head roughly quadrate, broadly rounded on right distal margin, subangular on left, internally with a concentration of melanin. Terminal stylet retractile into a subcentral depression. In 50 specimens from the type locality there was a large basal subcylindrical gland on the right side of the penis and two smaller, more nearly conical glands on the distal left side, all dusted with melanin and appearing darker than the blade of the penis. Scattered melanin granules are concentrated in the proximal portion of the blade.

Variation—Size and form of the shell differ substantially according to sex (Table 40), but within samples of a given sex there is little variation.

Comparisons—The shell is not as narrowly conical as in most species of the genus. The penis is distinctive in having a basal papilla on the right side, instead of on the left as in most species, and in that the basal papilla is more than twice the size of the distal papillae.

Observations on living animals—When the animals are crawling, visible in dorsal view are the rostrum, tentacles to just in front of or behind the eyes, and occasionally the anterior auriculate corners of the foot. The tentacles are divergent at an angle of about 90° and are waved up and down irregularly in no discernible pattern, occasionally touching the substratum. Both tentacles are uniformly ciliated and symmetrical in form; they are blunt-tipped, with no evident tapering, and attain the length of about three-fourths of the aperture. A faint melanin wash covers the surface, but does not obscure the lumen or pattern of granules within. The pattern of opaque-white hyaline granules in the tentacles varied slightly in the three populations stud-

TABLE 40—Measurements and descriptive statistics of shells of *Tryonia gilae* n.sp. Samples are larger specimens from type locality. N = 30 for both.

	Male	Female
Whorls		
Mean	4.44	5.48
Range	4–5	5–6¼
Length		
Mean	1.91	2.88
Range	1.67–2.17	2.51–3.41
S. D.	0.117	0.198
S. E.	0.021	0.036
Length of last two whorls		
Mean	1.69	2.31
Range	1.52–1.86	2.08–2.67
S. D.	0.088	0.115
S. E.	0.016	0.021
Length of peritreme		
Mean	0.80	1.00
Range	0.71–0.87	0.93–1.18
S. D.	0.031	0.053
S. E.	0.006	0.010
Length of peritreme/length		
Mean	0.421	0.349
Range	0.371–0.456	0.304–0.384
S. D.	0.019	0.019
S. E.	0.004	0.003
Length of peritreme/length of last two whorls		
Mean	0.477	0.433
Range	0.433–0.510	0.403–0.466
S. D.	0.018	0.015
S. E.	0.003	0.003
Width		
Mean	1.02	1.29
Range	0.90–1.18	1.18–1.43
S. D.	0.066	0.063
S. E.	0.012	0.012
Width/length		
Mean	0.534	0.449
Range	0.492–0.576	0.392–0.477
S. D.	0.022	0.022
S. E.	0.004	0.004
Width/length of last two whorls		
Mean	0.606	0.557
Range	0.561–0.648	0.526–0.595
S. D.	0.022	0.016
S. E.	0.004	0.003

ied. Characteristically, granules occurred both in front of and behind the eyes, restricted to the proximal one-fourth of the tentacle. In specimens from the type locality, granules were characteristically in a lengthwise belt with the eye lateral to its midpoint. In the two other springs, the snails had granules distributed in a triangle about three-fourths distad to the eye, the apex of the triangle also distad to the eye and directed mediad.

Intensity of melanin pigmentation varied among the three populations as well as among individuals. At the type locality most specimens were lightly pigmented; melanin occurred more heavily on the sides of the rostrum than on its dorsal surface, so that buccal mass and esophagus were readily visible. In the spring in sec. 20 snails were heavily pigmented, with no part of the foot or body as dark as the dorsal and lateral surfaces of the rostrum, and the buccal mass was nearly obscured.

Ciliation of the penis is restricted to its head and is asymmetrical. The ciliated surface extends from the left distal angle over the head to the right proximal end of the base. Hyaline granules, like those of melanin, occur in the blade of the penis but not in the glandular papillae, and are concentrated in the proximal part.

Localities and material examined—In addition to the type locality, the species was found at two other nearby springs also on the north bank of the Gila River, about 0.5 and 2 mi to the south. Both localities are in the same unsectionized township as the type locality: 3,100 ft W and 3,100 ft N in sec. 20, T3S, R22E, and in sec. 33, 3,800 ft N and 19,500 ft W of the township line.

Habitat—See under *Apachecoccus arizonae* n. gen. et sp.

TABLE 41—Measurements and descriptive statistics of penis of *Tryonia gilae* n.sp. N = 30, the same specimens for which shell measurements are given.

Width of head	
Mean	0.125
Range	0.10–0.16
S. D.	0.013
S. E.	0.002
Length of left anterior papilla	
Mean	0.163
Range	0.13–0.21
S. D.	0.015
S. E.	0.003
Width of left anterior papilla	
Mean	0.090
Range	0.07–0.12
S. D.	0.011
S. E.	0.002
Width/length of left anterior papilla	
Mean	0.556
Range	0.42–0.71
S. D.	0.069
S. E.	0.013
Length of left posterior papilla	
Mean	0.159
Range	0.12–0.19
S. D.	0.015
S. E.	0.003
Width of left posterior papilla	
Mean	0.097
Range	0.08–0.13
S. D.	0.010
S. E.	0.002
Width/length of left posterior papilla	
Mean	0.621
Range	0.42–0.88
S. D.	0.086
S. E.	0.016
Length of basal papilla	
Mean	0.264
Range	0.21–0.33
S. D.	0.030
S. E.	0.005
Width of basal papilla	
Mean	0.166
Range	0.13–0.22
S. D.	0.021
S. E.	0.004
Width/length of basal papilla	
Mean	0.634
Range	0.50–0.85
S. D.	0.084
S. E.	0.015

TRYONIA STOCKTONENSIS group

Shell elongate, with sculpture of raised spiral threads. Penial formula LB-2 RB-0. Head of penis not set off from blade, with a prominent left-lateral projection, bordering a depression into which the moderately large terminal stylet retracts. The two distal papillae are narrowly conical, not constricted at the base. The two basal papillae are of unequal size, the left relatively wider and shorter; it is also shorter than the distal papillae.

One species, *Tryonia stocktonensis* n.sp., in lower Diamond Y Draw of the Pecos River drainage in Trans-Pecos Texas.

TRYONIA STOCKTONENSIS, new species
Fig. **18**

Diagnosis—A narrowly conical species attaining a shell length of 5.5 mm, with a deeply incised suture and spiral sculpture of fine, raised threads. The penis has a large basal glandular papilla on either side, and two papillae on the distal left side of the blade.

Types—Holotype LACM 2090, a male preserved in alcohol, collected by D. W. Taylor, 27-X-1984. Paratypes UTEP 10,065.

Type locality—Diamond Y Draw, 9 mi N of Fort Stockton and 0.5 mi W of State Highway 18, Pecos County, Texas.

Etymology—Named for the nearby town of Fort Stockton.

Description—Shell (Fig. 18a, Table 42) narrowly conical, with obtuse apex and broadly rounded anterior end. Whorls 5-6 in larger females, regularly convex, separated by a deeply incised suture. Aperture ovate, broadly rounded anteriorly, subangular posteriorly. Parietal part of peritreme simply adnate to preceding whorl or slightly disjunct; a narrow umbilical opening present. Profile of aperture almost plane to weakly sinuous, oblique to axis of coil at about 10°, posterior end usually in advance. Sculpture of fine, irregular collabral growth lines and spiral raised threads variable in persistence and presence. Periostracum tan.

Penis (Fig. 18b) a flattened blade gradually widening proximad or of uniform width. The head is not set off from the blade by a constriction, but bears a conspicuous flare on the distal left side, bordering a depression into which the stylet retracts. Opposite one another on either side of the base are two large glandular papillae, the one on the left broader and shorter. On the left distal margin are two elongate glandular papillae of about equal size, which may be seated on a short base; they are longer than the left basal papilla. Concentration of melanin granules in the head is conspicuously greater than the overall dusting of melanin.

Operculum translucent, pale amber but nearly colorless, paucispiral, plane.

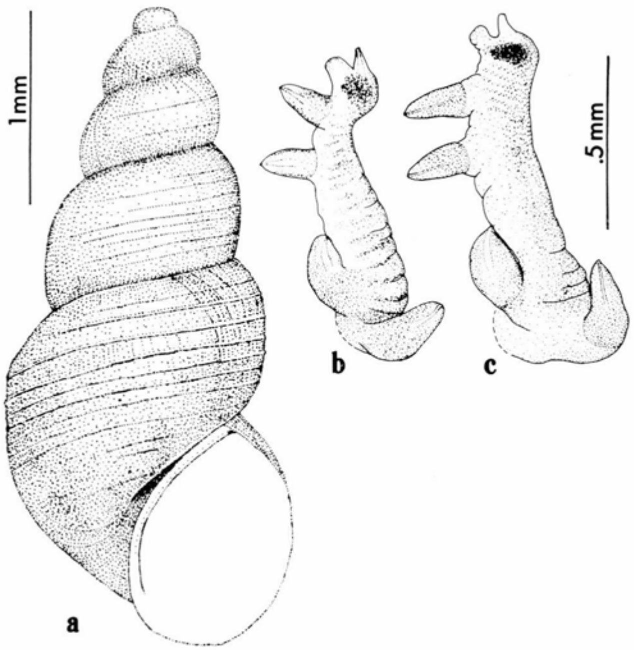

FIGURE 18—*Tryonia stocktonensis* n.sp.: **a**, Shell of larger female; **b**, **c**, penis, dorsal view.

TABLE 42—Measurements and descriptive statistics of 30 larger female shells of *Tryonia stocktonensis* n.sp.

Whorls	
Mean	5.49
Range	5¼–6
Length	
Mean	3.40
Range	2.99–3.67
S. D.	0.187
S. E.	0.034
Length of last two whorls	
Mean	2.64
Range	2.34–2.83
S. D.	0.128
S. E.	0.023
Length of peritreme	
Mean	1.12
Range	1.05–1.23
S. D.	0.044
S. E.	0.008
Length of peritreme/length	
Mean	0.329
Range	0.299–0.354
S. D.	0.013
S. E.	0.002
Length of peritreme/length of last two whorls	
Mean	0.424
Range	0.385–0.463
S. D.	0.017
S. E.	0.003
Width	
Mean	1.53
Range	1.36–1.66
S. D.	0.076
S. E.	0.014
Width/length	
Mean	0.449
Range	0.414–0.482
S. D.	0.015
S. E.	0.003
Width/length of last two whorls	
Mean	0.579
Range	0.546–0.622
S. D.	0.017
S. E.	0.003

Variation—Strength of spiral sculpture is the most conspicuous variable. Spiral threads begin usually on the second or third whorl. In more strongly sculptured specimens there are 10-12 spiral elements between sutures, either threads or narrow bands, usually separated by interspaces about twice as wide as the threads but sometimes narrower. Threads may become faint or obsolete on later whorls; in rare specimens no spiral sculpture is present.

Fifty-one specimens were examined for genial glands; all were uniform with respect to number and arrangement of the glands.

Observations on living animals—Proportions of body, behavior, overall pigmentation, and symmetrical ciliation are as in *Tryonia alamosae.*

Pale-yellow hyaline granules are conspicuous in the tentacles. They form an elongate cluster about twice as long as wide that reaches from beside the eye distad and occupies the full width of the tentacle. Proximad the granules end abruptly; distad they become fewer and may be scattered sparsely throughout the length of the tentacle.

Sugary-white granules are scattered in the head-foot behind the tentacles and may be visible even in the rostrum.

Habitat—The species is restricted to a single spring (21°C) and its outflow about 90 ft long, about 2 mi downstream from the nearest locality at which *Tryonia adamantina* was found. Flow was estimated at 5-10 gal/min; it forms a rivulet 3-4 ft wide over most of its course and is 2-3 in. deep between limestone boulders and over gravel. *Tryonia* was most abundant in soft mud at the margin, but occurred generally; the only other mollusc present was *Physa mexicana.* Neither was found in the adjacent main flow of Diamond Y Draw. The spring is mentioned by Hubbs et al. (1978: 489) as one of the main sources of water in the lower creek segment. They recorded two large springs at their Station 5; only one was flowing in 1984.

PAUPERTRYONIA, new subgenus

Diagnosis—Species of *Tryonia* lacking basal papillae on the penis.

Type species—Tryonia *cheatumi* (Pilsbry, **1935).**

Etymology—Latin *pauper,* poor, in reference to the lack of basal papillae; and *Tryonia.*

TRYONIA (PAUPERTRYONIA) CHEATUMI group

Shell smooth, elongate. Penial formula L0-2 R0-0. Head of penis set off from blade by a constriction; with left lateral projection; terminal stylet short. Two glandular papillae on distal left side that taper gradually to blunt ends and are weakly constricted at the base.

One species, *Tryonia cheatumi* (Pilsbry), in Phantom Lake and San Solomon Springs, Trans-Pecos Texas.

TRYONIA (PAUPERTRYONIA) CHEATUMI (Pilsbry, 1935)
Fig. 19

1935. *Potamopyrgue cheatumi* Pilsbry, p. 91, fig. 4; Phantom Lake near Toyahvale, Texas.

1935. *Potamopyrgus cheatumi* Pilsbry: Cheatum, p. 114; notes on habitat.

1948. *Lyrodes cheatumi* (Pilsbry): Berry, p. 68; Balmorhea State Park at Toyahvale, and Phantom Lake, Texas.

1948. *?Lyrodes diaboli* (Pilsbry & Ferriss) [misidentified]: Berry, p. 68; Balmorhea State Park at Toyahvale, and Phantom Lake, Texas.

1964. *Littoridina (Lyrodes) cheatumi* (Pilsbry): Baker, p. 171; type catalog.

1966b. *Tryonia cheatumi* (Pilsbry): Taylor, p. 196; list of species of *Tryonia.*

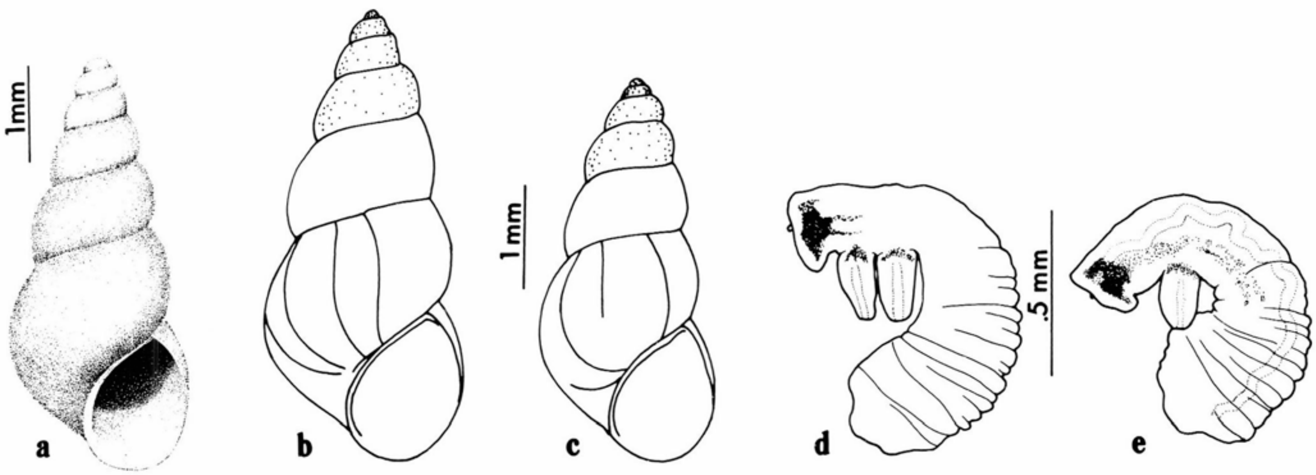

FIGURE 19—*Tryonia cheatumi* (Pilsbry) from Phantom Lake Spring outflow: **a–c,** Shells, *a* indeterminate sex (drawn by A. D'Attilio), *b* female, and *c* male, both with eroded spires; **d, e,** penis, dorsal view, *d* with two papillae as usual, *e* one specimen out of 80 with only one papilla.

1969. *Lyrodes cheatumi* (Pilsbry): Dundee & Dundee, pp. 207-209, fig. 3b; Phantom Lake Spring near Toyahvale; notes on habitat.

1971. 38. *Tryonia cheatumi* (Pilsbry): Cheatum & Fullington, p. 17, fig.

1972. *Tryonia cheatumi* (Pilsbry): Cheatum et al., p. 7; Jeff Davis County, Texas; no specific locality.

1982. *Tryonia cheatumi* (Pilsbry): Burch, p. 21, figs. 127, 128, 133.

1982. *Tryonia cheatumi* (Pilsbry): Fullington, pp. 63-64; characteristic of Chihuahuan biotic province.

1984. *Tryonia cheatumi* (Pilsbry): U.S. Fish & Wildlife Service, p. 21673; candidate endangered species.

Diagnosis—A narrowly conical species attaining a shell length of 4.2 mm, with weakly sinuous growth lines. The penis has a head expanded on the left side and two elongate papillae on the distal left side that are set off by basal constrictions.

Holotype—ANSP 163888, a dry shell; collected by E. P. Cheatum, 1934.

Type locality—Phantom Lake, Jeff Davis County, Texas.

Etymology—Named for the collector, Elmer Philip Cheat= (1901-1973), who was for many years on the faculty of Southern Methodist University.

Description—Shell (Fig. 19a-c, Table 43) narrowly conical, with obtuse apex and broadly rounded anterior end. Whorls $4^3/4$-$5^3/4$ in larger males and 5-6 in larger females, regularly convex and separated by an incised suture. Aperture ovate, broadly rounded anteriorly and subangular posteriorly. Parietal part of peritreme simply adnate to preceding whorl, with or without a narrow umbilical chink. Profile of aperture weakly sinuous, slightly oblique to axis of coil, posterior end in advance of anterior end. Sculpture of fine, irregular collabral growth lines. Periostracum olive tan.

Penis (Fig. 19d-e, Table 44) a flattened blade with broad proximal portion. The head is expanded laterally on the left side, set off posteriorly by a narrowing, and internally suffused with melanin granules. On the distal left side are two elongate glandular papillae that are constricted at their bases and contain a basal melanin suffusion.

Variation—Size and form of the shell vary as shown in Table 43, indicating the extent of sexual dimorphism. Shell proportions are much alike in both sexes, the principal difference being the greater size attained by females.

The 30 males measured all had two glandular papillae of similar size and shape on the left distal margin of the penis (Fig. 19d). Of additional 50 males, 49 had two papillae and one had only one papilla (Fig. 19e).

TABLE 43—Measurements and descriptive statistics of shells of *Tryonia cheatumi* (Pilsbry) from outflow of Phantom Lake Spring. N = 30 for both samples.

	Male	Female
Whorls		
Mean	5.3	5.6
Range	$4^3/_4$–$5^3/_4$	5–6
Length		
Mean	3.18	3.88
Range	2.86–3.63	3.50–4.20
S. D.	0.210	0.184
S. E.	0.038	0.034
Length of last two whorls		
Mean	2.55	3.03
Range	2.29–2.80	2.67–3.24
S. D.	0.148	0.130
S. E.	0.027	0.024
Length of peritreme		
Mean	1.16	1.31
Range	1.02–1.27	1.15–1.40
S. D.	0.067	0.066
S. E.	0.012	0.012
Length of peritreme/length		
Mean	0.366	0.338
Range	0.33–0.39	0.32–0.36
S. D.	0.016	0.012
S. E.	0.003	0.002
Length of peritreme/length of last two whorls		
Mean	0.456	0.432
Range	0.42–0.49	0.40–0.46
S. D.	0.016	0.014
S. E.	0.003	0.003
Width		
Mean	1.51	1.80
Range	1.34–1.72	1.65–1.97
S. D.	0.087	0.072
S. E.	0.016	0.013
Width/length		
Mean	0.475	0.466
Range	0.43–0.51	0.42–0.52
S. D.	0.021	0.019
S. E.	0.004	0.004
Width/length of last two whorls		
Mean	0.592	0.596
Range	0.53–0.63	0.56–0.64
S. D.	0.019	0.021
S. E.	0.004	0.004

TABLE 44—Measurements and descriptive statistics of penis of *Tryonia cheatumi* (Pilsbry) from outflow of Phantom Lake Spring. N = 30, the same specimens for which shell measurements are given.

Width of base	
Mean	0.308
Range	0.23–0.43
S. D.	0.045
S. E.	0.008
Width of head	
Mean	0.244
Range	0.12–0.31
S. D.	0.036
S. E.	0.007
Width of distal papilla	
Mean	0.122
Range	0.09–0.15
S. D.	0.013
S. E.	0.002
Length of distal papilla	
Mean	0.220
Range	0.18–0.26
S. D.	0.026
S. E.	0.005
Width/length of distal papilla	
Mean	0.561
Range	0.44–0.80
S. D.	0.086
S. E.	0.016
Width of proximal papilla	
Mean	0.127
Range	0.11–0.15
S. D.	0.014
S. E.	0.003
Length of proximal papilla	
Mean	0.211
Range	0.13–0.26
S. D.	0.027
S. E.	0.005
Width/length of proximal papilla	
Mean	0.605
Range	0.53–0.79
S. D.	0.063
S. E.	0.012

Observations on living animals—The surface of the head-foot mass is dusted with melanin and varies from pale to grayish brown. The thin shell is translucent except where coated by algae or rendered opaque by wear, and some internal structures thus can be seen. Overall tone of the body within the shell is brown in the posterior whorls, which contain the midgut gland, and grayish brown more anteriorly. The stomach is conspicuous by its darker color, and series of pale hyaline granules may outline the course of the intestine.

When the animal is crawling, visible in dorsal view are the anterior part of the rostrum, the tentacles to just behind the eyes, and sometimes one or both anterior corners of the foot. In more heavily pigmented specimens only the outline of the buccal mass can be seen; usually the buccal mass and salivary glands are readily discernible. The rostrum is the most heavily pigmented part of the body; in contrast, the lip pads are pale.

The tentacles are borne diverging at an angle of about 90°, usually curve slightly to the rear, and are continuously flexed in motion. They are dusted lightly with melanin and are paler than the rostrum. The melanin may be uniform dorsolaterad, or with a lengthwise dorsal light band. A ciliated tract runs along the ventral surface of each tentacle. Other ciliation is asymmetrical. The left tentacle bears pos terolateral tufts of cilia on low swellings on the posterior three-fourths.

Pale-yellow granules are scattered abundantly on the rostrum, in the core of the tentacles, and rarely on the dorsal surface of the foot below the rostrum. The densest concentration is mediad and just anteriorly to the eye; posterior "eyebrows" are lacking. Pale-yellow granules are densely concentrated also in the posterior part of the penis; since they disappear in preserved specimens, they are not shown by the illustrations (Fig. 19d–e).

Localities and material examined—The species is abundant in the outflows of Phantom Lake Spring and San Solomon Spring, both tributary to Toyah Creek and thence to the Pecos River. For data on history, spring flow, and geology see White et al. (1941) and Brune (1981). All localities are on U.S. Geological Survey Toyahvale quadrangle (1972), 1:24,000. Collections were made several times from 1965 to 1984.

Outflow of Phantom Lake Spring is led through a cement-lined irrigation canal with lateral ditches (hereafter termed "laterals") at intervals. Phantom Lake no longer exists; it was a spring-fed pond close to the source that has been eliminated by improvement of the outflow channel. Cheaturn (1935, pl. 5, fig. 4) published a photograph of the outflow stream before this improvement. The outflow is in Jeff Davis County, Texas, for about 0.4 mi, and then crosses the Reeves County line.

From Phantom Lake Spring to the first irrigation weir, about 300 ft, the canal is about 8 ft wide and has vertical cement walls and gravelly bottom with mud overlay. At gates on either side of the weir are muddy embayments with a growth of *Scirpus*. Here and in the canal above, *Tryonia cheatumi* and *Cochliopa* were abundant.

At the first lateral (leading north), about 0.25 mi below Phantom Lake Spring, collections were made in the main canal as well as in the lateral. *Tryonia brunei* was found in the lateral only, associated with *T. cheatumi* and *Cochliopa;* only the latter two were in the main canal. Habitat of the two sample sites differed in that the main canal was about 6 ft wide with sloping cement walls and a little mud on the bottom; vegetation consisted of filamentous green algae. The lateral was about 2 ft wide, water up to 6 in. deep, and with a thick marginal growth of *Scirpus*. Snails were sieved from the substratum, a thin layer of mud over firm earth.

At the second lateral (leading north), at the Kingston ranch house and about 0.4 mi below Phantom Lake Spring, collections were made also in the main canal and a lateral. Habitats and occurrence of the snails were similar to those at the first lateral. *Tryonia brunei* was in the lateral only; *T. cheatumi* and *Cochliopa texana* were generally distributed.

In the first lateral to the south, about 100 yards south of the Kingston ranch house and just downstream from a corral, a sample was collected from the enriched mud. Here the ditch was about 4 ft wide and several inches deep, with a dense growth of *Myriophyllum*. *Tryonia cheatumi* was enormously abundant in vegetation, but even more so in the mud substratum. The only other mollusc was *Physa mexiCana* .

Downstream from Kingston ranch house, samples of the snails in the main canal and laterals revealed fewer snails and less diversity. *Tryonia brunei* was found to be rare at the nearest sampling station below the ranch, and the other two species gradually dropped out. Distribution of the snails is evidently related in part to habitat diversity. The ditch downstream becomes a cement flume with less flow, bare cement bottom, and its temperature fluctuates increasingly from the source temperature (25°C) at Phantom Lake Spring. The laterals from this downstream portion of the ditch have no perennial flow.

The entire source of San Solomon Spring has been developed as a large swimming pool in Balmorhea State Park.

In 1981 *Thiara tuberculata* was abundant in both the swimming pool and outflow, together with smaller numbers of *Tryonia cheatumi* and *Cochliopa*. Only the latter two species were found in 1965.

Outflow of San Solomon Spring, about 22 x 10^6 gal/day, is led from the swimming pool through several canals for irrigation and maintenance of fish sanctuaries. The canal habitats are like those of Phantom Lake Spring, although none are similar to those of the smaller laterals. *Tryonia cheatumi* and *Cochliopa* were abundant and generally distributed in the canals in 1965-1981, with *Thiara* present also in 1981. *Physa mexicana* was scarce, both in the canals and swimming pool, but less so in the canals.

Habitat—All modern occurrences of *Tryonia cheatumi, T. brunei*, and *Cochliopa texana* are in fully developed waters; no unmodified habitat remains. From the present occurrence of the species it seems that *Tryonia cheatumi* is a species of larger creeks found in a wider range of habitats than its associates at present, and presumably also in the past. Before modification of Phantom Lake Spring, *Cochliopa* was likely found principally on vegetation and firm substratum, and closer to the source area than the other two; *Tryonia cheatumi* on firm substratum and also in soft mud further downstream from the source; and *T. brunei* in mud in slower current and marginal situations.

Species of *Tryonia* occur together only rarely. In the present case, *T. cheatumi* is the only form of the main outflow of Phantom Lake Spring and overlaps the smaller *T. brunei* that is found in lateral ditches. Precisely the same phenomenon is exhibited by the amphipod genus *Gammarus. Gammarus hyalleloides* Cole, 1976, is found in the main Phantom Lake Spring. Cole (1976) commented: "Most remarkable, however, is the presence of another *Gammarus* in the modern canal system fed by Phantom Lake Spring. It is found especially in lateral canals and probably does not occur in the *Chara* beds near the spring orifice; it is much like *G. pecos*."

TRYONIA (PAUPERTRYONIA) ADAMANTINA group

Shell smooth, broadly to narrowly conical, thin or massive. Penial formula L0-1 R0-1. Head of penis not set off from blade; without lateral projections; terminal stylet long. A glandular papilla on both left and right sides is slender, pointed, and tapered conspicuously, with no basal constriction.

Two species, *Tryonia adamantina* n. sp. of Diamond Y Draw in Pecos River drainage in Trans-Pecos Texas, and an undescribed species in southeastern Coahuila.

TRYONIA (PAUPERTRYONIA) ADAMANTINA, new species
Fig. 20

Diagnosis—A narrowly conical species attaining a shell length of 3.6 mm, with deeply incised suture. The penis has a head with a prominent stylet and one large elongate glandular papilla on either side of the blade.

Types—Holotype LACM 2089, a male preserved in alcohol, collected by D. W. Taylor, 26-VI-1968. Paratypes UTEP **10,060.**

Type locality—Diamond Y Spring, Pecos County, Texas.

Etymology—From Latin *adamas, adamantis,* a **diamond.**

Description—Shell (Fig. 20a, Table 45) narrowly conical, with obtuse apex and broadly rounded anterior end. Whorls $4^3/4$-$5^3/4$ in larger females, regularly convex and swollen to weakly shouldered, separated by a deeply incised suture. Aperture ovate, broadly rounded anteriorly and less so posteriorly. Parietal part of peritreme simply adnate to preceding whorl or slightly disjunct; an umbilical opening of variable size present. Profile of aperture almost plane, oblique to axis of coil at about 10°, posterior end in advance of anterior

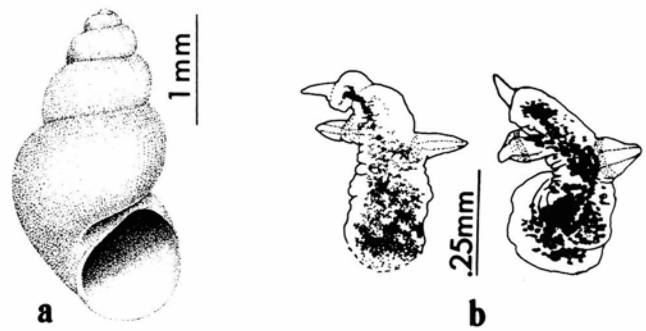

FIGURE 20—*Tryonia adamantina* n.sp.: **a,** Shell (drawn by A. D'Attilio); **b,** penis, dorsal view; specimen on left was dead before fixation and shows less melanin and atypical contraction at base of head.

TABLE 45—Measurements and descriptive statistics of 30 larger female shells of *Tryonia adamantina* n.sp.

Whorls	
Mean	5.27
Range	$4^3/_4$–$5^3/_4$
Length	
Mean	3.29
Range	2.91–3.63
S. D.	0.209
S. E.	0.038
Length of last two whorls	
Mean	2.70
Range	2.36–2.98
S. D.	0.162
S. E.	0.030
Length of peritreme	
Mean	1.16
Range	0.99–1.33
S. D.	0.085
S. E.	0.016
Length of peritreme/length	
Mean	0.355
Range	0.318–0.387
S. D.	0.020
S. E.	0.004
Length of peritreme/length of last two whorls	
Mean	0.431
Range	0.395–0.458
S. D.	0.016
S. E.	0.003
Width	
Mean	1.71
Range	1.49–1.89
S. D.	0.097
S. E.	0.018
Width/length	
Mean	0.522
Range	0.479–0.642
S. D.	0.031
S. E.	0.006
Width/length of last two whorls	
Mean	0.633
Range	0.583–0.744
S. D.	0.027
S. E.	0.005

end. Sculpture of fine, irregular collabral growth lines; fine, spiral, discontinuous incised lines present irregularly. Periostracum tan.

Operculum translucent, pale amber but nearly colorless, paucispiral, plane.

Penis (Fig. 20b) a flattened blade with broader proximal portion. The head is not set off from the blade by a constriction, nor expanded laterad, but bears a relatively large and massive stylet. This stylet is not seated in a depression or retractile into a cup as in other species. On the left distal side is a large, elongate glandular papilla, seated on a short base. On the right side in the middle, behind the left papilla, is another glandular papilla, usually larger than that on the left, seated directly on the blade of the penis. Melanin granules in the head of the penis are continuous with a medial belt that widens proximad so that the basal part of the penis is heavily smudged.

Habitat—Tryonia adamantina is found from Diamond Y Spring downstream for approximately 1 mi, in Diamond Y Draw proper, in the lowest course of tributary Leon Creek, and in local seepages with no surface-water connection to the main stream. Associated species in 1984 were *Physa mexicana* Philippi (generally distributed), *Lymnaea caperata* Say (locally) and *Assiminea pecos*, n.sp. (generally distributed, but at the margin of flowing water). In Diamond Y Spring proper, species formerly associated were *Ferrissia californica* (Rowell), *Laevapex fuscus* (Adams), and *Pisidium casertanum* (Poli).

The characteristic habitat of *Tryonia adamantina* is in mud among sedges and cattails, and in more rapidly moving segments of the creek rather than slow, marshy pools. The mutually exclusive distribution of *T. adamantina* and *T. stocktonensis* is probably due to competitive exclusion rather than different habitat requirements, because the two species occur in such similar situations. In general, throughout the range of *Tryonia* only one species occurs at a given locality.

TRYONIA (PAUPERTRYONIA) ALAMOSAE group

Shell smooth, narrowly or broadly conical, or aciculate. Penial formula L0-1 R0-0. Head of penis not set off from blade; without lateral projection; terminal stylet short. One glandular papilla on distal left side that is conical to broadly rounded, subangular at the tip or broadly convex, with no basal constriction.

Three species, *Tryonia alamosae* n.sp. at the head of Alamosa Creek in Socorro County, New Mexico, *T. Brunei* n.sp. in Phantom Lake Spring, Trans-Pecos Texas, and *T. kosteri* n.sp. in springs of the Roswell area, Chaves County, New Mexico.

TRYONIA (PAUPERTRYONIA) ALAMOSAE, new species
Fig. 21

1984. *Tryonia* **sp.: U.S.** Fish & Wildlife Service, p. 21673; candidate endangered species.
1985. Alamosa spring snail: New Mexico Department of Game & Fish, account MOLL/LI/TR/AA; endangered species. 1986. Alamosa spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A relatively small and broadly conical species with marked sexual dimorphism. Mean length of larger male shells is 1.41 mm, of female shells 2.30 mm. Mean width/ length of male shells is 0.743, of female shells 0.618. The penis bears a single, broadly conical glandular papilla on the distal left side.

Types—Holotype LACM 2188, a male preserved in alcohol, collected by D. W. Taylor, 13-IV-1979. Paratypes UTEP 10,061.

Type locality—Ojo Caliente, 700 ft W, 1,700 ft S, sec. 31, T8S, R7W, unsurveyed, **Socorro** County, New Mexico.

Etymology—Named after Alamosa Creek, as the species is restricted to springs that form the source of its perennial flow.

Description—Shell (Fig. 21a–b, Table 46) conical, with obtuse apex and broadly rounded anterior end. Whorls 3^1/44 in larger males and 4-5^1/4 in larger females, strongly convex and separated by an incised suture. Aperture broadly ovate, broadly rounded anteriorly and narrowly rounded posteriorly. Parietal part of peritreme simply adnate to preceding whorl or slightly disjunct; in any case, a narrow umbilical chink is present. Profile of aperture plane, slightly oblique to axis of coil, posterior end in advance of anterior end. Sculpture of fine, irregular collabral growth lines. Periostracum pale tan.

Penis (Fg. 21d–e, Table 47) a flattened blade with relatively wide proximal portion, smudged basally with melanin. A single broadly conical glandular papilla, usually slightly longer than wide, on the left distal **margin.**

Variation—Size and form of the shell vary as shown in Table 46, indicating also the pronounced sexual dimorphism. The largest male and female shells are illustrated (Figs. 21a–b). Additional shell variation is in the degree to which the latter part of the body whorl is appressed or disjunct from the preceding whorl, and in the cross section of the whorl. Some female shells have a relatively flat lateral outline and shouldered body whorl.

The 30 male specimens whose shells were measured are the source of the measurements of penis in Table 47. All the males measured had a single penial gland on the left distal margin (Figs. 21d–e). Additional 20 specimens from the same subsample were examined; 19 had the usual single gland and one had two in the same place.

Observations on living animals—The surface of the head-foot mass is dusted with melanin and varies from opaque black to gray. The thin shell is translucent and permits observation of some internal structures except where coated by algae or rendered opaque by wear. Overall tone of the body within the shell is dark gray.

When the animal is crawling, visible in dorsal view are the anterior part of the rostrum, the tentacles to just behind the eyes, and sometimes a corner of the foot (Fig. 18c). Deep pigmentation of the rostrum mostly obscures the buccal mass. Lip pads may be dark or pale gray, often paler than the rostrum.

The tentacles are borne diverging at an angle of about 45°, but are continuously flexed in motion. They are lightly dusted with melanin and paler than the rostrum. This melanin may be uniform dorsolaterad, or with a lengthwise dorsal band, or lateral bands. A ciliated tract runs along the ventral surface of each tentacle. Other ciliation is asymmetrical. The left tentacle bears posterolateral tufts of cilia on low swellings on the posterior half. These swellings and the cilia are inconspicuous and cannot be shown at the scale of the illustrations.

Above and in front of the eye are clumped some pale hyaline granules; a few granules are scattered also in more distal parts of the tentacles.

Pigmentation of the penis varies from intense to only a few scattered melanin and hyaline granules; in darker specimens the melanin is scattered through the core of the penis.

Observations were made of series from both Ojo Caliente and springs about 0.5 mi west. The series from Ojo Caliente was somewhat paler in general, but in both populations the penis was equally pale.

Habitat—Ojo Caliente is the second largest thermal spring in New Mexico as listed by Waring (1965). The flow cited (1,200 gal/min) is evidently a composite from several sources in the vicinity. The U.S. Geological Survey Montoya Butte quadrangle (1964), 1:24,000, restricts the name Ojo Caliente to a single source, as used here.

At the type locality *Tryonia alamosae* was abundant in mi-

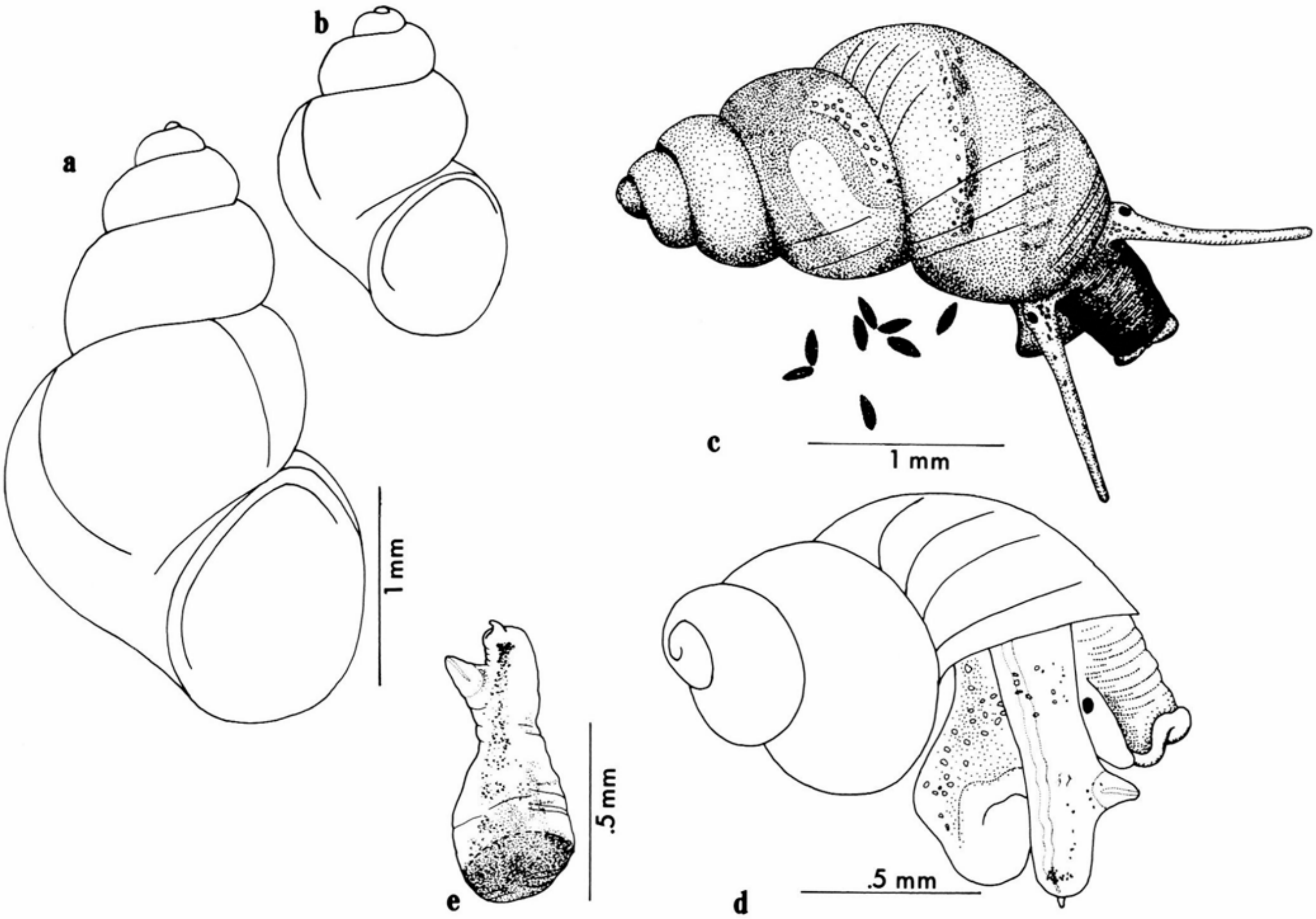

FIGURE 21—*Tryonia alamosae* n.sp.: **a, b,** Shells, *a* largest female and *b* largest male in subsample measured; **c,** living animal; **d,** male anesthetized before fixation, showing maximum extension of penis; **e,** penis, dorsal view.

TABLE 46—Measurements and descriptive statistics of shells of *Tryonia alamosae* n.sp. N = 30 for both sexes.

	Male	Female
Whorls		
Mean	3.52	4.59
Range	3 1/4–4	4–5 1/4
Length		
Mean	1.41	2.30
Range	1.22–1.64	1.89–3.02
S. D.	0.100	0.230
S. E.	0.018	0.042
Length of peritreme		
Mean	0.714	0.982
Range	0.62–0.82	0.87–1.26
S. D.	0.054	0.081
S. E.	0.010	0.015
Length of peritreme/length		
Mean	0.506	0.428
Range	0.44–0.55	0.39–0.47
S. D.	0.024	0.021
S. E.	0.004	0.004
Width		
Mean	1.05	1.42
Range	0.93–1.22	1.24–1.75
S. D.	0.075	0.118
S. E.	0.014	0.021
Width/length		
Mean	0.743	0.618
Range	0.65–0.81	0.56–0.68
S. D.	0.039	0.030
S. E.	0.007	0.005

TABLE 47—Measurements and descriptive statistics of penis of *Tryonia alamosae* n.sp. N = 30, the same specimens for which shell measurements are given (Table 46).

Width of base	
Mean	0.328
Range	0.23–0.46
S. D.	0.068
S. E.	0.012
Width of head	
Mean	0.125
Range	0.09–0.16
S. D.	0.018
S. E.	0.003
Width of papilla	
Mean	0.112
Range	0.08–0.15
S. D.	0.016
S. E.	0.003
Length of papilla	
Mean	0.130
Range	0.07–0.18
S. D.	0.022
S. E.	0.004
Width/length of papilla	
Mean	0.890
Range	0.56–1.50
S. D.	0.198
S. E.	0.036

nor rivulets out of the main channel in the canyon where the springs rise. In such situations there was a mat of watercress and filamentous green algae over water 1–2 in.

deep, flowing over fine gravel and sand among angular rhyolitic cobbles and boulders. The snails were found in slow current on gravel as well as among vegetation. Associated molluscs were *Lymnaea parva* Lea and *Physa mexicana* Philippi. The highest temperature of any of the immediate sources was 27°C.

Nearly 0.5 mi west of Ojo Caliente is a group of thermal springs with another population of *Tryonia alamosae*. The northernmost sources have been improved to increase flow; here *Tryonia* was abundant in the slower current of the source area on rhyolitic pebbles and cobbles with organic film. *Physa mexicana* was likewise abundant, but usually in swifter current. The outflow of the springs forms a brook 2-4 ft wide, in which *Physa* is common but *Tryonia* becomes scarcer and then absent as one leaves the source area and current increases. The highest temperature measured here was 28°C.

The lowest spring source, several hundred feet south of the improved area, is a relatively small spring rising in soft mud among sedges and watercress. Here the only molluscs found were *Lymnaea parva* Lea, *Physa mexicana* Philippi, *Pisidium casertanum* (Poli), and *P. singleyi* Sterki. The habitat at this source seemed to be that in which most species of *Tryonia* are found—fine mud at a spring source that is mildly thermal. The absence of *Tryonia* at this site and its presence on stones at the other two localities lead to the speculation that it is specialized for browsing on organic film.

TRYONIA (PAUPERTRYONIA) BRUNEI, new species
Fig. 22

Diagnosis—A turriform species attaining a shell length of 4 mm. The penis bears a conical glandular papilla on the distal left side. Proximal portion of the penis relatively narrow.

Types—Holotype LACM 2251, a male preserved in alcohol, collected by D. W. Taylor, 5-XI-1981. Paratypes UTEP 10,062.

Type locality—Outflow of Phantom Lake Spring at Joe Kingston ranch, Jeff Davis County, Texas.

Etymology—The name honors Gunnar Brune, in recognition of his distinguished work *Springs of Texas* (Brune, 1981).

Description—Shell (Fig. 22a–b, Table 48) turriform, with blunt apex and broadly rounded anterior end. Whorls up to 61/2 in larger specimens, regularly convex and separated by an incised suture. Aperture ovate, broadly rounded anteriorly and narrowly rounded posteriorly. Parietal part of peritreme simply adnate to preceding whorl, leaving an umbilical chink. Profile of aperture and later growth lines conspicuously sinuous; posteriorly concave, anteriorly convex, posterior end in advance of anterior end. Sculpture of fine, irregular collabral growth lines and weak, irregular spiral striae. Periostracum pale tan.

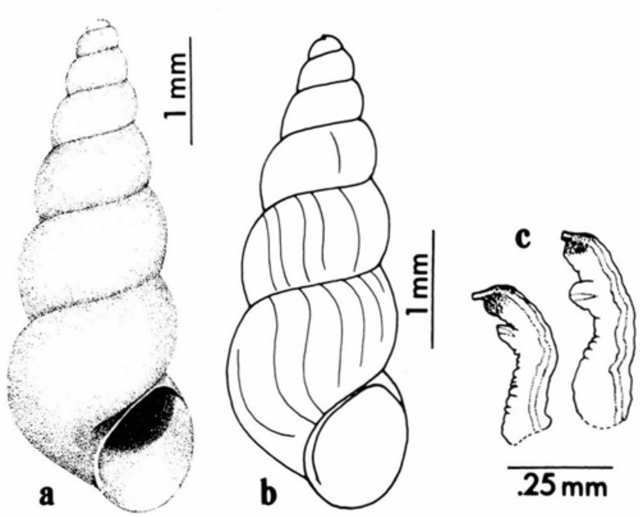

FIGURE 22—*Tryonia brunei* n.sp.: **a, b,** Shells, *a* unsexed (drawn by A. D'Attilio), *b* larger female; **c,** penis, dorsal view.

Penis (Fig. 22c, Table 49) a flattened blade with little or no taper and melanin concentrated in the head. A single conical papilla on the left distal margin, with a relatively small gland.

Variation—The shell varies slightly in proportions (Table 48). The amount of material and quality of preservation did not allow measurement of a series of male shells, but from inspection sexual dimorphism appears to be less evident than in *Tryonia kosteri.* The penis varies principally in size of the glandular papilla, from insignificant to well developed. The shape is generally conical, either wider than long or longer than wide, but is not so variable as in either T. *kosteri* or *T. alamosae.* A single papilla was present in 33 specimens examined.

Observations on living animals—The surface of the head-foot mass is dusted with melanin and is generally pale gray

TABLE 48—Measurements and descriptive statistics of 30 larger female shells of *Tryonia brunei* n.sp.

Whorls	
Mean	6.0
Range	5–6$^1/_2$
Length	
Mean	3.391
Range	2.56–3.97
S. D.	0.376
S. E.	0.069
Length of last two whorls	
Mean	2.456
Range	2.00–2.90
S. D.	0.221
S. E.	0.040
Length of peritreme	
Mean	0.989
Range	0.80–1.17
S. D.	0.083
S. E.	0.015
Length of peritreme/length	
Mean	0.293
Range	0.264–0.349
S. D.	0.020
S. E.	0.004
Length of peritreme/length of last two whorls	
Mean	0.403
Range	0.379–0.439
S. D.	0.015
S. E.	0.003
Width	
Mean	1.353
Range	1.11–1.66
S. D.	0.119
S. E.	0.022
Width/length	
Mean	0.401
Range	0.354–0.458
S. D.	0.024
S. E.	0.004
Width/length of last two whorls	
Mean	0.551
Range	0.511–0.581
S. D.	0.016
S. E.	0.003

TABLE 49—Measurements and descriptive statistics of penis of *Tryonia brunei* n.sp. N = 30.

Width of base	
Mean	0.243
Range	0.14–0.42
S. D.	0.061
S. E.	0.011
Width of head	
Mean	0.168
Range	0.12–0.24
S. D.	0.024
S. E.	0.004
Width of papilla	
Mean	0.114
Range	0.07–0.18
S. D.	0.027
S. E.	0.005
Length of papilla	
Mean	0.106
Range	0.04–0.18
S. D.	0.035
S. E.	0.007
Width/length of papilla	
Mean	1.189
Range	0.70–2.50
S. D.	0.465
S. E.	0.085

and darker gray on the dorsal surface of the rostrum. The thin shell is translucent and thus permits observation of some internal structures except where coated by algae or rendered opaque by wear. Overall tone of the body within the shell is pale to purple brown; the stomach is conspicuously darker than other structures.

When the animal is crawling, visible in dorsal view are the anterior part of the rostrum, the tentacles to just behind the eyes, and anterior corners of the foot. Even in the more heavily pigmented individuals the buccal mass is visible within.

The tentacles are borne diverging at an angle of 45 to 90° and are continuously flexed in motion. They are dusted lightly with melanin; no pattern is evident. A ciliated tract runs along the ventral surface of each tentacle. Other ciliation is asymmetrical. The left tentacle bears posterolateral tufts of cilia on low swellings on the posterior two-thirds.

Pale-yellow granules are scattered through the core of the tentacles, most densely across the surface of the head behind the tentacles, and sparsely on the rostrum. Patches concentrated behind the eyes as "eyebrows" are not discrete.

The penis has a faint dusting of melanin on the head and pale-yellow granules within. These are concentrated in the base, becoming sparser distad and rare beyond mid-length. They disappear after fixation in alcohol and thus are not shown (Fig. 22c).

Comparisons—Most similar to T. *kosteri,* see under that species. The Pleistocene *T. pecosensis* (Leonard & Ho) is similar in turriform shape, but differs in being even more elongate, attaining a larger size, and having plane aperture and growth lines in contrast to these markedly sinuous features in T. *brunei.*

Localities, material examined, habitat—See under *Tryonia cheatumi.*

TRYONIA (PAUPERTRYONIA) KOSTERI, new species
Fig. 23

1906. *Paludestrina seemanni* Frauenfeld [misidentified]: Pilsbry & Ferriss, p. 170; South Spring Creek near Roswell, Pleistocene; J. D. Tinsley, collector, 1899.

1917. *Paludestrina seemanni* Frauenfeld [misidentified]: Henderson, p. 135; North Spring River about 2 mi E of Roswell, Pleistocene; M. M. Ellis, collector, 1916.

1985. Koster's spring snail: New Mexico Department of Game & Fish, account MOLL/LI/TR/BB; endangered species.

1986. Koster's spring snail: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A narrowly conical species of *Tryonia* attaining a shell length of 4.5 mm. The penis bears a glandular papilla on the distal left side that is markedly variable in shape, but generally nearly twice as wide as long. Proximal portion of the penis relatively narrow.

Types—Holotype LACM 2252, a male preserved in alcohol; collected by D. W. Taylor, 29-X-1981. Paratypes UTEP **10,064.**

Type locality—Sago Spring, 900 ft W, 2,400 ft S, sec. 5, T1OS, R25E, Chaves County, New Mexico.

Etymology—Named for William J. Koster, formerly of the University of New Mexico, commemorating his pioneering efforts in zoology of the state.

Description—Shell (Fig. 23a-b, Table 50) narrowly conical, with blunt apex and broadly rounded anterior end. Whorls up to 5³/4 in larger specimens of both sexes, regularly convex and separated by an incised suture. Aperture broadly

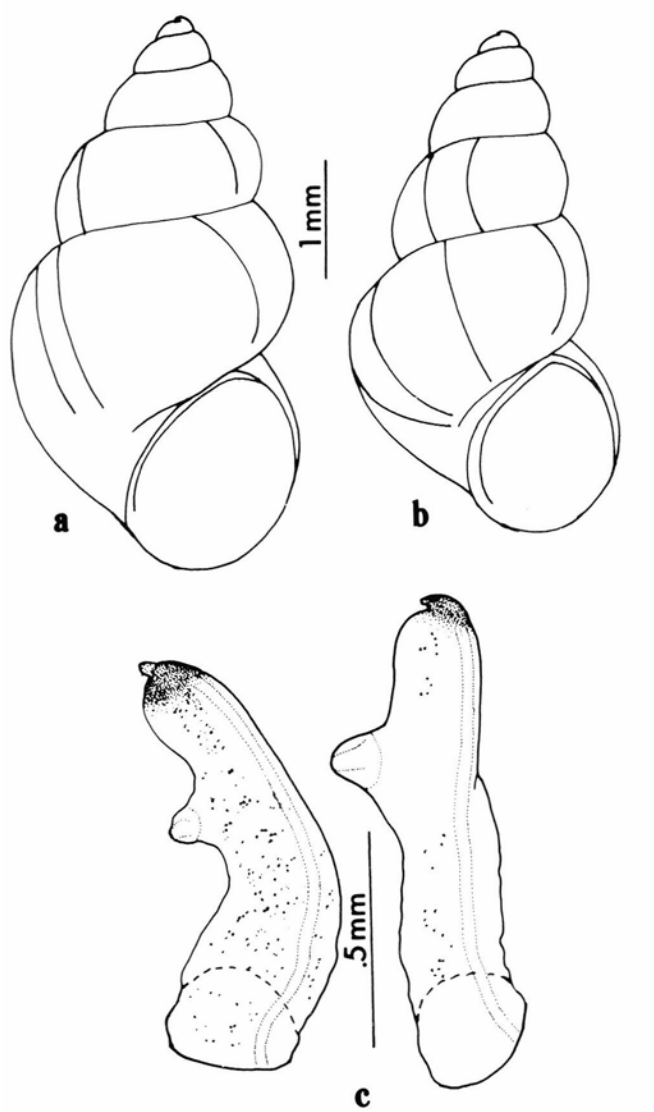

FIGURE 23—*Tryonia kosteri* n.sp.: **a, b,** Shells from type locality, *a* female, *b* male; **c,** penis, dorsal view, two specimens from Roswell Country Club.

TABLE 50—Measurements and descriptive statistics of shells of *Tryonia kosteri* n.sp. from type locality. N = 30 for both sexes.

	Male	Female
Whorls		
Mean	4.9	5.3
Range	4¼–5¾	4¾–5¾
Length		
Mean	3.16	4.05
Range	2.64–4.16	3.32–4.56
S. D.	0.337	0.285
S. E.	0.062	0.052
Length of last two whorls		
Mean	2.67	3.41
Range	2.28–3.32	2.92–3.80
S. D.	0.235	0.195
S. E.	0.043	0.036
Length of peritreme		
Mean	1.24	1.61
Range	1.04–1.48	1.44–1.72
S. D.	0.083	0.072
S. E.	0.015	0.013
Length of peritreme/length		
Mean	0.395	0.398
Range	0.35–0.44	0.35–0.44
S. D.	0.024	0.022
S. E.	0.004	0.004
Length of peritreme/length of last two whorls		
Mean	0.465	0.473
Range	0.43–0.51	0.44–0.51
S. D.	0.020	0.019
S. E.	0.004	0.004
Width		
Mean	1.78	2.35
Range	1.60–2.24	2.16–2.64
S. D.	0.133	0.126
S. E.	0.025	0.023
Width/length		
Mean	0.565	0.582
Range	0.51–0.64	0.53–0.66
S. D.	0.032	0.035
S. E.	0.006	0.006
Width/length of last two whorls		
Mean	0.667	0.690
Range	0.62–0.72	0.63–0.76
S. D.	0.028	0.031
S. E.	0.005	0.006

ovate, broadly rounded anteriorly and narrowly rounded posteriorly. Parietal part of peritreme simply adnate to preceding whorl, leaving an umbilical chink. Profile of aperture plane, slightly oblique to axis of coil, posterior end in advance of anterior end. Sculpture of fine, irregular collabral growth lines. Periostracum pale tan.

Penis (Fig. 23c, Table 51) a flattened blade with little or no taper, opaque at the tip but generally with weak pigmentation of scattered melanin granules. A single papilla on the left distal margin is markedly variable in shape, averages much wider than long, and has a relatively small gland.

Variation—Size and form of the shell varies as shown in Table 50, indicating also the extent of sexual dimorphism. The male and female shells figured are representative of larger, but not the largest, specimens. Shell proportions are the only evident variation; the common disjunction of the body whorl and shouldering seen in *Tryonia alamosae* have not been observed.

The pale-tan pigmentation of the penis (as observed in preserved specimens) is intensified at the tip. Proximad, there is only a faint suggestion of the usual concentration

TABLE 51—Measurements and descriptive statistics of penis of *Tryonia kosteri* n.sp. from Roswell Country Club. N = 30.

Width of base	
Mean	0.203
Range	0.12–0.28
S. D.	0.041
S. E.	0.007
Width of head	
Mean	0.138
Range	0.11–0.18
S. D.	0.016
S. E.	0.003
Width of papilla	
Mean	0.104
Range	0.05–0.18
S. D.	0.036
S. E.	0.007
Length of papilla	
Mean	0.065
Range	0.04–0.12
S. D.	0.021
S. E.	0.004
Width/length of papilla	
Mean	1.77
Range	0.73–4.0
S. D.	0.873
S. E.	0.159

of melanin granules characteristic of *Tryonia* and related genera. Intensity of melanin flecking varies, but does not show a concentration at the base of the penis as in *T. alamosae.* All 30 specimens examined from Sago Spring (type locality) showed the same number and location of glandular papillae: one on the distal left margin. Of 50 specimens from Roswell Country Club, 49 were as usual and one with only a slight transverse enlargement of the penis at the site of the papilla and no gland.

Comparison—Tryonia kosteri is most like *T. brunei.* The penis in both is small, with scarcely any taper, and melanin is largely restricted to the head. In *T. kosteri* the penial papilla is more variable in form than in *T. brunei* and averages wider than long. The shell of *T. kosteri* is not only larger, but also proportionately wider.

Observations on living animals—Only one series, from Lost River, was studied in detail. Overall pigmentation is varied, from a general coating of melanin that renders most of the body opaque to a weak dusting. Outlines of the larger organs can be seen through the translucent shell of weakly pigmented animals, but in heavily pigmented individuals all internal details are obscured and overall tone is dark gray.

When the animal is crawling, visible in dorsal view are the anterior part of the rostrum, the tentacles to just behind the eyes, and anterior corners and hind end of the foot. In pale animals the head-foot mass shows no melanin and the pink buccal mass is visible within the rostrum. At the other extreme, in heavily pigmented individuals, the rostrum is dark gray and the buccal mass barely discernible. Melanin coating of the tentacles varies from a faint dusting to none. In individuals with a melanin dusting there is a slightly darker smudge on the dorsal surface of the tip of each tentacle.

The tentacles are borne diverging at an angle of about 90° and are continuously flexed in motion. A ciliated tract runs along the ventral surface of each tentacle; the left tentacle bears posterolateral tufts of cilia on low swellings on the posterior two-thirds.

Sugary-white granules are scattered through the core of the tentacles, across the surface of the head behind the tentacles (most densely), and on the rostrum. Pattern of granules on the rostrum is roughly symmetrical with an irregular strip or series of patches on either side of the midline. Rarely the rostrum is nearly without granules.

The penis has a concentration of melanin in the head, and melanin may occur sparsely in the shaft as well. White granules are concentrated in the proximal one-half to two-thirds of the penis. These may be mixed with melanin to give a salt-and-pepper appearance.

Localities and material examined—All known localities of *Tryonia kosteri* are near Roswell, Chaves County, New Mexico, on U.S. Geological Survey Bitter Lake quadrangle (1962), 1:24,000. The westernmost occurrence is a spring northeast of the clubhouse of Roswell Country Club, 600 ft W, 850 ft N, sec. 22, T1OS, R24E, collected at various times from 1968 to 1981. Other localities are all within Bitter Lake National Wildlife Refuge. Lost River contains an enormous population throughout its entire length, from the source on the township line between T9S, R25E and T1OS, R25E, to the mouth of the river at Bitter Lake—a stream length of approximately one mile. Outflow of Sago Spring (the type locality), also tributary to Bitter Lake, supports another enormous population. Southeast of Bitter Lake, in NE1/4 sec. 9, T1OS, R25E, a creek along the west side of Refuge unit 3 supports *Tryonia* through a distance of about 0.25 mi, but not in such numbers as in the tributary to Bitter Lake. Seepage into a drainage ditch along the west side of Refuge unit 6, in the NEI/4 sec. 16, T1OS, R25E, supports a fifth population, dense but local. Localities within the Refuge were collected in May and October 1981 and November 1984.

None of the series from within the Refuge proved amenable to the usual anesthetization with menthol. The most satisfactory material was obtained from the Country Club, hence measurements of penial features (Table 48) and the penises illustrated (Fig. 23c) are from that locality. The future of the population is doubtful and hence the type locality chosen (Sago Spring) is one in Bitter Lake National Wildlife Refuge where protection is maintained. As is so commonly the case in dense snail populations, trematode infestation and incidence of parasitic castration are high at the latter locality.

Pleistocene fossils referred to *Tryonia kosteri* all are from Chaves County, New Mexico, in the vicinity of the modern populations. Their catalogue numbers and localities are as follows:

SSB 5436, UMMZ 119292: Berrendo River, 4 mi NE of Roswell; from B. Walker collection.

UCM 9030: North Spring River about 2.5 mi E of Roswell; M. M. Ellis et al., 1916.

ANSP 119233: Near new Pecos bridge near Roswell, west side of river, from white marl; T. D. A. Cockerell, 1905.

ANSP 76965: South Spring River near Roswell; J. D. Tinsley, 1899.

Habitat—At Roswell Country Club the spring is fresh, its flow being maintained largely by agricultural irrigation and watering of the nearby golf course. The remaining free-flowing spring-brook amounts to only about 20 ft between an improved source and the slack water toward the inflow into the Country Club lake. Little mud bottom remains in the center of the flow, but *Tryonia* and associated *Fontelicella roswellensis* were found in numbers on pebbles and cement blocks.

Within Bitter Lake National Wildlife Refuge the waters are gypsum-rich, hence the name. In Lost River, for a length of about 1 mi, *Tryonia kosteri* is nearly the only aquatic mollusc. The snails are found as is usual with *Tryonia,* in the upper layers of fine substratum or, less often, climbing on marginal vegetation or other firm surfaces. Throughout its length below the source pools, Lost River is a sinuous creek **2-6 ft wide,** generally less than 1 ft deep, with fine-mud bottom.

Other localities within the Refuge are similar to Lost River in having a soft substratum within which *Tryonia* is abundant. At two localities *Fontelicella roswellensis* was associated, but without the separation of habitat that is usually observed elsewhere.

Family SPHAERIIDAE

PISIDIUM (CYCLOCALYX) SANGUINICHRISTI, new species

Fig. 24

1985. Sangre de Cristo pea-clam: New Mexico Department of Game & Fish, account MOLL/SP/PI/AA; endangered species.
1986. Sangre de Cristo pea-clam: U.S. Fish & Wildlife Service, p. 29671; candidate endangered species.

Diagnosis—A species similar in size, low muscle scars, and hinge to *Pisidium milium,* but distinct by its silky (not glossy) surface, sculpture of broad, smooth riblets that set off the smooth beaks, short and wider ligament pit, and the range of form that includes specimens similar to *P. milium* but also larger, more nearly circular specimens.

Holotype—LACM 2258, a pair of dry valves, collected by D. W. Taylor, 21-V-1981.

Type locality—Middle Fork Lake, a cirque lake at 10,845 ft (3,306 m) elevation in the Sangre de Cristo Mountains, Taos County, New Mexico. The lake forms the principal source of the Middle Fork of Red River, tributary to the Rio Grande.

Etymology—The name *sanguinichristi* is latinized Sangre de Cristo.

Description of holotype—Shell small (length 2.4 mm, height 2.0 mm, diameter 1.6 mm), solid, yellowish gray, swollen (index of convexity, 100D/2H = 41), rounded trapezoidal in outline; index of height, 100H/L = 83. Beaks broad, smooth, low, posterior to mid-length. Dorsal margin short, passing abruptly into the truncate posterior margin and gradually into the anterior margin. Ventral margin broadly curved, passing gradually into the posterior margin, set off from the nearly straight anterior margin by a narrowly curved anterior end. Greatest shell length below the horizontal midline. Sculpture consists of smooth riblets. Initially there are four broad bands 0.06-0.07 mm wide, separated by incised lines. Over the disc the riblets are narrower, 0.02-0.03 mm wide, and are separated by subequal interspaces. Hinge plate narrow, arcuate, about 70% of shell length. All and PII strong and high; cusp of PII distal, of All central. AI and PI strong but lower, both with central cusps. PIII low, straight, with central cusp; All barely developed. PI and Pill barely converge. C2 and C4 short, lamellar, of equal height; C3 arcuate, slightly wider posteriorly. Cardinal teeth closer to anterior lateral teeth than to posterior lateral teeth. Ligament pit short (0.4 mm long), more than half as wide as hinge plate. Muscle scars narrowly elongate, both below the horizontal midline.

Variation—The shape of the shell varies according to the convexity of the valves and the prominence of the beaks. Many shells are similar in form to the usual *Pisidium* one of the least variable species of the genus, as noted by Ellis (1962). But the range of variation in *P. sanguinichristi* includes also more nearly circular specimens without prominent beaks and without the inflated quadrangular form so characteristic of *P. milium.* These specimens, so unlike *P. milium,* intergrade with the more usual *P. sanguinichristi.* In addition to the sculpture, the surface may bear irregular grooves that Herrington (1962) termed "rest periods" in *P. milium.*

In addition to the holotype, ten large, complete specimens were measured. Means of the following measure-

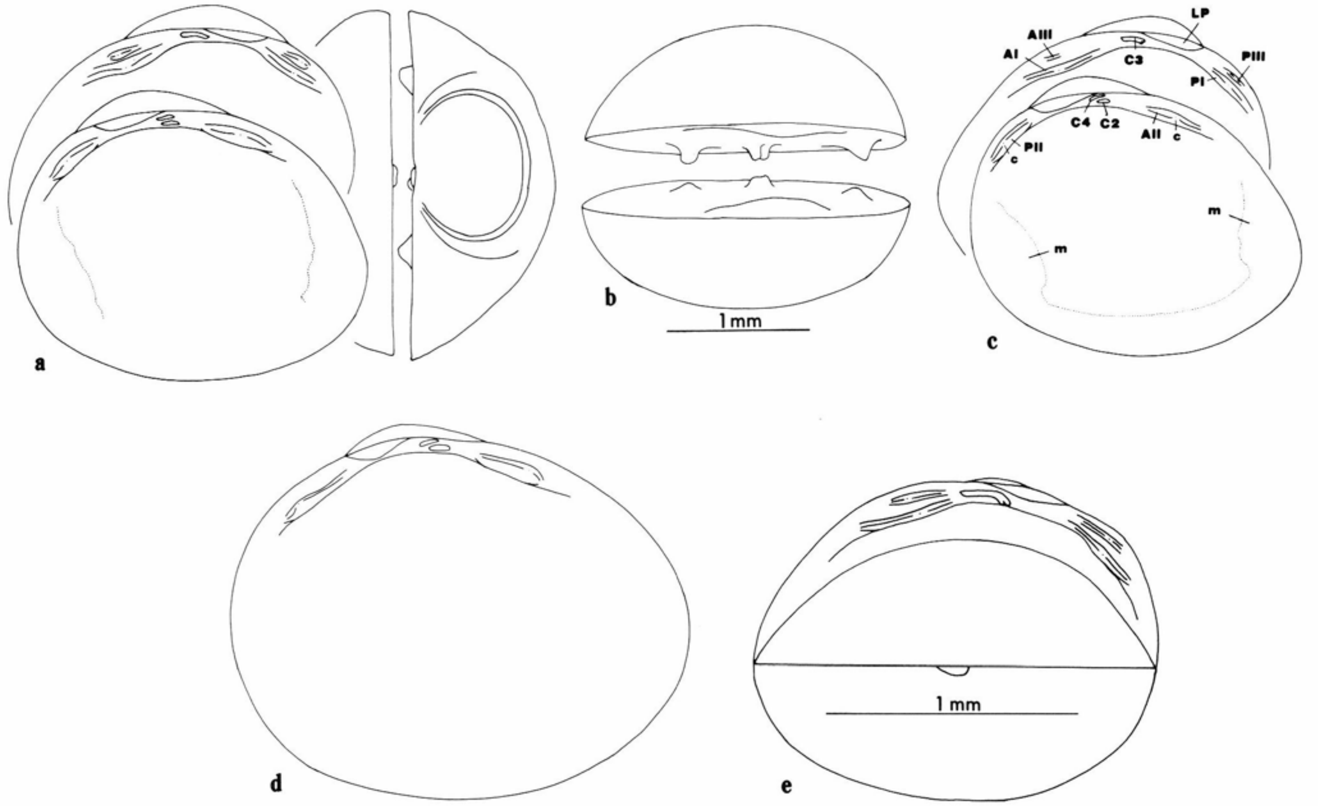

FIGURE 24—*Pisidium sanguinichristi* n.sp.: **a,** Interior of valves and dorsal view showing embryonic shell outlined by a broad fold; **b, c,** holotype; **d,** largest specimen; **e,** juvenile, with dorsal view inset into lateral view. Abbreviations: AI, AII, AIII, anterior lateral teeth; C2, C3, C4, cardinal teeth; LP, ligament pit; PI, PII, PIII, posterior lateral teeth; c, cusp of tooth; m, muscle scar.

ments are of 11 specimens. The largest specimen is a left valve that is not included in the summary of mean and range for the 11 complete specimens.

	Length	Height	Diameter	100D/2H	100H/L
Mean	2.43 mm	1.98 mm	1.84 mm	46.6	81.1
Range	2.3-2.6	1.8-2.1	1.6-2.3	40-54	78-86
Largest	3.2	2.6	2.3	44	83

Variation in hinge characters in these 10 specimens was as follows: cusp of PII central in one, distal in nine; cusp of All central in all 10. AIII usually developed as well as Pill, with a central cusp. C2 and C4 lamellar, not quite parallel. C3 lamellar, slightly wider posteriorly, weakly arcuate. Ligament pit 60-80% of width of hinge plate. Posterior laterals were transposed in one specimen. In other respects the features of the hinge agreed with those of the holotype.

Habitat—Middle Fork Lake is a glacial cirque lake about 1,100 ft long. It contains no submergent aquatic vegetation, and emergent grasses are present only in shallows of rare sheltered embayments. Molluscs were collected by sieving mud among the grasses at the edge of the lake and in the outlet stream where mud and dead wood accumulated among emergent grasses. In both situations *Pisidium sanguinichristi* and *P. casertanum* (Poli) were common and *Gyraulus parvus* (Say) was rare. *Pisidium contortum* Prime was found only in the lake, and then rarely.

Clark & Read (1972) mapped the geology of the region including Middle Fork Lake. They showed the moraine damming the lake as of undifferentiated Wisconsinan age, Qw.

Discussion—Discovery of this new species is certainly remarkable, as most species of the genus are widespread and there are no other localized aquatic molluscs known from the Sangre de Cristo Mountains. The species was found in quantity, and *Pisidium milium* is known from the same mountains in its characteristic form. Hence, there can be no doubt that the species is indeed distinct. It is hardly likely that this new form is restricted to Middle Fork Lake. Yet, nine lakes in the Sangre de Cristo Mountains have been sampled for *Pisidium* and only in Middle Fork Lake has the present species been found. The Sangre de Cristo Mountains are one of the great ranges of the southern Rocky Mountains, hence further studies may show the species of *Pisidium* to be more diverse than presently known.

The nearest area in the Rocky Mountains where glacial lakes have been samples for *Pisidium* is west of Boulder, Colorado, where Junius Henderson collected intensively in the early part of this century. His materials were studied by Sterki (Henderson, 1924; Sterki, 1923), who would have readily recognized the present species as new. Thus, while *P. sanguinichristi* may live in the northern Sangre de Cristo range in southern Colorado, it probably does not occur farther north.

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Selected conversion factors*

TO CONVERT	MULTIPLY BY	TO OBTAIN
Length		
inches, in	2.540	centimeters, cm
feet, ft	3.048×10^{-1}	meters, m
yards, yds	9.144×10^{-1}	m
statute miles, mi	1.609	kilometers, km
fathoms	1.829	m
angstroms, Å	1.0×10^{-8}	cm
Å	1.0×10^{-4}	micrometers, μm
Area		
in^2	6.452	cm^2
ft^2	9.29×10^{-2}	m^2
yds^2	8.361×10^{-1}	m^2
mi^2	2.590	km^2
acres	4.047×10^{3}	m^2
acres	4.047×10^{-1}	hectares, ha
Volume (wet and dry)		
in^3	1.639×10^{1}	cm^3
ft^3	2.832×10^{-2}	m^3
yds^3	7.646×10^{-1}	m^3
fluid ounces	2.957×10^{-2}	liters, l *or* L
quarts	9.463×10^{-1}	l
U.S. gallons, gal	3.785	l
U.S. gal	3.785×10^{-3}	m^3
acre-ft	1.234×10^{3}	m^3
barrels (oil), bbl	1.589×10^{-1}	m^3
Weight, mass		
ounces avoirdupois, avdp	2.8349×10^{1}	grams, gr
troy ounces, oz	3.1103×10^{1}	gr
pounds, lb	4.536×10^{-1}	kilograms, kg
long tons	1.016	metric tons, mt
short tons	9.078×10^{-1}	mt
oz mt^{-1}	3.43×10^{1}	parts per million, ppm
Velocity		
ft sec^{-1} (= ft/sec)	3.048×10^{-1}	m sec^{-1} (= m/sec)
mi hr^{-1}	1.6093	km hr^{-1}
mi hr^{-1}	4.470×10^{-1}	m sec^{-1}

TO CONVERT	MULTIPLY BY	TO OBTAIN
Pressure, stress		
lb in^{-2} (= lb/in^2), psi	7.03×10^{-2}	kg cm^{-2} (= kg/cm^2)
lb in^{-2}	6.804×10^{-2}	atmospheres, atm
lb in^{-2}	6.895×10^{3}	newtons (N)/m^2, N m^{-2}
atm	1.0333	kg cm^{-2}
atm	7.6×10^{2}	mm of Hg (at 0° C)
inches of Hg (at 0° C)	3.453×10^{-2}	kg cm^{-2}
bars, b	1.020	kg cm^{-2}
b	1.0×10^{6}	dynes cm^{-2}
b	9.869×10^{-1}	atm
b	1.0×10^{-1}	megapascals, MPa
Density		
lb in^{-3} (= lb/in^3)	2.768×10^{1}	gr cm^{-3} (= gr/cm^3)
Viscosity		
poises	1.0	gr cm^{-1} sec^{-1} *or* dynes cm^{-2}
Discharge		
U.S. gal min^{-1}, gpm	6.308×10^{-2}	l sec^{-1}
gpm	6.308×10^{-5}	m^3 sec^{-1}
ft^3 sec^{-1}	2.832×10^{-2}	m^3 sec^{-1}
Hydraulic conductivity		
U.S. gal day^{-1} ft^{-2}	4.720×10^{-7}	m sec^{-1}
Permeability		
darcies	9.870×10^{-13}	m^2
Transmissivity		
U.S. gal day^{-1} ft^{-1}	1.438×10^{-7}	m^2 sec^{-1}
U.S. gal min^{-1} ft^{-1}	2.072×10^{-1}	l sec^{-1} m^{-1}
Magnetic field intensity		
gausses	1.0×10^{5}	gammas
Energy, heat		
British thermal units, BTU	2.52×10^{-1}	calories, cal
BTU	1.0758×10^{2}	kilogram-meters, kgm
BTU lb^{-1}	5.56×10^{-1}	cal kg^{-1}
Temperature		
°C + 273	1.0	°K (Kelvin)
°C + 17.78	1.8	°F (Fahrenheit)
°F − 32	5/9	°C (Celsius)

**Divide by* the factor number to reverse conversions.
Exponents: for example 4.047×10^{3} (see acres) = 4,047; 9.29×10^{-2} (see ft^2) = 0.0929.

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