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PLIOCENE MOLLUSCS AND FISHES FROM NORTHEASTERN CALIFORNIA AND NORTHWESTERN NEVADA

By

D. W. Taylor[1] and G. R. Smith[2]

Abstract.—Pliocene assemblages of freshwater molluscs and fishes are described from Honey Lake, Lassen Co., California, and Mopung Hills, Churchill Co., Nevada. Seven species of molluscs and five species of fishes from Honey Lake show evidence of the former Snake River that flowed from southern Idaho across Oregon into northeastern California. The fishes show clear affinities with those of the Pliocene Glenns Ferry Formation, Idaho. The molluscs are not so similar, but do include a number of species with discontinuous distribution in lakes and large streams from southern Idaho to northeastern California.

Six molluscs and four fishes from Mopung Hills represent the fauna of a large lake. All but one of the molluscs are extinct and lack close relatives in the immediate region. By contrast, the fishes are ancestral to those of the Lahontan Basin. We infer the molluscs were specialized for living in a lake and became extinct through environmental changes, whereas the fishes survived in tributary streams.

INTRODUCTION

The fossil assemblages described herein provide new evidence about the evolution of drainage in the northwestern Great Basin. Pliocene molluscs and fishes from Honey Lake, Lassen County, California, seem to come from a former lake that was connected with the Snake River, which was at that time flowing from southern Idaho through northeastern California.

Fossil molluscs and fishes from the Mopung Hills, Churchill County, Nevada, come from a large lake that already had a long independent history. The molluscan fauna is sharply distinct from other Pliocene assemblages, but the fishes seem ancestral to the modern fauna of the Lahontan Basin.

Faunal Lists

Honey Lake

Molluscs: *Valvata utahensis* Call
Fontelicella melina Taylor, n. sp.

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Gyraulus parvus (Say)
Helisoma newberryi (Lea)
Vorticifex lasseni Taylor, n. sp.
Pisidium compressum Prime
Pisidium ultramontanum Prime

Fishes: *Rhabdofario* cf. *R. lacustris* Cope
Gila (*Gila*) sp.
Catostomus sp.
Chasmistes cf. *C. cujus* Cope

Mopung Hills

Molluscs: *Sphaerium nevadense* Taylor, n. sp.
Pisidium compressum Prime
Valvata nevadensis Taylor, n. sp.
Lutrilimnea polyskelidis Taylor, n. gen. et sp.
Menetus carinifex Taylor, n. sp.
Physa humboldtiana Taylor, n. sp.

Fishes: *Salmo* sp.
Gila (*Siphateles*) sp.
Catostomus cf. *C. tahoensis* Gill and Jordan
Cottus cf. *C. beldingi* Eigenmann and Eigenmann

FOSSILS FROM HONEY LAKE, LASSEN COUNTY, CALIFORNIA

Location and Previous Work

Fossils were collected from two localities in the SE1/4 NW1/4 sec. 27, and the SE 1/4 NW1/4 NW1/4 sec. 34, T. 27 N., R. 15 E., by Gerald Smith and a University of Michigan field party and by D. W. Taylor, in June, 1979. Our visit was stimulated by an earlier collection (now California Academy of Sciences locality 36969) made by C. W. Chesterman, G. Dallas Hanna and Margaret M. Hanna in 1960. Some of the fundamental geological data are lacking: nearly all of the specimens seem to have been reworked from underlying sediments. Hence we are careful in discriminating collecting site, topographic position and details of preservation.

Collection A. Fossils from the upper locality, A, were found weathering from a light tan silt bed about 3 ft. thick at ca. 3995 ft. elevation, along an outcrop about 300 yards N-S beginning about 100 ft. N. of the quarter-section fence, along the east side of a narrow ridge. The silt is overlain by about 5 ft. of coarse sand and fine gravel with a few scattered algal limestone heads that evidently date from a high level of Lake Lahontan. Some of the fossils might have come from the overlying sand, but most are derived from the silt as judged by abundance on the outcrop.

Collection B. Fossils were found in abundance on the shore of historical Honey Lake (now dry), at about 3980 ft. elevation, on the west side of the narrow ridge opposite collection "A", but extending several hundred meters further to the south, along the west beach of "The Island." All were winnowed by the former lake.

Collection C. Fossils were found in silts at about 4000 ft. elevation at the southwest corner of "The Island." Associated ribs, vertebrae and skull bones were found in place in the original matrix of burial, evidently indicating the general stratigraphic origin of the specimens collected at A and B.

The west-facing cliffs between collections B and C are colorfully-banded, highly-deformed sands and silts that are vertical in places. More resistant beds can be followed along strike westward across the valley floor. The Honey Lake beach lies directly on these beds and is apparently excavating and winnowing the coarse fish fossils from them.

Preservation and Source of Specimens

Two assemblages of molluscs can be recognized from differences of preservation. Three species are thought to be from the latest Pleistocene Lake Lahontan, whereas most are derived from a deformed and faulted Pliocene deposit. The lower collection, B, differs from the higher collection of molluscs, A, by lacking some small species, by including more large specimens, and by having larger specimens of the larger species. The differences can all be accounted for by winnowing at the edge of former Honey Lake. Some details of preservation are mentioned in "Accounts of Species," below. Here we are concerned principally with source of the specimens.

Mineralized, black, fish fragments are fewer and smaller at locality A, but larger and more abundant at B. A large fish and smaller fragments were found at C.

Most of the fossil shells are mineralized and worn, many white but also many blue-gray, pale tan, pale pink, or limonite-stained. A few specimens (*Helisoma newberryi, Valvata utahensis*) have lithified sandstone matrix within the aperture and also in the umbilicus. These specimens seem clearly to have been derived from an older deposit. The strongest evidence of derivation is a specimen of *Valvata utahensis* (Pl. 1, Fig. 2) that has lithified matrix within and has been compressed. This deformed specimen evidently comes from a pre-Lahontan source.

Unmineralized and younger-seeming specimens account for two species, *Planorbella* and *Vorticifex effusus*. Both are known otherwise from Lake Lahontan. An unmineralized cleithrum of a channel catfish, *Ictalurus punctatus* (introduced in Honey L.), has a soft porous texture and off-white color which contrast sharply with the hard, black, mineralized texture and color of fossils with which it was found.

The deformed and faulted thin-bedded diatomite and fine clastic sediments exposed in cliffs (in the NW1/4 sec. 34 and SW1/4 sec. 27, T. 27 N., R. 15 E.) are mapped as Tl, undifferentiated Tertiary lake deposits, on the Geologic Map of California, 1:250,000 Westwood sheet (1960). No molluscs were found in place in these fine-grained cliff-forming sediments. Their probable source is a coarse-grained unit, on the basis of the lithified sandstone matrix of a few shells, on the single deformed specimen, and on the distribution of the fossils. All molluscs are from about 100 to 1000 ft. north of the fine-grained cliff-forming sediments; none are from immediately adjacent to the cliff.

Age

Eight species of molluscs are interpreted as coming from a pre-Lahontan deformed bed. Only two are extinct, and most of the rest live in the Honey Lake drainage basin. Except for the extinct species, all are found in the Snake River valley of southern Idaho, where abundant molluscs are known from the Pliocene Glenns Ferry Formation, from the early Pleistocene Bruneau Formation, and from many younger deposits. By comparison with the sequence in that area the Honey Lake fossils would appear to be Pleistocene rather than Pliocene. This correlation is not precise, however, as there is a substantial hiatus between the Glenns Ferry and Bruneau formations, and as there may also have been regional differences in fauna. Furthermore, the Bruneau Formation has yielded no extinct species of molluscs.

Five species of fishes are represented in the collections, one species of trout (*Rhabdofario*), one species of minnow (*Gila*), and two species of suckers. The suckers, the *Gila*, and the trout show similarities to species in the Pliocene Glenns Ferry Formation of Idaho. The species of *Gila* is more similar to Pliocene members of the genus than it is to the Recent species of the Lahontan Basin, which is in the subgenus *Siphateles*. A Pliocene age for the Honey Lake fossils therefore seems likely.

Former Drainage and Habitat

Most of the Honey Lake molluscs are restricted to perennial waters, and all could be found in a lake, or in a river or creek not subject to flood scour. One of the fishes, *Chasmistes*, is rarely found outside of lakes except during spawning runs (Miller and Smith, 1981). Klamath Lake, Oregon, and Eagle Lake, California, both have modern faunas including a number of the species of molluscs and fishes found as fossils at Honey Lake. A former perennial lake, not necessarily more than a few tens of feet deep, would provide a suitable habitat for the molluscs. The fish evidence suggests a lake larger than Eagle Lake.

Three species of molluscs and one of the fish genera found at Honey Lake are extant, but occur only in markedly disjunct populations. Their living and fossil occurrences are within or adjacent to the northern and western margins of the Great Basin, and together they provide strong evidence for interconnections of rivers and lakes (compare maps of distribution of *Valvata utahensis, Helisoma newberryi, Pisidium ultramontanum*, and *Chasmistes*, Figs. 1–4). The ancestral Honey Lake, now devoid of molluscs and *Chasmistes*, was formerly one of the few places where all four taxa were found.

The most informative molluscan species as to drainage connections is *Fontelicella melina* n. sp. It belongs to the subgenus *Natricola* ("Snake River dwellers"), characteristic of the Snake River and its present and former tributaries from western Wyoming to Oregon (Fig. 5). The nearest occurrence is in the basin of Abert Lake, Oregon, and a former continuity of habitat between the two areas is implied. *Catostomus* sp. is most similar to *Catostomus cristatus* of the Glenns Ferry Formation; the trout is intermediate between *Salmo clarki henshawi* of Pyramid Lake, and *Rhabdofario lacustris* of the Glenns Ferry Formation.

The mark of the Snake River on the Honey Lake fauna is thus strong. Four out of eight species of molluscs, and all of the fishes, have disjunct distributions indicating former drainage connections from southern Idaho across southern Oregon to northeastern California (Figs. 1–5). But though the biogeographical ties are strongly indicated, the chronology is imprecise. The Honey Lake fossils may date from a time after the Snake River ceased to flow independently to the sea through a southern route. Honey Lake might have drained externally (presumably northward or northwestward), or even internally.

Accounts of Species

The information provided for the species below is documentation for the generalizations about taxonomy, preservation and range. Notes on preservation at locality A or B are provided where appropriate, with stratigraphic range, occurrence in Lake Lahontan or other fossil deposits, and modern occurrence in the basin of Honey Lake, adjacent Eagle Lake, or elsewhere.

Molluscs

Family Unionidae

Anodonta sp.

Locality A, flakes of shell not thoroughly mineralized. These are most likely from *Anodonta californiensis* Lea that lived in Lake Lahontan. The species lives also in the Honey Lake Basin.

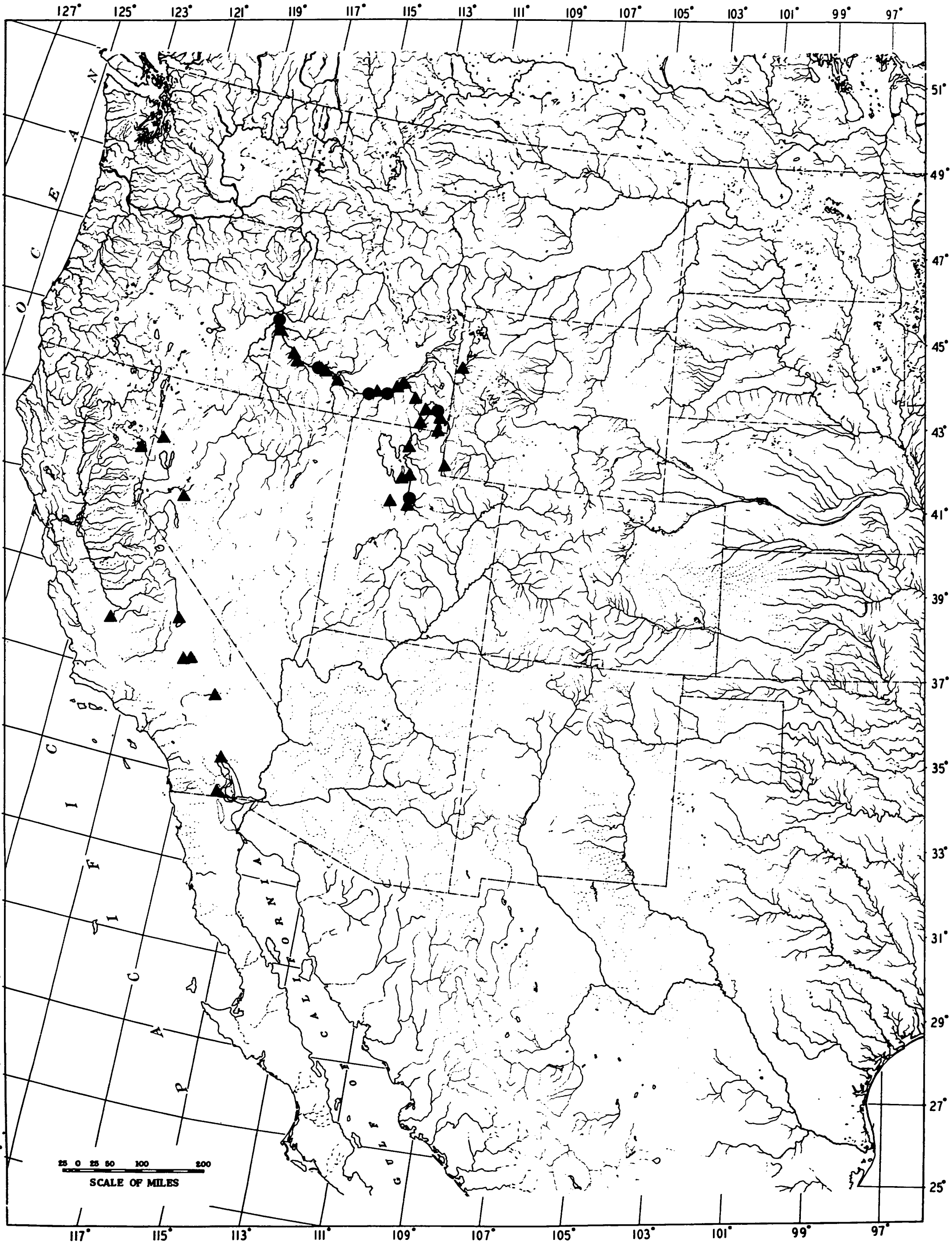

Figure 1 — Distribution of freshwater snail *Valvata utahensis* Call. Solid dots, modern; triangles, fossil.

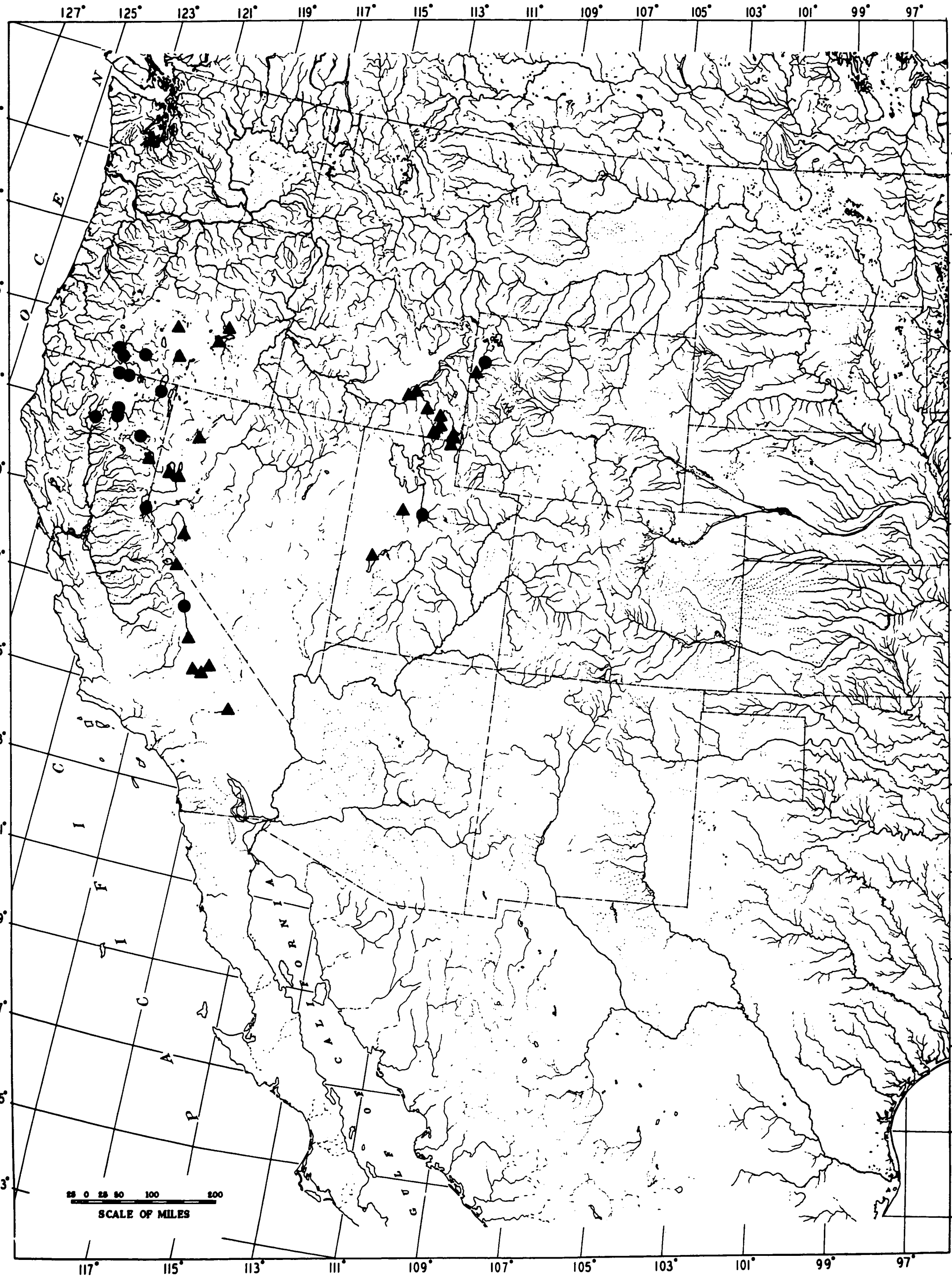

Figure 2 — Distribution of freshwater snail *Helisoma newberryi* (Lea). Solid dots, modern; triangles, fossil.

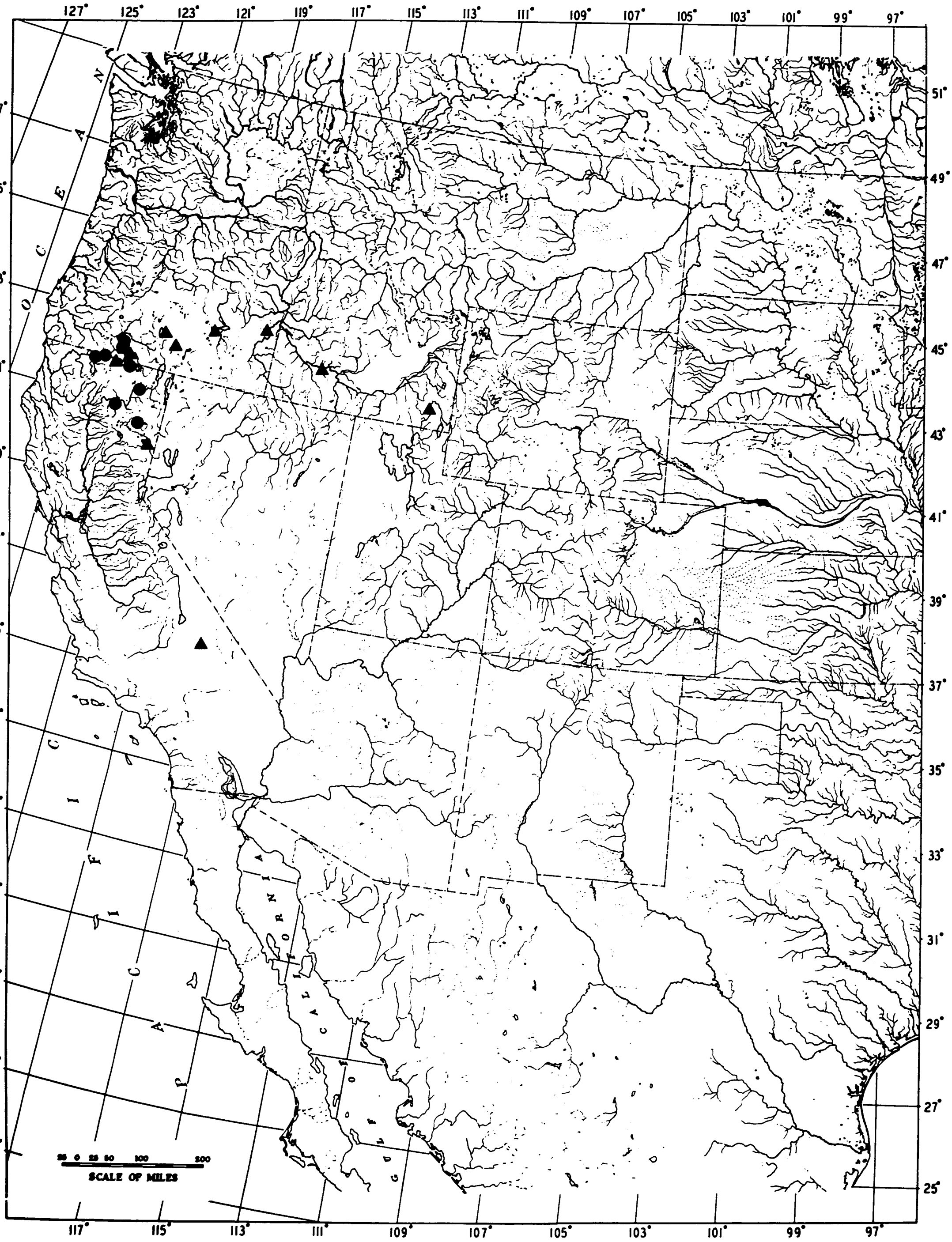

Figure 3 — Distribution of freshwater clam *Pisidium ultramontanum* Prime. Solid dots, modern; triangles, fossil.

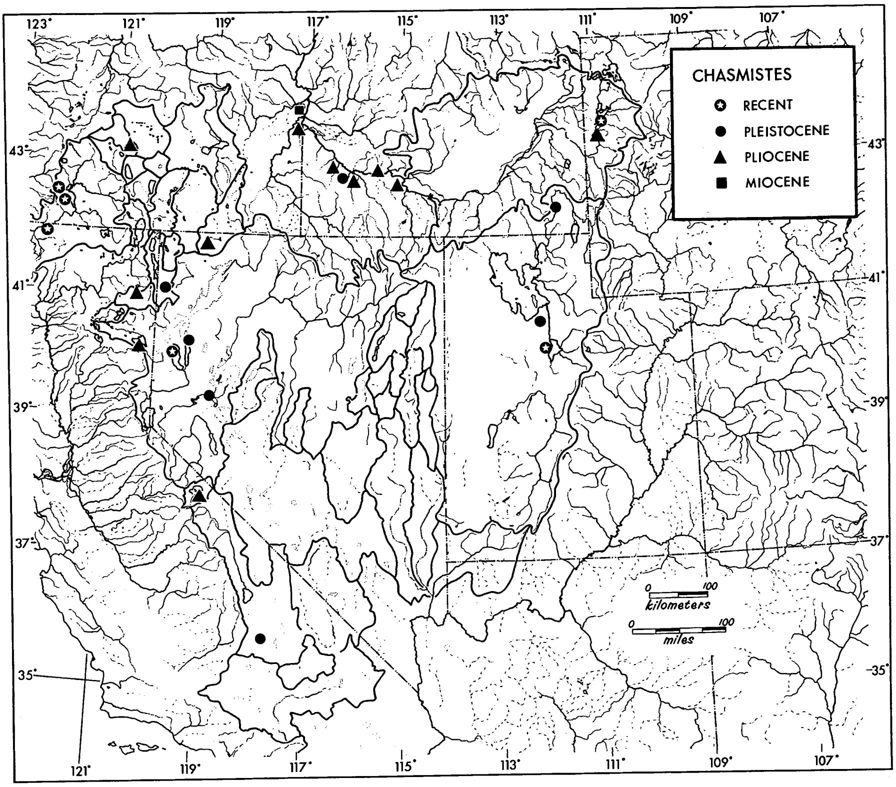

Figure 4 — Distribution of the catostomid fish genus, *Chasmistes*.

Family Sphaeriidae

Pisidium compressum Prime

Pl. 1, Figs. 5,7

Locality A. Miocene-Recent. Lake Lahontan, and living in Eagle Lake and in the Honey Lake basin.

Pisidium ultramontanum Prime

Pl. 1, Figs. 4,6

Locality A. Miocene-Recent. Living in Eagle Lake (Fig. 3).

Family Valvatidae

Valvata humeralis Say

Pl. 1, Fig. 1

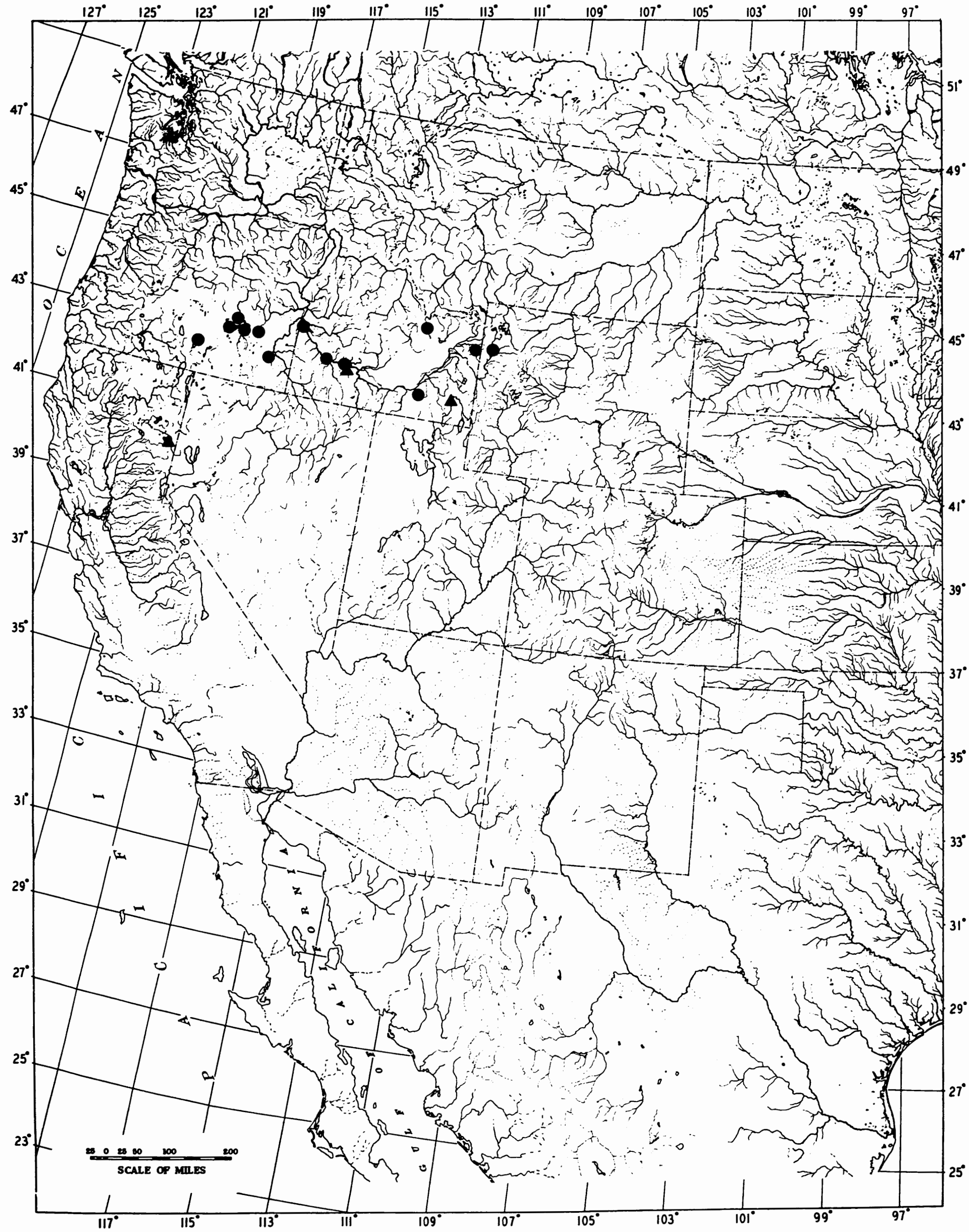

Figure 5 — Distribution of freshwater snail *Fontelicella*, subgenus *Natricola*. Solid dots, modern; triangles, fossil.

One specimen, from A. One specimen, from B, is translucent and might be modern or from Lahontan deposits. Miocene-Recent. Lake Lahontan, and living in Eagle Lake and in Honey Lake basin.

Valvata utahensis Call

Pl. 1, Figs. 2,3

From a series at A, three have lithified sandstone matrix within the shell and a little externally; shell color pale tan; one of the three is deformed by pressure (compressed, Pl. 1, Fig. 2). One specimen was found at B. The range is Pleistocene to Recent; the Honey Lake occurrence thus the oldest yet known. It occurred in Lake Lahontan, but locally only (Fig. 1).

Family Hydrobiidae

Fontelicella (*Natricola*) *melina* Taylor, n. sp.

Pl. 2, Figs. 1,2

Numerous specimens, from both A and B. The living species *F. idahoensis* (Pilsbry) is found in the Pliocene Glenns Ferry Formation, Idaho, the oldest occurrence of the subgenus. No records in Lake Lahontan.

Family Planorbidae

Gyraulus parvus (Say)

Pl. 2, Figs. 3,4

A series, A; one, B. Miocene-Recent. Lake Lahontan, and living in Eagle Lake and in Honey Lake basin.

Helisoma newberryi (Lea)

Pl. 2, Figs. 5,6

About 50 specimens, locality A. Two worn specimens have lithified sandstone matrix inside the aperture and in the spire-pit. These two and nearly all the rest are white, except for one mineralized blue-gray fragment and another that is limonite-stained. About 40 specimens, locality B. Most are at least partly blue-gray, pale tan or pink. Pliocene-Recent. Lake Lahontan locally, in the major western basins (Fig. 2). Living, Eagle Lake.

Planorbella sp.

Locality A, part of the inner whorls and a part of the body whorl that might represent the same individual. The fragments are white, thin, unmineralized, and probably come from Lake Lahontan. They could belong to the local living species *P. tenuis* (Dunker).

Vorticifex effusus (Lea)

Pl. 2, Fig. 7

In a series from locality A the specimens are relatively more broken, more affected by pitting of the shell surface, and less mineralized than the associated *V. lasseni*. These are probably from Lake Lahontan. Locality B, one specimen. The shell is white and preservation equivocal; it could be from the Pliocene sediments or Lake Lahontan. The latter interpretation is simpler and hence preferred. Pleistocene-Recent. Lake Lahontan, and living in Eagle Lake and in the Honey Lake basin.

Vorticifex lasseni Taylor, n. sp.

Pl. 2, Figs. 8,9

Locality A, a series that is white, mineralized and worn. Locality B, a series of about 100, mostly blue-gray or pale tan or pink at least in part.

Fishes

Family Salmonidae

Rhabdofario cf. *R. lacustris* Cope

Pl. 17, Fig. 1

One maxilla and three vertebrae were collected at locality B. The maxilla is rounded in cross-section, as in *Rhabdofario lacustris* of the Glenns Ferry Formation. It is otherwise similar to the Lahontan form, *Salmo clarki henshawi*. *Rhabdofario* is known only from the Miocene and Pliocene of the Snake River Plain (Kimmel, 1975; G. R. Smith, 1975) and the Pliocene of Mexico (M. L. Smith, 1980).

Gila (*Gila*) sp.

Pl. 18, Figs. 1,2,6,7

Three dentaries are identified from locality A. Locality B produced three pharyngeals, 12 dentaries, one maxilla, four frontals, 11 opercles, two parietals, one hyomandibular, one articular-angular, and five cleithra.

The pharyngeals are similar to *Gila bicolor* except that there is definite evidence of an inner row of teeth in addition to the main row. They are therefore referred to the subgenus *Gila*, which is widespread in western North America in the Miocene and Pliocene (Smith and Miller, in press). The teeth are heavier, with less development of grinding surface than in *Gila bicolor* or the *Gila* from the Mopung Hills. The pharyngeal teeth are not as heavy as those of *Mylopharodon hagermanensis* Uyeno from the Glenns Ferry Formation (Smith, 1975). However, the dentaries are nearly identical to those of *M. hagermanensis* in the short, laterally flared, and dorsally truncate gnathic ramus. These features show resemblance to *Lavinia*, as well. The dentaries of *Gila* from Mopung Hills are referable to the subgenus *Siphateles*; they are intermediate between the Honey Lake dentaries and those of *Gila bicolor*.

Family Catostomidae

Catostomus sp.

Pl. 19, Figs. 4,5,6

Five dentaries and five maxillae from locality B. This Honey lake fossil is not related to any sucker known from the Great Basin, but is similar to forms from the Pliocene Glenns Ferry Formation in Idaho. The dentaries resemble *Catostomus cristatus* Cope; the maxillae resemble *C. shoshonensis* Cope (Smith, 1975).

Chasmistes cf. *C. cujus* Cope

Pl. 19, Figs. 9,10

Locality A, one partial maxilla. Locality B, three maxillae, two dentaries, one preopercle, one hyomandibular, three opercles, numerous fragments. The maxillae resemble *C. cujus* as well as several Pliocene and Pleistocene forms distributed along the western margin of the Great Basin (Miller and Smith, 1981).

Descriptions of New Species, Honey Lake

Class Gastropoda

Family Hydrobiidae

Fontelicella (*Natricola*) *melina* Taylor, n. sp.

Pl. 2, Figs. 1,2

Diagnosis.—A species of *Natricola* with mean length/width 1.47 (95 percent confidence limits=1.44-1.49) and length/length of aperture mean 2.16 (95 percent confidence limits=2.11-2.22).

Description.—Shell small, dextrally coiled, elongate-oval with acute conical to slightly convex spire and broadly rounded anterior end. Whorls 4-5, weakly convex, separated by a distinctly impressed suture. Aperture broadly ovate, broadly rounded anteriorly, obtusely subangular posteriorly. Parietal wall with a distinct callus that completely or almost covers a narrow umbilical chink. Sculpture of fine, irregular growth lines oblique to the axis of coil.

Type.—UMMZ 250095, locality A, length 4.9 mm, width 3.1, with 5 whorls.

Variation.—The closeness of coiling and the rate at which the whorl enlarges account for the variation observed (see Table 1).

Comparisons.—The species of *Natricola* are much alike in shell features, being differentiated by characters of the reproductive system not preserved in fossils. Variation in the shell of living species is influenced by habitat, which affects size, form, and thickness of shell. Comparison was made with samples of *Fontelicella* (*Natricola*) from Oregon and Idaho (Table 1), including samples of *F. hendersoni* from spring, river, and lake habitats (samples 2–4, respectively). There is substantial overlap in most of the five meristic characters analyzed, the most effective discriminant being length/width ratio (Fig. 6). Figure 6 shows two noteworthy features. First, the samples of *F. hendersoni* are clustered, but the lake sample (4) is the least like *F. melina* even

TABLE 1 —Descriptive statistics of measurements of *Fontelicella.*

	Sample					
Number of whorls	1	2	3	4	5	6
Mean	4.5	4.8	4.9	5.0	4.9	5.3
Range	4–5	4½–5¼	4½–5¼	4¾–5½	4½–5½	4¾–6
S. D.	.24	.17	.21	.18	.31	.30
S. E.	.04	.03	.04	.03	.06	.05
Length						
Mean	4.70	5.01	5.77	5.31	6.16	5.96
Range	3.96–5.13	4.61–5.85	5.27–6.69	4.74–6.05	5.13–7.67	5.07–7.34
S. D.	.36	.32	.33	.39	.61	.52
S. E.	.07	.06	.06	.07	.11	.10
Width						
Mean	3.21	3.20	3.65	3.28	3.64	3.21
Range	2.79–3.64	2.86–3.77	3.44–3.96	2.93–3.71	3.12–3.96	2.93–3.83
S. D.	.67	.21	.20	.21	.21	.24
S. E.	.12	.04	.04	.04	.04	.04
Length of aperture						
Mean	2.18	2.24	2.54	2.17	2.51	2.09
Range	1.82–2.40	1.95–2.73	2.21–2.79	1.82–2.66	2.08–2.86	1.69–2.54
S. D.	.14	.19	.17	.23	.22	.21
S. E.	.03	.03	.03	.04	.04	.04
Width of aperture						
Mean	1.79	1.78	2.01	1.74	2.00	1.70
Range	1.49–2.27	1.62–2.15	1.76–2.21	1.56–2.15	1.69–2.27	1.49–2.08
S. D.	.16	.12	.12	.14	.13	.16
S. E.	.03	.02	.02	.03	.02	.03
Length/width						
Mean	1.47	1.57	1.58	1.62	1.69	1.86
Range	1.30–1.60	1.47–1.66	1.45–1.72	1.48–1.78	1.48–2.00	1.71–2.06
S. D.	.07	.05	.07	.08	.13	.10
S. E.	.01	.01	.01	.01	.02	.02
Length/length of aperture						
Mean	2.16	2.25	2.28	2.46	2.46	2.86
Range	1.82–2.60	2.03–2.60	2.05–2.56	2.16–2.86	1.98–3.09	2.59–3.38
S. D.	.16	.13	.13	.19	.27	.20
S. E.	.03	.02	.02	.03	.05	.04

though that is from a lake. Perhaps this shows an effect of sediment texture rather than lake habitat. Secondly, the population geographically nearest to *F. melina* (5, from Abert Lake) is not the most similar.

Samples.—From the series of *Fontelicella melina* in collections A and B, 30 large specimens were preserved well enough to permit five standard measurements. Both collections are pooled in Table 1.

Other samples for comparison are the 30 largest specimens from the collections available. Sources are as follows:

1) *Fontelicella melina* Taylor, n. sp.
2) *F. hendersoni* (Pilsbry), Hughet Spring, NE 1/4 NE 1/4 sec. 8, T. 27 S., R. 29 E., Harney Co., Oregon; D. W. Taylor, 4-VII-1975.
3) *F. hendersoni* (Pilsbry), South Fork of Malheur River, NE 1/4 sec. 7, T. 27 S., R. 36 E., Harney Co., Oregon; D. W. Taylor, 28-VI-1975.
4) *F. hendersoni* (Pilsbry), Pleistocene, sec. 1, T. 28 S., R. 29 1/2 E., Harney Co., Oregon; K. D. Gehr coll.

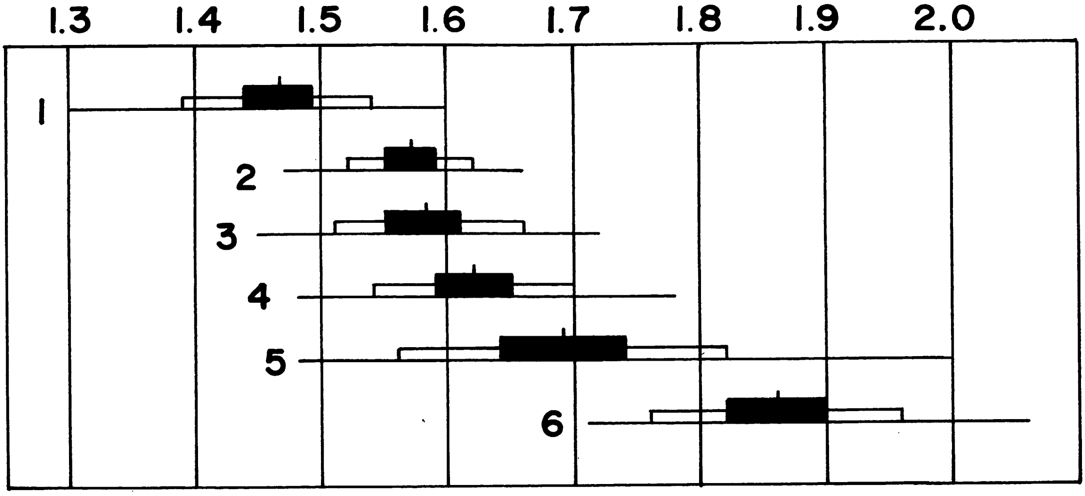

Figure 6 — Length/width ratio of shells of *Fontelicella (Natricola)*. Samples numbered as in text; N=30 for all. Each diagram indicates mean (central line), 95 percent confidence limits of mean (black), one standard deviation from mean (open rectangle), and sample range (basal line).

5) *F.* sp., XL Spring, NE corner sec. 27, T. 32 S., R. 21 E., Lake Co., Oregon; D. W. Taylor, 19-X-1976.
6) *F. idahoensis* (Pilsbry), Snake River, center NW 1/4 sec. 4, T. 6 S., R. 8 E., Owyhee Co., Idaho; D. W. Taylor, 2-X-1956.

Family Planorbidae

Vorticifex lasseni Taylor, n. sp.

Pl. 2, Figs. 8,9

Diagnosis.—A relatively large species of *Vorticifex* attaining a length of over 13 mm, with mean length/width ratio of .98 (10 specimens). The aperture is more than 3/4 of shell length, and relatively elongate, with mean length/width 1.27.

Description.—Shell large for the genus, dextrally coiled, globose, with short obtuse spire and bluntly rounded anterior end. Whorls 3 1/4, swollen, separated by a weakly impressed suture. Aperture effuse, with broadly convex outer margin, concave parietal margin and nearly straight columellar margin. Umbilical chink covered by reflected lip and commonly bordered by subangulation of body whorl. Sculpture of fine, irregular growth lines oblique to axis of coil.

Type.—UMMZ 250100, locality B, length 11.8 mm, width 12.1, with 3 1/4 whorls.

Variation.—As in the living *Vorticifex effusus*, there is substantial variation in height of spire, rate of whorl enlargement, and degree of subangulation of the anterior end of the aperture. No costate shells occur in the series studied, but populations of *V. effusus* may be entirely costate, entirely non-costate or mixed.

Comparisons.—*Vorticifex lasseni* is most similar to the living species *V. effusus*, in particular to the subspecies or ecological form *klamathensis*, of the Klamath Lake basin, California-Oregon. This is distinguished only by its relatively large size, according to specimens examined, and is not surely of taxonomic value. *V. lasseni* attains an even larger size, has a proportionally

TABLE 2 —Descriptive statistics of measurements of *Vorticifex*

	lasseni N=10	*gesteri* N=10	*effusus* N=20
Max. length	12.6mm	15.75	10.8
Max. no. whorls	3 1/2	4 1/2	3+
Length/Width			
Mean	.982	.981	.853
Range	.92–1.1	.89–1.1	.73–.97
S. D.	.057	.066	.069
S. E.	.018	.021	.015
Length of aperture/Length			
Mean	.787	.608	.737
Range	.67–.87	.52–.69	.65–.97
S. D.	.070	.052	.091
S. E.	.022	.016	.020
Length of aperture/Width of aperture			
Mean	1.274	1.099	.997
Range	1.06–1.45	.93–1.28	.82–1.43
S. D.	.130	.119	.127
S. E.	.041	.038	.029

more globose shell with length/width ratio approaching unity, and relatively narrower aperture (Table 2).

The Pliocene species *Vorticifex gesteri* Hanna, from California and Nevada (Taylor, 1966), is similar to *V. lasseni* in its relatively large size, and similar length/width ratio. It differs by attaining even larger size, and has a relatively smaller aperture that is nearly equidimensional (Table 2).

The samples measured come from the following sources:

1) *Vorticifex lasseni* Taylor, n. sp. Collection B, the 10 largest specimens on which measurements could be taken.
2) *Vorticifex gesteri* Hanna. Mono Co., California. From beneath basalt north of Adobe Meadows, east of Mono Lake; W. F. Foshag, 1924. Ten largest specimens.
3) *Vorticifex effusus* (Lea). Siskiyou Co., California. Sheepy Creek, 400 ft. W. of SE corner sec. 35, T. 48 N., R. 1 E.; D. W. Taylor, 26-X-1976. Twenty largest specimens; the apex was eroded on practically all and number of whorls could not be counted accurately.

FOSSILS FROM MOPUNG HILLS, CHURCHILL COUNTY, NEVADA

Location and Previous Work

The Mopung Hills are the western tip of the West Humboldt Range, in Churchill County, Nevada, separating Carson Sink from Humboldt Sink. Folded and faulted limestone outcrops over a total area of about 1/2 mile^2 (Fig. 7), and is locally rich in fossils. No fossils have been described from this fossiliferous unit before, but there are a few earlier references to the rock unit and one of the species (cited below). Taylor (1966) applied the name Mopung Hills local fauna to the assemblage.

The fossils shells described here were mostly collected by Taylor in 1955, a few in 1957 when he returned to map the outcrop area. Fossil fishes were collected by G. R. Smith and party in 1979.

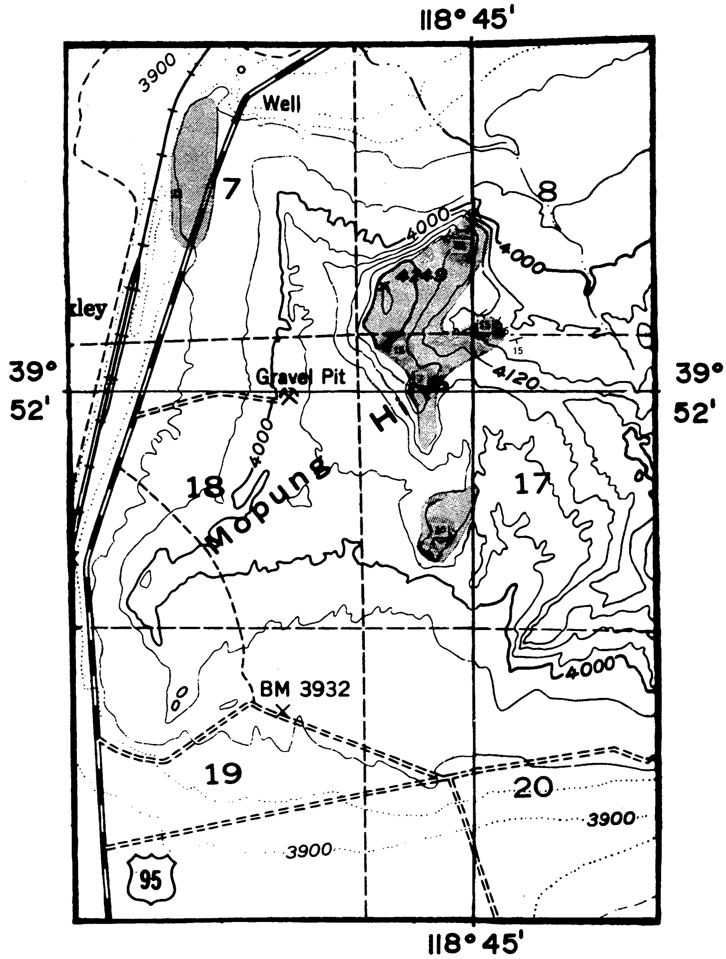

Figure 7 — Map showing location of outcrop of Tertiary limestone in Mopung Hills. Enlarged from portions of U. S. Geological Survey Carson Sink and Desert Peak quadrangles, 1:62500. Contour interval 40 ft.

Stratigraphy

The Tertiary lacustrine limestone in the Mopung Hills (Fig. 7) occurs in three outcrops with similar fossil content and lithology. They would be referable to the upper part of the Truckee Formation in the sense of Axelrod (1956). The limestone rests on eroded volcanic terrain and is locally folded and faulted, forming the resistant caps of low hills in the SW 1/4 sec. 8 and W 1/2 sec. 17, T. 23 N., R. 29 E., Churchill Co, Nevada. Minimum thickness is about 75 ft., the total being perhaps 150 ft. Lithology varies from a coquina and shelly limestone to massive thick-bedded limestone, weathering gray. In the NE 1/4 SW 1/4 sec. 8, about 20 ft. of pale oolitic limestone is exposed, stratigraphically below the fossiliferous horizons.

The geologic map of the Mopung Hills by Willden and Speed (1974) does not include the area of outcrop of the lacustrine limestone, but they mentioned it (p. 51) as "shell limestone of probable Pliocene age at the west end of the Mopung Hills."

Age

In the Hot Springs Mountains, 7-8 miles southwest of the Mopung Hills across Carson Sink, molluscs have been described from the lower member of the Truckee Formation (Yen, 1950). Fishes from the lower Truckee Formation have been described by Bell (1974) and Baumgartner (in press). Axelrod (1956) considered the lower Truckee late Clarendonian in age (late middle Miocene) on the basis of stratigraphy and available fossil mammals. These molluscs and fishes are interpreted to have lived in a lake, just as the Mopung Hills assemblage, but there are no closely related species except possibly among trouts and *Gila*. Evidently a substantial interval separates the two faunas, hence a Pliocene age is assigned to the Mopung Hills fossils.

The fossils from Mopung Hills would seem to be younger than those of Honey Lake on the basis of differences in two species of fishes. Specimens of *Gila* and of *Catostomus* cf. *C. tahoensis* are intermediate between those from Honey Lake and modern forms. If they are as old as the Honey Lake forms, they indicate early evolution of some Lahontan fishes while isolated from the Honey Lake area, which was at some time connected with drainages in southern Idaho.

Former Drainage and Habitat

The species represented in our Mopung Hills collections all belong to groups that are usually or always restricted to perennial waters. The lateral extent of the coquina and the species composition seems to indicate clearly deposition near the shore of a former lake. Outline of the lake basin is uncertain, but we speculate that it may have occupied at least the area of Carson Sink and Humboldt Sink, perhaps 1500 square miles, making it one of the major lakes in western Nevada. Other traces of it are to be expected.

All the molluscs are characteristically freshwater forms, not found in brackish water. Perhaps the lake had overflow to the south, but the molluscan fauna is so different from those to the west and north that drainage in those directions seems precluded. Possibly the lake was in an internal basin. It might have been chemically stratified at the time represented by our fossils, but if so, it had been so for only a small fraction of the time in which its distinctive fauna developed. The fishes include cool-water species, in contrast to those of warm-water, lowland habitat reported from the Truckee Formation elsewhere.

Elsewhere species of molluscs from Mopung Hills have no close relatives in the immediate area, and the one species still living is widespread. In contrast, the fishes are ancestral to the modern fauna of the Lahontan basin, and especially of Pyramid Lake. We interpret these data to indicate that our fossils come from an ancestral Lahontan basin, in which a substantial freshwater lake came to an end by desiccation or became saline, extinguishing the lacustrine molluscs. The fishes survived in tributary streams, and re-occupied lakes that formed later within the basin.

Fossil Localities, Mopung Hills Local Fauna

A. Flat-lying coquina, shelly limestone and limestone about 10–12 ft. thick exposed for about 1/2 mile in N-S extent between the Southern Pacific RR tracks and the Fallon-Lovelock road, mostly in the NW 1/4 sec. 7, T. 23 N., R. 29 E. Fossils were found over most of the area, but most specimens of molluscs and all fishes are from around an abandoned lime kiln and up to 200 ft. south.

University of California Museum of Paleontology collection B-932 is labeled "Central Utah, near line of R.R." On closer inspection one can see the label read originally "Nevada," and Utah was written in after erasure. Matrix and fossils are like those collected at locality A, and there seems no reasonable doubt that this is the source of the material. The record by Hannibal (1910: 107) of *Valvata calli* from "Central Nevada, near R.R." is probably based on this collection.

Lee et al. (1916: 182) mentioned the old lime kiln, attributing the source of the material to a shore deposit of Lake Lahontan.

California Academy of Sciences locality 34952 is from the vicinity of the lime kiln, collected by Don Castleberry in 1955 and 1957.

B. Limestone and coquina capping a ridge in the NW 1/4 sec. 17, T. 23 N., R. 29 E. Fossils were collected weathering on the surface at the south end of the outcrop, 1100–1200 ft. E., 1600–2000 ft. S. of the NW section corner.

C. Shelly limestone and coquina capping a square-nosed point in the SW 1/4 sec. 17, T. 23 N., R. 29 E.; strike N 60° W, dip 4° NE; thickness 15–20 ft. Fossils were collected weathering on the surface, 1100–1300 ft. E., 1300–1400 ft. N. of the SW section corner.

The assemblage of molluscs is much alike at all three localities, so that they may be contemporaneous.

Species	Locality A	Locality B	Locality C
Sphaerium nevadense		X	
Pisidium compressum		X	
Valvata nevadensis	X	X	X
Lutrilimnea polyskelidis	X	X	X
Menetus carinifex	X	X	X
Physa humboldtiana	X	X	X

Accounts of Species

Molluscs

Class Pelecypoda

Family Sphaeriidae

Sphaerium (*Amesoda*) *nevadense* Taylor, n. sp.

Pl. 3, Figs. 1–6

Diagnosis.—A species of the *Sphaerium striatinum* group distinguished by moderately inflated shell with subcircular outline.

Description.—Shell of medium size, moderately inflated, with subcircular outline and slightly prominent beaks nearly at midlength. Sculpture consists of strong, regular, concentric undulations on the beaks that fade out on the disc, and generally of growth lines consisting of irregular fine raised threads separated by roughly equal interspaces. Hinge-plate strong and arched, expanded into the lumen of the valves strongly below the anterior lateral teeth and weakly below the posterior laterals. C2 strong, short, cuneiform, the wide end at the inner edge of the hinge-plate, the tip pointing at the apex of the beak. C4 narrow, arcuate, originating slightly anterior to C2 and directed mediad of P2. C3 bow-shaped or L-shaped, with a medial isthmus and strongly expanded ends, the posterior end a little closer to the inner edge of the hinge plate. Lateral teeth short, massive, about equal in size. Cusps in right valve low, blunt, central to distal, with opposing faces finely granulose. A3 and P3 straight, A1 and P1 weakly to strongly curved. Cusps in left valve relatively high, blunt, subcentral. A2 shorter and wider than P2, straight or slightly convex inwards. P2 relatively more lamellar, straight or slightly concave inwards.

Type.—UMMZ 250102, a right valve, locality B.

Comparisons.—The most similar species is *Sphaerium idahoense* Meek, from the Pliocene Glenns Ferry Formation, southwestern Idaho and adjacent Oregon. That species differs by being more elongate or trigonal, not subcircular, with broader and usually more tumid beaks, and usually coarser sculpture on the disc.

Pisidium compressum Prime, 1852

One partial left valve referable to this widespread living species was found at locality B. It was somewhat worn before fossilization, with most of the cardinal teeth eroded. The remaining bases of the teeth indicate a short, arcuate C4, short, massive almost triangular C2, and a strongly curved C3 with posterior end much larger than the anterior. Both A2 and P2 are massive; A2 has a distal cusp and steep distal end, P2 a central cusp. Exteriorly there is a low ridge on the beak, and sculpture of fine, irregular raised threads separated by incised lines. The ventral margin is not preserved, but there is a trace of subangulation on the lower anterior slope. All these characters agree with those of *Pisidium compressum*. As preserved, the specimen is 3.6 mm long.

Class Gastropoda

Subclass Prosobranchia

Family Valvatidae

Valvata nevadensis Taylor, n. sp.

Pl. 3, Figs. 7–12

Valvata calli Hannibal, 1910: 107, in part; Taylor 1966: 66 ("central Nevada, near R.R.").

Diagnosis.—A helicoid *Valvata* with 5–9 equidistant spiral cords.

Description.—The helicoid shell has a deeply impressed suture, nearly circular cross-section of the whorls, and blunt spire. Sculpture consists of spiral carinae in the form of rounded cords, rather than sharp keels as in *V. calli* or *V. tricarinata*, and of straight growth lines slightly oblique to the axis of coil.

Measurements of the figured specimens are as follows (mm):

	Height	Width	Whorls	Carinae	
Fig. 7	4.0	4.2	3 3/4	5 major,	1 minor
Fig. 8	3.7	4.6	3 1/4	5	2
Fig. 9	4.1	4.9	3 1/2	5	2
Figs. 10–11	5.2	5.3	3 3/4	5	2
Fig. 12	3.5	3.9	3 1/2	6	1

Type.—UMMZ 250104, locality C.

Variation.—From the series at the type locality, 57 specimens were well preserved enough to score for number and strength of carinae. The spiral cords characteristically occur in discrete sizes, designated major and minor. Total numbers of carinae are plotted (Fig. 9) from the raw scores as follows:

Carinae		Specimens
4 major,	1 minor	8
4	2	5
5	0	7
5	1	8
5	2	8
5	3	2
5	4	1
6	0	7
6	1	6
6	2	3
6	3	2

Comparisons.—*Valvata calli* Hannibal (1910) from the Pliocene of Summer Lake, Oregon (Fig. 8) is distinct by its sculpture of three sharp spiral keels and generally higher spire. Comparison and tabulation of sculpture (Fig. 9) were made with a sample from U.S. Geological Survey locality 20350, from the NW 1/4 sec. 34, T. 31 S., R. 18 E., Lake Co., Oregon, collected by F. D. Trauger.

Valvata idahoensis Taylor is the most similar species, refigured (Pl. 4) herewith. It is like *V. nevadensis* in having sculpture of rounded spiral cords, but these are stronger and generally fewer (Fig. 9).

Valvata idahoensis Taylor, new name

Pl. 4, Figs. 1–12

Valvata multicarinata Yen, 1946: 487; not of Hislop, 1860.

Valvata cf. *V. octonaria* Brusina, Yen 1946: 488.

Measurements of the figured specimens are as follows (mm); those published by Yen (1946) are not in agreement.

	Height	Width	Whorls	Carinae	
Fig. 1–2	4.1	4.7	3 1/4?	4 major	
Fig. 3	2.9	4.2	3	4	1 minor
Fig. 4–5	4.2	4.8	3 3/4	4	2
Fig. 6	4.0	3.9	3 1/2	4	2
Fig. 7–8	4.2	4.7	3 3/4	5	
Fig. 9, 12	4.2	4.8	3 1/2	5	
Fig. 10–11	4.2	5.2	3 1/4?	4	

Variation.—From the original series 65 specimens were scored for numbers and strength of carinae to compare with *V. nevadensis*. The raw data below are plotted (Fig. 9) as total number of carinae.

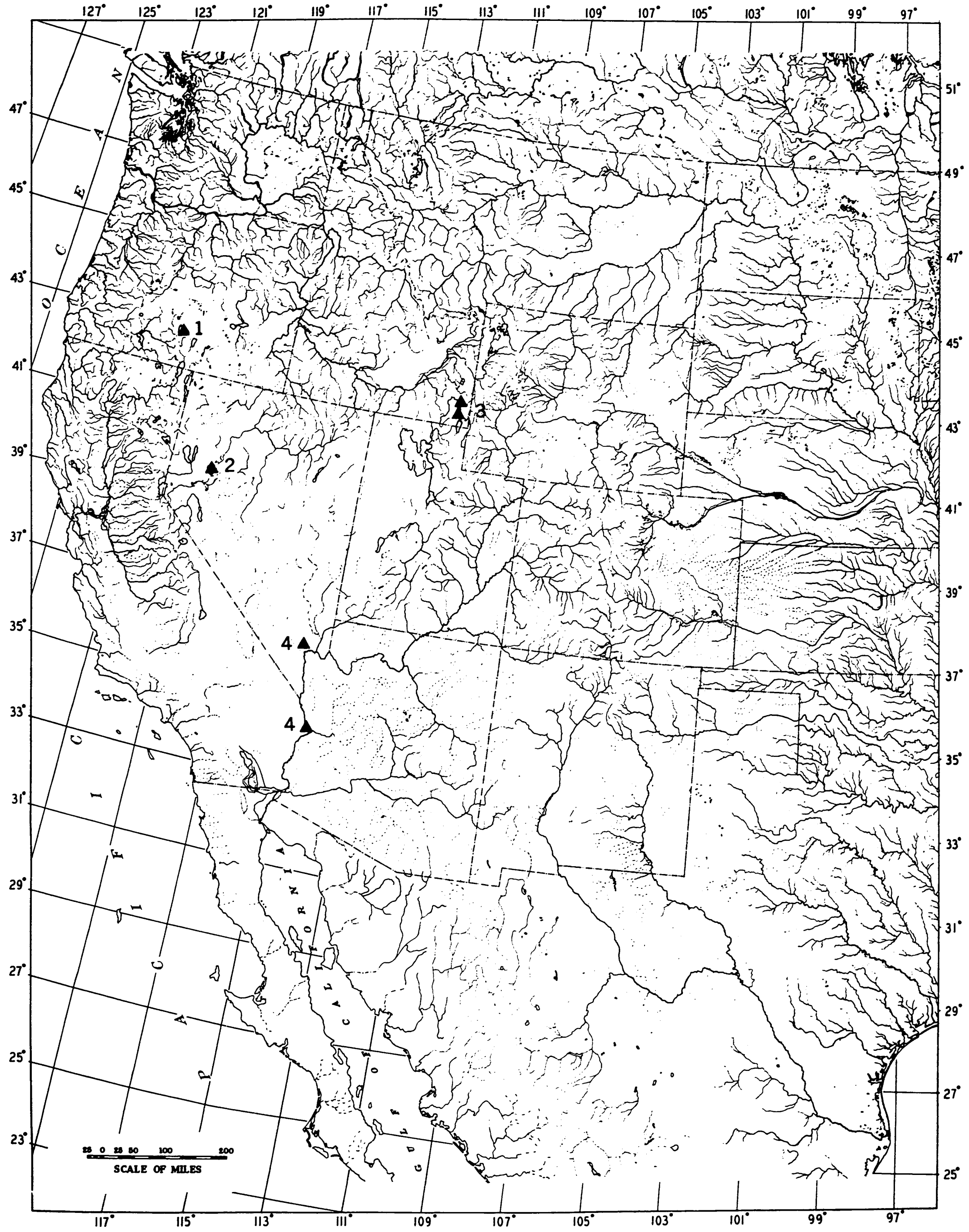

Figure 8 — Distribution of some species of *Valvata*. (1) *V. calli* Hannibal, 1910, Pliocene, Summer Lake, Oregon; (2) *V. nevadensis* Taylor, n. sp., Pliocene, Mopung Hills, Nevada; (3) *V. idahoensis* Taylor, new name, Miocene, Salt Lake Formation Idaho; (4) *V.* cf. *V. idahoensis* Taylor, Miocene, Muddy Creek Formation, Nevada, and probable equivalent, Arizona and California.

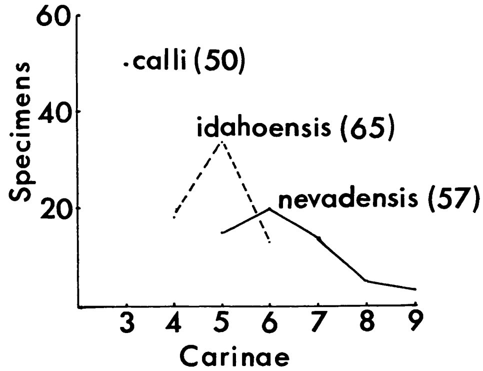

Figure 9 — Numbers of carinae in species of *Valvata.*

Carinae		Specimens
4 major	0 minor	16
4	1	17
4	2	6
5	0	14
5	1	4
6	0	1

As the original description and discussion of variation by Yen (1946) was inadequate, the separation of what he called *Valvata* cf. *V. octonaria* seems unjustified.

Valvata idahoensis is known from two localities in the Salt Lake Formation, southeastern Idaho (Fig. 8). The locality additional to the type locality is U. S. Geological Survey M2559, NE1/4 SE1/4 SW1/4 sec. 25, T. 10 S., R. 43 E., Bear Lake County, collected by S. S. Oriel, 1964.

A species of *Valvata* similar in size, form, and number of carinae occurs in southern Nevada and southeastern California (Fig. 8; Taylor, in prep.). It is represented by molds that show 4–5 carinae in strength and spacing like those of *V. idahoensis.* As preserved, the carinae appear narrower and sharper than in *V. idahoensis,* but compacting of the fossils after solution of the shells might account for this feature. In any case, these fossils are the only Miocene *Valvata* that are similar to *V. idahoensis.* They prompt the speculation that there was formerly drainage from southeastern Idaho to the lower Colorado River valley, before development of the present internal drainage in Utah.

Locality data for these southern occurrences are as follows:

USGS 20227. San Bernardino Co., Calif. Near power line road near where it crosses the W line of T. 4 N., R. 25 E., 5 mi. S. of Needles Boat Landing; C. B. Hunt et al.; probably Bouse Formation.

USGS 22252. Clark Co., Nev. SW1/4 sec. 26, T. 19 S., R. 63 E.; Muddy Creek Formation, calcareous facies; W. H. Hays, 1958.

Subclass Pulmonata

Family Lymnaeidae

Lutrilimnea Taylor, new genus

Diagnosis.—Lymnaeidae with relatively sharp apex, steeply inclined suture, large body whorl, and a lack of spiral sculpture as in *Radix*, but differing by the more sinuous growth line and/or coarser axial sculpture.

Type.—*L. polyskelidis* Taylor, n. sp. Other species are found in the Pleistocene and Holocene of Idaho and Utah, and Miocene of Arizona (Fig. 10).

Lutrilimnea polyskelidis Taylor, n. sp.

Pl. 5–7

Diagnosis.—A very large species attaining proportions of about 45 x 60 mm, with very short spire, large body whorl, and prominent sculpture of numerous rounded axial ribs spaced roughly equally.

Description.—Shell usually with a short spire only 10–15 percent of shell length, and expanded body whorl. Judged by the largest specimen (Pl. 5, Fig. 9) the species attained a length of 60 mm. Aperture elongate-oval to subcircular. Body whorl generally rounded, rarely shouldered (Pl. 5, Figs. 6, 8, 16) or even subangular (Pl. 5, Fig. 5). Sculpture consists of weakly sinuous growth lines and parallel rounded ribs separated by interspaces about 2–4 times their width. A columellar fold is developed weakly (Pl. 6, Figs. 6, 8) or not at all (Pl. 7, Figs. 1, 4, 8).

Measurements of the figured specimens are as follows (mm):

	Whorls	Length	Width	Ribs on last whorl
Pl. 5, Figs. 1–3, 7, type	4+	36	34	—
Figs. 4–5	3+	27	20	10
Figs. 6, 8, 11	3+	44	22	—
Fig. 9	—	44	45	—
Figs. 10, 12, 13	4+	43	32	—
Figs. 14, 15, 18	3	7.1	6.5	20
Figs. 16–17	3+	39	28	—
Pl. 6, Figs. 1–2	3+	11.5	8.4	—
Figs. 3, 9	3 1/4	11.2	9.4	20
Fig. 4	4 3/4	15.3	7.8	—
Figs. 5–6	3 1/4	7.4	5.9	20
Fig. 7	3+	5.8	5.2	—
Figs. 8, 10, 11	4+	7.5	5.5	17
Pl. 7, Figs. 1–2	3+	10.5	8.1	15
Figs. 3–4	3+	10.2	7.0	12
Figs. 5, 6, 9	2 1/4	6.0	4.1	19
Figs. 7–8	3	11.3	7.5	18
Fig. 10	4	9.2	5.6	—
Figs. 11–12	3 1/4	15.3	14.1	32

Type.—UMMZ 250106, locality C.

Variation.—All the shell features are so variable that a precise characterization is impossible. Most shells are heavily ribbed, a few weakly ribbed and some even without ribs. The spire is nearly always very short, but rarely elevated (Pl. 6, Fig. 4). Contour of the body whorl varies

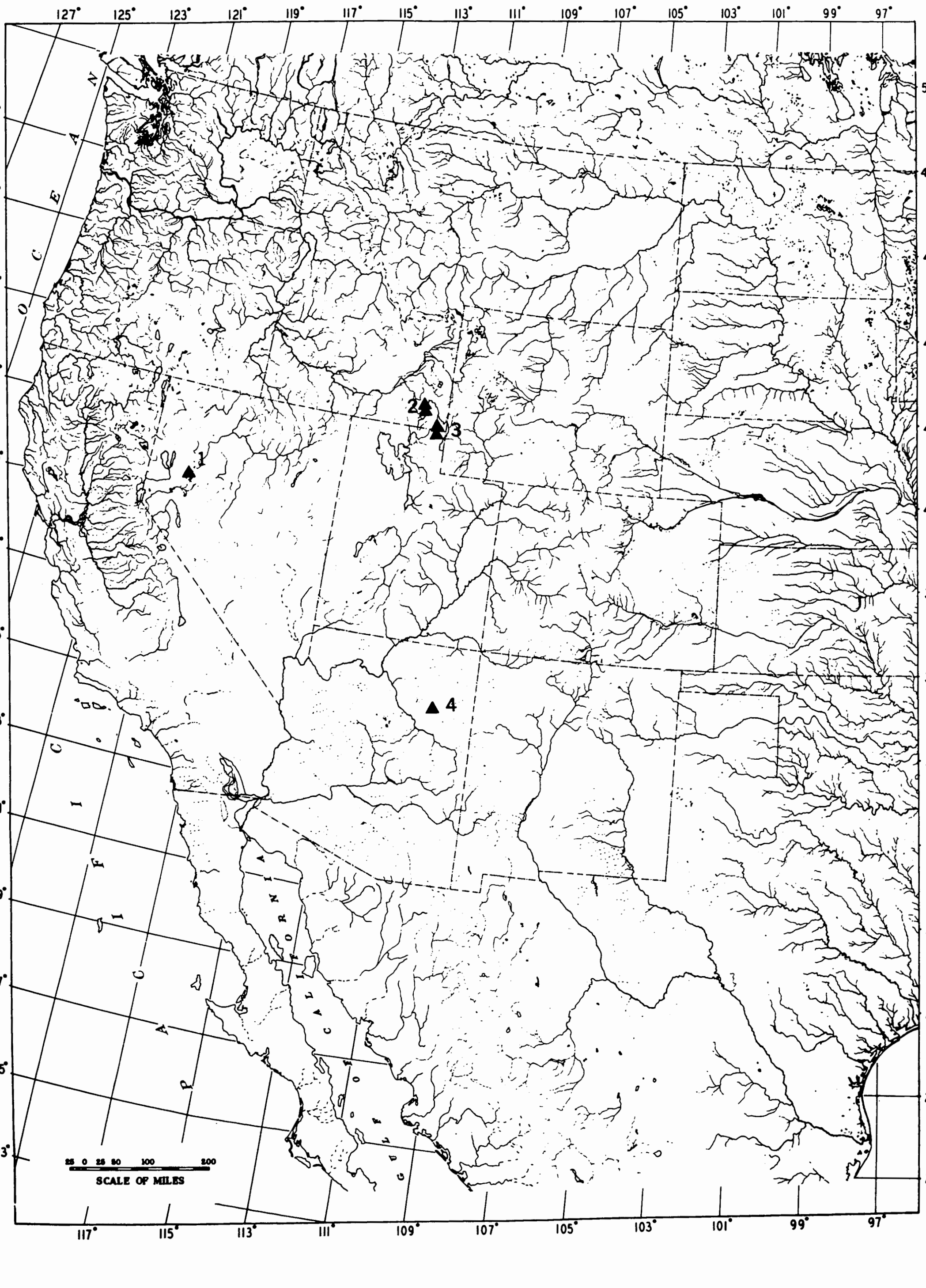

Figure 10 —Distribution of freshwater snail *Lutrilimnea*. (1) *L. polyskelidis* Taylor, n. sp., Pliocene, Mopung Hills, Nevada; (2) *L. gentilis* Taylor, n. sp., and *L. ursina* Taylor, n. sp., Pleistocene Lake Thatcher, Idaho; (3) *L. ursina* Taylor, n. sp., Pleistocene-Holocene, Bear Lake, Idaho-Utah; (4) *L. dineana* (Taylor, 1957), Miocene, Bidahochi Formation, Arizona.

from broadly rounded to subangular, and the aperture similarly varies in shape. A columellar fold is usually absent, but sometimes weakly developed.

Comparison.—In specimens with the tip of the spire preserved (Pl. 7, Figs. 5,6) the apex can be seen as acute, with a steeply descending suture as in *Radix*. Likewise the absence of spiral sculpture marks the species as similar to *Radix*.

Lutrilimnea gentilis Taylor, n. sp.

Pl. 8

Diagnosis.—A medium-sized species attaining proportions of about 19 x 11 mm, with aperture usually about 60 percent of shell length, and axial sculpture of fine growth lines and low rounded swellings.

Description.—Shell broadly to narrowly conical, with short to moderately high spire. Aperture narrowly ovate. Body whorl broadly rounded, with periphery in middle of whorl or posterior to middle. Axial sculpture consists of markedly sinuous growth lines formed by nearly regular, crowded raised threads separated by fine incised lines, and by coarser wrinkles and low rounded swellings. The wrinkles 2–3 times as wide as the growth threads are usually smooth, whereas the low rounded swellings, with indistinct boundaries but up to 5–6 times as wide as the growth threads, bear growth threads. Spiral sculpture is irregularly present, and consists of interruption of the fine axial threads to form elongate segments about 3–6 times as long as wide, and either straight or arcuate towards the aperture. These interruptions of the fine threads rarely interrupt the coarser wrinkles, but not the low axial swellings. They may be aligned as spiral striae on earlier whorls, but on the body whorl are usually not so aligned. A columellar fold is characteristically present, either weakly or well developed.

Measurements of the figured specimens are as follows (mm):

	Whorls	Length	Length peristome	Width	Width peristome
Figs. 1–3	4	13.3	8.9	10.5	6.5
4–5, type	5	15.2	9.9	9.1	6.4
6–7, 10	4 1/4	14.4	9.6	8.5	5.9
8–9	4 1/2	16.0	10.3	10.7	7.9

Type.—UMMZ 250110, SE1/4 SW1/4 sec. 12, T. 11 S., R. 40 E., Caribou Co., Idaho; Main Canyon Formation, Pleistocene; R. C. Bright, 1957 (Hanks 3 locality).

Variation.—The principal variate is height of spire. Short-spired specimens (Pl. 8, Figs. 1–3) may approach *L. ursina* in form, but retain the more sinuous growth lines and less irregular growth threads of *L. gentilis*.

Comparisons.—The most similar species is *L. dineana* (Taylor, 1957) from the Miocene Bidahochi Formation, Arizona. It is like *L. gentilis* in sinuous growth line, details of sculpture, form of aperture, and size, differing only by the narrower spire with concave outline.

Recognition of the significance of the subtle features of acute apex and steep suture leads to the transfer of *L. dineana* from *Pseudosuccinea*, to which it was first assigned. The species is superficially quite unlike *L. polyskelidis*. It attains a far smaller size, is elongate with a higher spire, and lacks costate sculpture. Yet it agrees precisely in features of the apex and is like the more elongate specimens of *L. polyskelidis* in having a steeply inclined suture. The virtual lack of spiral sculpture is another feature that is like *Radix* and unlike *Pseudosuccinea*. The axial sculpture of fine raised threads is coarser than that of *Radix*, but similar to the fine sculpture of *L. polyskelidis*.

Occurrence.—Lutrilimnea gentilis is known only from the deposits of Pleistocene Lake Thatcher, southeastern Idaho (Bright, 1967; Fig. 10). Locally it is a common species, mostly found in marly sediments of the Main Canyon Formation, dated 27,000–600,000 years B. P. (Bright, personal communication, 1980).

Although two species of *Lutrilimnea* lived in Lake Thatcher, their external relationships are quite different. *L. gentilis* is closely similar to a species from the Miocene of Arizona; *L. ursina* to a Pliocene species of Nevada. Hence it appears likely that the species had differentiated before the formation of Pleistocene lakes in southeastern Idaho. This region then can be considered a refugium, where the species survived last.

Lutrilimnea ursina Taylor, n. sp.

Pl. 9

Lymnaea utahensis (Call) (misidentified): Sterki 1909: 142; Bear Lake, Utah, Hayden Survey. Henderson and Daniels 1917: 56, 58; Bear River sloughs and Bear Lake, Idaho. Henderson 1924: 173 in part; Bear Lake, Idaho. Henderson 1931a: 78 in part, Pl. 6, Fig. 7, not Fig. 6; Bear Lake, Utah-Idaho. Henderson 1931b: 109; Bear Lake, Utah-Idaho. Henderson 1936: 124 in part, Pl. 2, Fig. 7, not Fig. 6; Bear Lake, Utah-Idaho. Yen 1951a: 1376, 1951b: 2; SE end of Bear Lake, Utah. Branson et al. 1966: 150; Bear Lake, Idaho.

Galba bonnevillensis (Call) (misidentified): Baker 1911: 105 in part, not Pl. 17, Figs. 6–8; Bear Lake, Utah.

Galba utahensis (Call) (misidentified): Baker 1911: 458 in part, Pl. 24, Figs. 22–27; not Pl. 22, Figs. 9–11; Bear Lake Utah, Hayden Survey.

Lymnaea bonnevillensis Call (misidentified): Mansfield 1927: 115; spit between Bear Lake and Mud Lake, Idaho.

Polyrhytis utahensis (Call) (misidentified): Chamberlin and Jones 1929: 143 in part, not Text-fig. 66; Bear Lake, Utah.

Lymnaea lepida Gould (misidentified): Chamberlin and Jones 1929: 125, Text-fig. 59; Bear Lake, Utah.

Stagnicola kingi (Meek) (misidentified): Jones 1940: 41 in part; Bear Lake, Idaho. Miller 1963: 703–704; Pleistocene, Gentile Valley, Caribou Co., Idaho; R. C. Bright coll.

Lymnaea kingi utahensis Call (misidentified): Baily and Baily 1951–52: 85 in part; Bear Lake at Lifton, Idaho, and Ideal Beach, Utah.

Stagnicola utahensis Call (misidentified): Williams et al. 1962: 34; Holocene, Bear Lake, Utah-Idaho. Smart 1963: 197; Bear Lake, Utah-Idaho.

Diagnosis.—A medium-sized species attaining proportions of about 14 x 9 mm, with aperture usually about 50 percent of shell length, and axial sculpture ranging from irregular, crowded raised threads to coarse, rounded ribs.

Description.—Shell broadly to narrowly conical, with short to moderately high spire. Aperture ovate to semilunar. Body whorl broadly rounded to weakly shouldered. Axial sculpture consists of weakly sinuous growth lines formed by conspicuously irregular, crowded raised threads separated by fine incised lines; varying to irregular cords, or to coarse rounded ribs that form low swellings on which the finer axial sculpture is superimposed. Spiral sculpture is irregularly present, and consists of interruption of the fine axial threads to form elongate segments 3–6 times as long as wide, and either straight or arcuate towards the aperture. These interruptions of the fine threads do not interrupt the coarser cords or ribs. They may be aligned as spiral striae on earlier whorls, but on the body whorl are usually not so aligned. The columella may be thickened but a fold is usually not present.

Measurements of the figured specimens are as follows (mm):

	Whorls	Length	Length peristome	Width	Width peristome
Figs. 1–3	3+	10.0	6.9	7.1	4.9
4–5	3 3/4	10.1	5.5	6.1	3.5
6–7	3 3/4	11.6	7.3	8.0	5.6
8	3	10.8	6.7	6.7	4.5
9–10	3+	9.7	6.9	6.9	4.4
11	Broken after illustration				
12	4 1/4	13.1	6.0	6.9	3.7
13	3 3/4	10.9	5.7	7.1	4.3
14	4 1/4	14.1	8.3	9.1	5.7
15	3 3/4	12.9	7.7	8.9	5.5
16	4	13.5	7.3	8.4	5.1
17	4 1/4	11.9	6.8	7.3	4.7

Type.—UMMZ 250113, drift on shore at south end of Bear lake, SW 1/4 sec. 23, T. 13 N., R. 5 E., Rich Co., Utah; Holocene; D. W. Taylor, 1950.

Variation.—All shell features are variable, especially shape and strong sculpture. The constant features include the axial sculpture of irregular threads, the weakly sinuous growth line, and acute apex.

Comparisons.—The most similar species is *L. polyskelidis.* Specimens of the two species selected for similarity in size and coarse sculpture differ in that *L. ursina* has a higher spire, relatively smaller aperture, shallower suture, and less discrete, lower, more irregular ribs.

Lymnaea kingi is superficially much like *Lutrilimnea ursina.* It differs by having a blunt apex and less steeply inclined suture on the spire, as in other species of the subgenus *Stagnicola*, and by having a columellar fold characteristically present. Commonly the spire is more nearly flat-sided, rather than concave as in many *ursina*, and the spiral sculpture on the body whorl stronger and more regular. The coarser sculpture of *L. ursina* consists of broader and higher ribs than are developed in the most heavily sculptured *L. kingi.*

Occurrence.—*Lutrilimnea ursina* is abundant on the shores of Bear Lake, Idaho-Utah, as a Pleistocene and Holocene fossil. The youngest radiometric dates for shells in the lake indicate the fauna became extinct about 8000 years ago (Williams et al., 1962). Most museum collections have series from Bear Lake, hence no listing of material examined seems warranted.

Outside of Bear Lake Valley, *L. ursina* is known from the Pleistocene deposits of Lake Thatcher, in the next lake basin to the west (Fig. 10). It lived in the same lake as *L. gentilis*, but the two species have not been found together. In Lake Thatcher, *L. ursina* lived on sandy substratum closer to shore and in situations more exposed to wave action. *L. gentilis* lived in quieter, deeper water, characteristically where marl was being deposited. The 13 known localities for *L. ursina* in the Thatcher basin are all in the Main Canyon Formation, dated at 27,000–600,000 years B. P. (Bright, personal communication, 1980).

The comparison of *Lutrilimnea* with fossil species of *Radix* led to reillustration of *R. venusta* (Russell, 1938) and *R. intermontana* Taylor (1966).

Radix venusta (Pl. 10, Figs. 1–5, 9) from the Oligocene Antero Formation (Stark et al., 1949) of South Park, Colorado, was described as *Pseudosuccinea*. The holotype (Pl. 10, Figs. 4, 5, 9) has a spire longer than usual for the species. Other associated specimens show the short insignificant spire and large body whorl more typical of *Radix* (Pl. 10, Figs. 1, 3). As the holotype is an internal mold with the tip of the specimen broken away, it is likely that it would have appeared more like the holotype of *R. intermontana* (Pl. 10, Figs. 6–8, 10) before loss of the shell material. This represents the earliest known occurrence of *Radix* in North America.

Radix intermontana is a substitute name for *Lymnaea idahoensis* Yen (1946), preoccupied. The holotype (Pl. 10, Figs. 6–8, 10), from the Miocene Salt Lake Formation, southeastern Idaho, is refigured here for comparison with referred material from Nevada (Pl. 10, Figs. 11, 13–15). Associated with the original material of *Lymnaea idahoensis* were specimens identified by Yen (1946) as *Lymnaea petaluma* Hanna. The specimen illustrated by Yen is refigured here (Pl. 10, Fig. 12) to show how closely it resembles the type of *L. idahoensis*. Examination of the series of specimens identified by Yen does not reveal justification for separation in more than one species. *Lymnaea petaluma* Hanna, according to examination of the type material and topotypes, belongs to the genus *Bulimnea*.

Family Planorbidae

Menetus carinifex Taylor, n. sp.

Pl. 11–12

Diagnosis.—A *Menetus* with plane or convex right side, subangular keel or raised ridge bordering the right side, and commonly a keel bordering the narrow spire-pit on the left side.

Description.—Shell planispiral to high-spired hyperstrophic, with up to 4 1/4 whorls. Right side plane or convex, left side with a funicular spire-pit about 1/4 shell diameter. Right side bordered by a keel varying from subangular to produced and set off by lateral grooves. Left side commonly with a low keel bordering the spire pit. Aperture oval to roundly trigonal. Growth lines regularly retractive. More strongly sculptured specimens with fine incised spiral striae that cut the growth lines, producing a decussate surface.

Measurements of the figured specimens are as follows (mm):

	Height	Width	Whorls
Pl. 11, Figs. 1–3	2.0	4.4	3 1/4
Figs. 4–6	1.8	4.6	3 1/4
Fig. 7	—	6.8	4 1/4
Figs. 8–10	2.5	6.2	3 3/4
Figs. 11–12, type	2.9	6.6	3 3/4
Pl. 12, Figs. 1–3, 6	2.9	5.8	3 3/4
Figs. 4–5, 7	3.7	5.2	—
Figs. 8–11	3.9	6.7	—

Type.—UMMZ 250115, locality A.

Variation.—The most conspicuous variation is in height of spire. Many specimens have a plane right side (Pl. 11, Figs. 2, 5, 9) or even barely concave, but others have a moderate spire making this the only hyperstrophic species of the genus. The extreme of spire height (Pl. 12, Figs. 5, 8) produces a shell in form much like *Helisoma* (*Carinifex*) *newberryi*, hence the specific name. Correlated with higher spire is the occurrence of a well-marked keel on the left side, and a narrower and deeper spire-pit. These *Carinifex*-like shells are not like those more typical of *Menetus* (Pl. 11, Figs. 1–6), but the series collected show complete intergradation between the two. Likewise the form of the aperture varies continuously from rounded or oval in shells lacking carinae (Pl. 11, Figs. 2, 5), to almost triangular (Pl. 12, Fig. 5) in high-spired, carinate shells.

Comparisons.—Menetus carinifex is distinct from other species of the genus by its plane to convex, or even high-spired, right side, and relatively broad spire pit on the left side. Other nominal fossil species in the genus are as follows.

Menetus idahoensis (Yen, 1946) from the Miocene Salt Lake Group, southeastern Idaho, was described as *Planorbifex idahoensis* and *Carinifex brevispira*; the former name is selected as valid. The examination of types and series of paratypes of the two nominal forms shows complete intergradation. The species is characterized by a broadly concave to plane right side, and a narrow, steep-sided spire-pit on the left side contained 3–4 times in the shell diameter. Degree of carination is variable. The keel bordering the right side may be subangular, or produced and set off by shallow lateral grooves. The margin of the spire-pit may be narrowly rounded, or marked by a subangular ridge, set off by a lateral groove. The peripheral keel may be absent or subangular. *Carinifex brevispira* was based on specimens with the right and left keels more strongly developed, *Planorbifex idahoensis* on those with the more evident peripheral angle.

Menetus planulatoides Henderson and Rodeck (1934), from the Miocene of southeastern Oregon, was compared by a series of topotypes. The species is characterized by a broadly concave to plane right side, a narrow spire-pit on the left side contained about five times in the shell diameter, and relatively rapidly enlarging whorls with transversely elongate aperture. Sculpture is highly variable: there may be no carinae, or four, and these may be subangular or produced, and set off by shallow marginal grooves. Carinae are located on the periphery, bordering the spire-pit, and on the right and left margins. In more strongly sculptured specimens the growth lines may form fine, close-set, raised threads.

Menetus vanvlecki (Arnold, 1910), type of *Planorbifex* Pilsbry (1935), was described from the Pliocene Tulare Formation of the Kettleman Hills, California. The spiral sculpture is coarser than in other species of the genus. The keel bordering the spire-pit on the left side is a low, rounded prominence 3–5 times the width of the other keels; it is set off from the keel bordering the left side by a conspicuous groove. The keel of the right side is nearly in the middle of the whorl, rather than at the edge of the right side as in all other species of the genus. The right keel, and that bordering the left side, vary from subangular to produced and are set off by marginal grooves as in other species of *Menetus*.

Pilsbry (1935) described *Planorbifex* as a subgenus of *Menetus*, and subsequently Baker (1945) viewed it as a distinct genus. The only distinguishing feature cited is the position of the right keel, doubtfully worthy of even subgeneric distinction.

Family Physidae

Physa (*Costatella*) *humboldtiana* Taylor, n. sp.

Pl. 13, 14

Diagnosis.—A medium-sized species of *Costatella*, attaining a height of about 10 mm, with broadly rounded body whorl bearing 23 rounded, nearly straight ribs separated by interspaces about twice their width.

Measurements of the figured specimens are as follows (mm):

	Height	Width	Whorls
Pl. 13, Figs. 1,3	7.8	5.7	3 1/2
Figs. 2,5	7.1	4.3	4
Fig. 4	8.0	5.1	4 1/2
Figs. 6,7	10.3	8.3	4
Pl. 14, Fig. 1	7.5	5.7	3 1/2
Fig. 2	—	6.4	—
Figs. 3,5	6.2	4.8	3 3/4
Figs. 4,6	6.9	5.7	3 3/4
Figs. 7,9, type	7.5	5.7	—

Type.—UMMZ 250118, locality A.

Variation.—One costate specimen, the type, was found among series of *Physa* from localities A, B, and C; these lacked incipient ribbing on any specimens. Thus it is uncertain whether more than one species is present. The shape of the ribbed specimen falls within the range of those without ribs (Pl. 13, Figs. 1–7; Pl. 14, Figs. 1–6) and hence all are considered tentatively as one species.

Comparisons.—The present species has no subangulation of the body whorl as in *Physa wattsi* (Pl. 15), and in its rounded body whorl is more like *P. harpa* (Pl. 16). The costate specimen has 23 ribs on its body whorl, greater than the numbers found in either *P. harpa* or *P. wattsi.* The ribs are discrete and regular as in *P. harpa*, but differ by being nearly parallel to the axis of coil rather than distinctly arcuate.

The distribution of the species of the subgenus *Costatella* (Fig. 11) is not parallelled closely by any other group. All species are lacustrine, but none has been found in the Pliocene Glenns Ferry Formation, Idaho, which has yielded a rich lacustrine fauna.

Physa (*Costatella*) *harpa* Taylor, n. sp.

Pl. 16

Diagnosis.—A relatively small species of *Costatella*, attaining a length of about 6.5 mm, with broadly rounded body whorl bearing about 12–14 rounded arcuate ribs separated by interspaces about twice their width.

Description.—Shell sinistral with low spire and broadly rounded to ventricose whorls, separated by an impressed suture. Aperture with a broadly rounded outer margin, more narrowly rounded anterior margin, sinuous inner margin and broad posterior angle. Parietal callus thin, narrow, not expanded beyond aperture or columella. Sculpture conspicuous, consisting of about 12 rounded arcuate ribs on the last whorl, separated by interspaces about twice their width. Fine growth lines inconspicuous.

Measurements of the figured specimens are as follows (mm):

	Height	Width	Whorls	Ribs on last whorl
Figs. 1,2	4.2	3.1	3	17
3,4	4.2	3.4	2 3/4	13
5,6	4.5	3.4	2 3/4	13
7–9, type	5.5	4.0	3	12
10–12	6.4	4.1	3	12

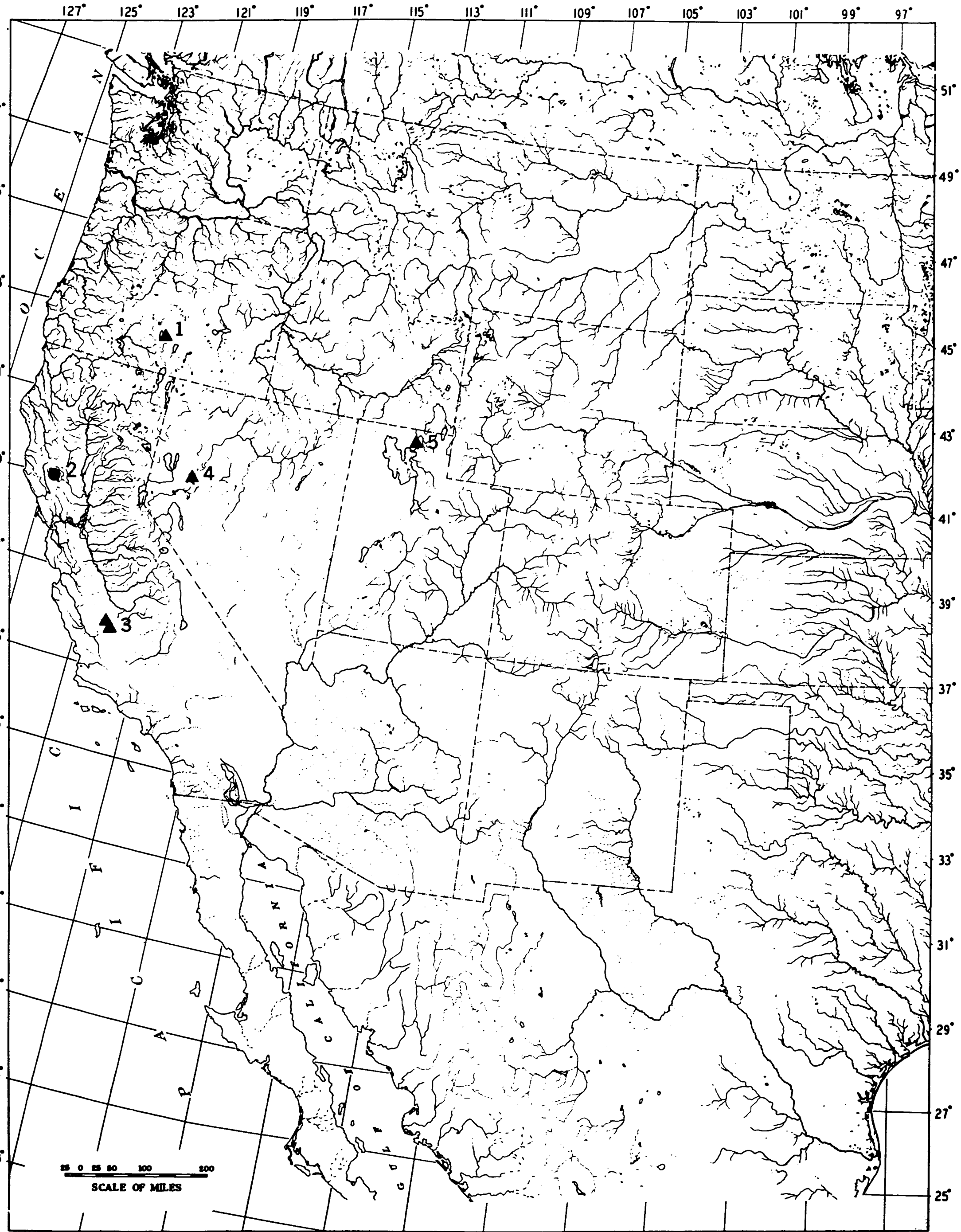

Figure 11 —Distribution of freshwater snail *Physa (Costatella).* (1) *P.* sp., Pliocene, Summer Lake, Oregon; (2) *P. costata* Newcomb, 1861, living, Clear Lake, California; (3) *P. wattsi* Arnold, 1910, Pliocene, Tulare Formation, California; (4) *P. humboldtiana* Taylor, n. sp., Pliocene, Mopung Hills, Nevada; (5) *P. harpa* Taylor, n. sp., Pliocene, Cache Valley Formation, Utah.

Type.—USNM 305783. U. S. Geological Survey locality 20093. Box Elder Co., Utah. SE 1/4 sec. 16, T. 13 N., R. 2 W., Cache Valley Formation; D. W. Taylor, 1956.

Variation.—Strength of ribbing varies conspicuously, from specimens with no ribs (rare) to those in which strong ribs occur over the later whorls (usual). Intermediate conditions are those in which ribbing is weak but persistent, and those in which the ribs fade away (Pl. 16, Fig. 3). Origin of the ribs varies also; they begin fairly abruptly, but at 1–2 whorls.

Number of ribs on the last whorl was counted in 22 specimens (including those illustrated) in which ribs occurred over all the whorls, as follows:

Ribs on last whorl	Number of specimens
11	2
12	6
13	6
14	4
15	2
16	0
17	2

Comparisons.—The species is distinct from all others in the subgenus by its relatively small size, broadly rounded body whorl, and more arcuate ribs.

Physa (*Costatella*) *wattsi* Arnold, 1910

Pl. 15

Diagnosis.—A small to medium-sized species of *Costatella*, attaining a height of about 10 mm, with subangular to tabulate whorls bearing about 10–15 irregular, furrowed ribs most prominent on the shoulder of the whorl.

Measurements of the figured specimens are as follows (mm):

	Height	Width	Whorls	Ribs on last whorl
Figs. 1–3	11.0	7.9	3+	10
Fig. 4	8.8	6.5	4	—
Fig. 5	4.9	3.5	3 1/4	18
Fig. 6	4.0	2.9	3	18
Figs. 7–9	fragmented after illustration			
Fig. 10	"	"	"	
Figs. 11–12	6.2	4.1	3 3/4	15
Figs. 13–14	5.3	3.6	3 1/2	16

Variation.—Principal variation is in height of spire, degree of shouldering, and in ribbing. Even when the ribs are distinct they are commonly furrowed, and one part of a whorl may have distinct ribs while the rest has an irregularly wrinkled surface. No precise tabulation of rib numbers was possible in the material examined.

Comparisons.—The subangular whorls and irregular short ribs distinguish *P. wattsi* from *P. harpa* and *P. humboldtiana*. In sculpture *P. wattsi* is most like the living *P. costata* Newcomb, as noted by Arnold (1910).

Comparison is based on two series of *Physa wattsi* from the Tulare Formation in the Kettleman Hills, California, as follows:

U. S. Geological Survey locality 12479. North Dome, 370 ft. S., 2080 ft. W. of NE corner sec. 35, T. 21 S., R. 17 E.

USGS 12556. North Dome, 100 ft. N., 2350 ft. W. of SE corner sec. 14, T. 22 S., R. 17 E.

Both localities are included in the report by Woodring et al. (1940) that provides also further information on geology and stratigraphy.

Fishes

Order Salmoniformes

Family Salmonidae

Salmo sp.

Pl. 17, Figs. 2,3,4,5

Description and Comparison.—Three diagnostic bones have been collected (UMMP V 74361). All are clearly more similar to Recent *Salmo* than to *Salvelinus* or other salmonid genera; they are also similar to *Rhabdofario* but bones most diagnostic of that genus (or subgenus) are not present in the Mopung Hills material. The right articular-angular has a high coronoid angle like *Salmo* and *Rhabdofario* but unlike *Oncorhynchus*; it lacks the strong fossa that usually occurs on the lateral face of the coronoid process in *Salvelinus*. Its dorsal ridge is similar to *Salmo clarki henshawi*. The right dentary has a robust tooth platform that is not sharply undercut posteriorly (unlike *Salvelinus*). The vertebra (anterior) has fossae and pits arranged as in *Salmo*.

The bones are especially similar to *Salmo clarki henshawi* from Pyramid Lake. Other *Salmo*, and *Rhabdofario*, are similar but not in as many details. The lower jaw bones are not as similar to the fossil trout (UMMP V 74362) collected by Michael Bell from diatomite beds of the Truckee Formation near Hazen, 30 mi. southwest of the Mopung Hills locality. The Hazen specimen has shorter dentaries than other trout, with fewer teeth.

Salmo cyniclope LaRivers (1964) and *Salmo esmeralda* LaRivers (1966) were described from beds that may be Miocene in Pershing (near Rabbit Hole) and Esmeralda (near Silver Peak) Counties. They appear to lack characteristics different from *Salmo*, but are too incomplete to be thoroughly analyzed, except to rule out *Rhabdofario* and *Oncorhynchus*. The two trouts described by LaRivers and the specimens from Hazen and Mopung Hills may be relatives of western North American *Salmo*. The frequent and perhaps persistent occurrence of trouts in this area from middle Miocene to Recent is remarkable (LaRivers, 1964). The Honey Lake trout differs from the Nevada trouts in the possession of a thick maxilla like *Rhabdofario*, otherwise known from Miocene and Pliocene beds of southwest Idaho.

Order Cypriniformes

Family Cyprinidae

Gila (*Siphateles*) sp.

Pl. 18, Figs. 3,4,5,8,9

Description and Comparison.—Minnows are represented by four dentaries (three left, one right), one right maxilla, one right premaxilla, one right palatine, a left hyomandibular, one right and two left cleithra, plus two fragmentary pharyngeal arches and several teeth (UMMP V 74359). The dentaries are similar to *Gila bicolor* in the flattened shape of the gnathic edge; they differ markedly from *G. coerulea* and *G. atraria.* However, the gnathic edge is flatter than typical *bicolor*, and expanded laterally, somewhat as in the *Gila* from Honey Lake and *Lavinia.* The pharyngeal bones are similar to *bicolor* in the possession of sharp grinding surfaces and terminal hooks on the teeth, which occur in single rows of four or five. The premaxilla, maxilla, and palatine are more similar to *bicolor* than *coerulea.* The maxilla differs slightly from *bicolor* in the long anterodorsal condyle and the slender dorsal process, character states similar to *Lavinia.* Other bones in the collection, the hyomandibular and cleithra, also resemble *bicolor.* The similarity of the fossils to *bicolor* suggests a direct relationship to that species. The minor differences are consistent with the elapsed time between samples, late Pliocene to Recent.

Family Catostomidae

Catostomus cf. *C. tahoensis* Gill and Jordan

Pl. 19, Figs. 1,7

Description and Comparison.—The collection (UMMP V 74358) consists of three maxillae (two right, one left), a right dentary, a partial urohyal, a fragment of a right fourth rib of the Weberian apparatus, a partial left cleithrum, a left subopercle, and a parasphenoid. All specimens are from individuals smaller than 30 cm in standard length.

The bones are clearly similar to *C. tahoensis* (Pl. 19, Figs. 2,8) from Pyramid Lake. The maxillae and dentaries differ in several details from *C. rimiculus* and *occidentalis.* The fossils have a more prominent ventral keel on the maxilla, a more prominent postdorsal extension of the flange for the labial cartilage on the dentary, and a lower, less truncate coronoid process on the dentary. The jaw bones from the Mopung Hills fauna are more similar to *C. tahoensis* than to the Honey Lake specimens.

Order Perciformes

Family Cottidae

Cottus cf. *C. beldingi* Eigenmann and Eigenmann

Pl. 17, Figs. 6,7,8

Description and Comparison.—Sculpins are represented by one right maxilla, one right palatine, a left quadrate, and a right cleithrum (UMMP V 74360). The cleithrum is like *C. beldingi* and *pitensis.* It differs from *Myoxocephalus* by the presence of a strong pelvic pedicel and the angle of the anterior limb. It differs from *Kerocottus* and *Cottus bairdi, rhotheus,* and *confusus* by the presence of a prominent posterior flange or apron at the center of the bone. The maxilla is thicker than in *bairdi,* with a shorter platform for the palatine and lachrymal. The quadrate matches *beldingi,* not *bairdi* or *pitensis,* in the shapes of the mesial and lateral faces of the articular condyle. The palatine is distinct from *C. bairdi, confusus,* and *rhotheus* in the absence of teeth; it is similar to *beldingi* and *pitensis.* On the whole, the fossils are most similar to

C. beldingi. This species is known from (Pliocene?) diatomite from 5 mi. south of Stillwater (east side of Lahontan Valley), Churchill Co. (Jordan, 1926).

DISCUSSION

Study of both molluscs and fishes of these two sites less than 100 miles apart in the bed of Pleistocene Lake Lahontan leads to conclusions not possible from the study of either group alone. Both sites are probably Pliocene.

The Mopung Hills molluscs (excepting one species) are extinct forms, lacking close relatives in the immediate region. They are pre-Lahontan on faunistic grounds, and are from rocks considered Pliocene on geological grounds (Willden and Speed, 1974).

The Honey Lake fossils occur in faulted and folded, frequently vertical, beds that were evidently deposited before early Pleistocene tectonism modified this region. All of the kinds of fishes are distinct from Lahontan species, showing resemblances and relationships to the Pliocene fauna of the Glenns Ferry Formation on the southwestern Snake River Plain. Relationships of most species of molluscs with the Snake River Plain are also evident. Excepting two widespread species, the molluscs are not characteristically Lahontan. Two are extinct, known only from Honey Lake. The remaining three species are known only from the major western basins within the modern Lahontan drainage.

The differences in the faunas emerge in the comparisons within groups. In contrast to the fishes of Honey Lake, those from the Mopung Hills lake are only slightly different from Lahontan species and can be regarded as ancestral to Lahontan forms. They probably survived in surrounding tributaries when desiccation or high salinity of the Mopung Hills lake eliminated the molluscs.

Molluscs from Mopung Hills are practically all known only from that area. They show no close relationships to any modern or extinct fauna. The Honey Lake molluscs include two localized species, but these, like most of the extant forms with which they were found, show relationships to Pleistocene and modern lakes and large streams along a band within and bordering the Great Basin. Some of these species are known from late Pleistocene Lake Lahontan, but most did not spread through that lake. Instead, they were or are confined to the major western basins now part of the Lahontan drainage.

In both faunas the narrowly localized species are molluscs, not fishes. But persistence of fauna within a given basin is inconsistent. The Mopung Hills fishes, not molluscs, show ancestral relationship to the modern fauna of nearby Pyramid Lake. The Honey Lake fishes are more like those of the Pliocene in southern Idaho, whereas the molluscs mostly survived nearby.

Environmental factors that could account for the different histories of the molluscs and fishes include elimination of certain habitats by climatic and tectonic changes. The lake in which the Mopung Hills species lived was effectively eliminated. Those forms specialized for a strictly lacustrine existence (molluscs) became extinct, while those able to live also in streams (fishes) survived to populate the Lahontan basin. Ancestral Honey Lake too was eliminated. The species that survived (molluscs not fishes) were those able to live also in creeks or large springs. Large-stream species became extinct. Possibly we see an effect of body size, determining minimum necessary habitat volume.

The distinctions between the Pliocene faunas from the Mopung Hills and Honey Lake localities require a barrier separating the two basins during the Pliocene and until near the end of the Pliocene. The remarkable lack of faunal overlap suggests that the basins were unconnected, and had remained so for some time. We infer that the present Lahontan basin is composite, including formerly separate basins with separate histories. Seemingly the Lahontan basin has enlarged by the reduction of topographic divides from the late Pliocene onward.

A similar conclusion has been drawn concerning the Bonneville basin (Taylor, in press), on similar grounds. Distribution of Miocene to modern molluscs indicates the breakup of external drainage and unification of several former drainages. This interpretation provides a similarity of history parallel to the modern topographic symmetry of the Bonneville and Lahontan basins. Late Pleistocene Lakes Bonneville and Lahontan, though impressive in volume and area, were relatively brief phenomena with little effect on distribution and evolution of molluscs and fishes.

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EXPLANATION OF PLATE 1

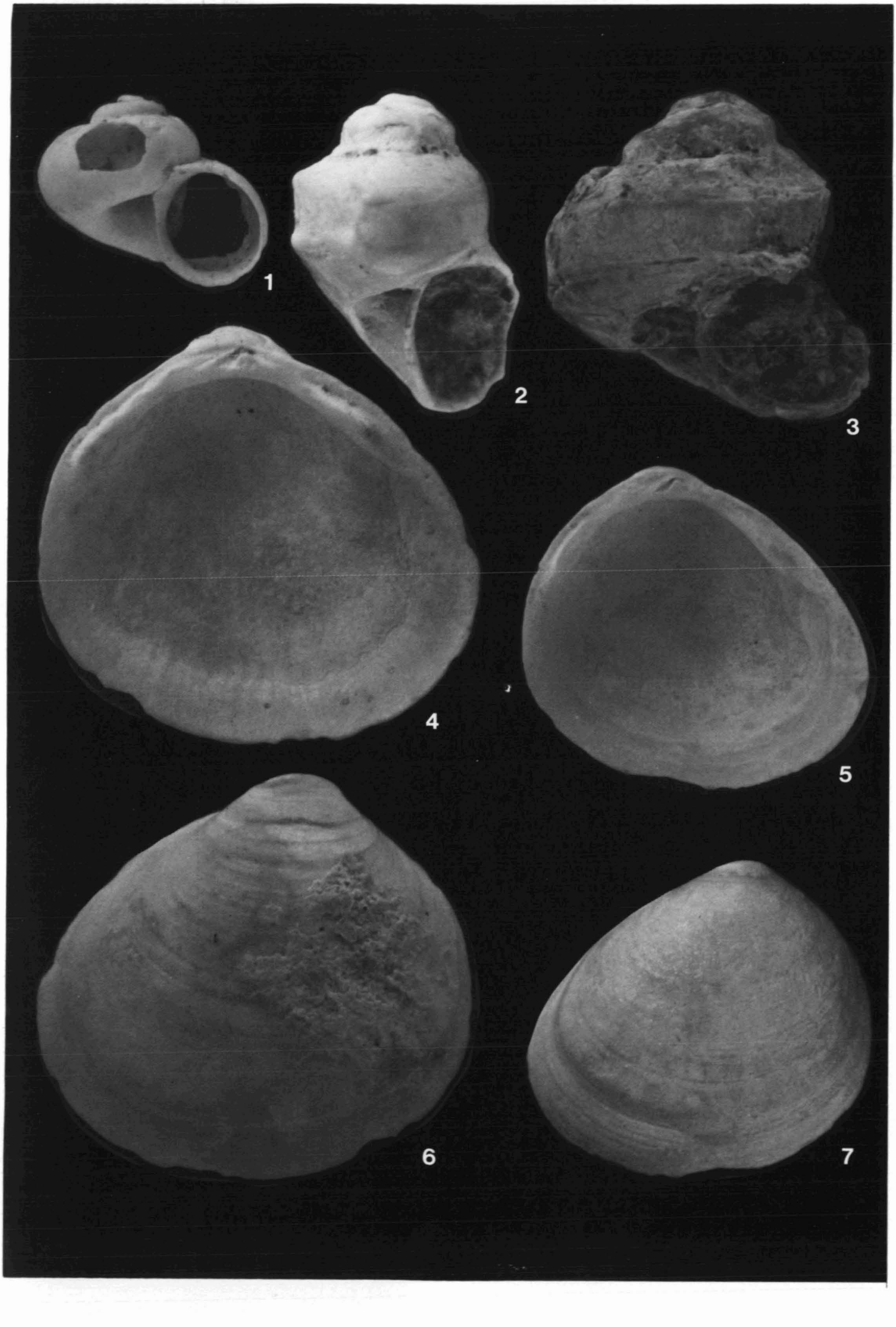
Fossil molluscs from Honey Lake, locality A

Figure 1 — *Valvata humeralis* Say, UMMZ 250091, width 3.4 mm.

Figures 2, 3 —*Valvata utahensis* Call, (2) UMMZ 250092, length 4.7 mm; (3) UMMZ 250092, length 4.7 mm.

Figures 4, 6 —*Pisidium ultramontanum* Prime, UMMZ 250093, length 6.2 mm.

Figures 5, 7 —*Pisidium compressum* Prime, UMMZ 250094, length 4.8 mm.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EXPLANATION OF PLATE 2

Fossil molluscs from Honey Lake

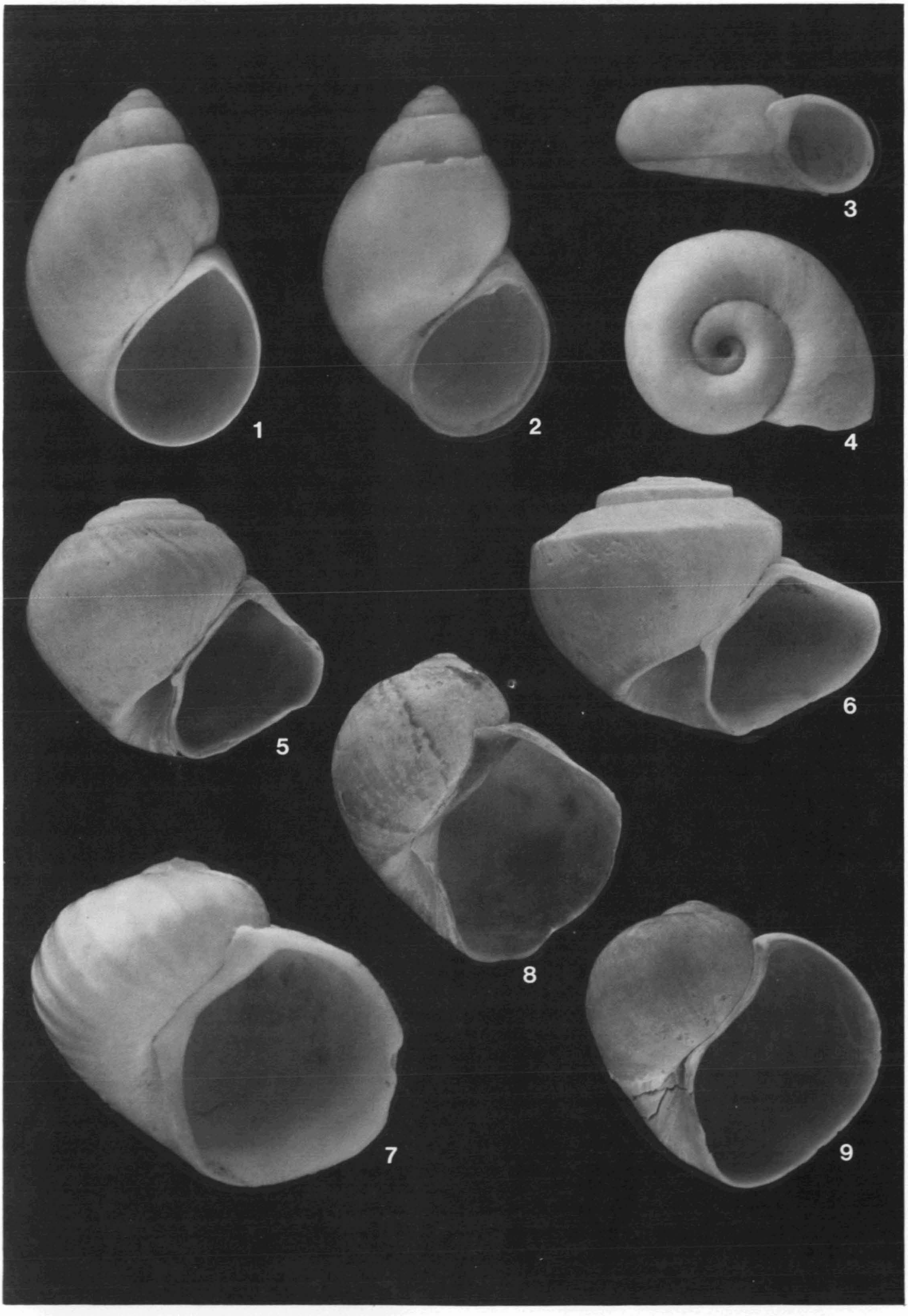
Figures 1, 2 —*Fontelicella melina* Taylor, n. sp., Pliocene, locality A, (1) UMMZ 250096, length 5.0 mm; (2) type, UMMZ 250095, length 4.9 mm.

Figures 3, 4 —*Gyraulus parvus* (Say). Pliocene, locality A, UMMZ 250097, width 3.6 mm.

Figures 5, 6 —*Helisoma newberryi* (Lea), Pliocene, locality B, (5) UMMZ 250098, length 10.5 mm; (6) UMMZ 250098, length 10.6 mm.

Figure 7 — *Vorticifex effusus* (Lea), Pleistocene, locality A, UMMZ 250099, length 4.5 mm.

Figures 8, 9 —*Vorticifex lasseni* Taylor, n. sp., Pliocene, locality B, (8) UMMZ 250101, length 12.5 mm; (9) type, UMMZ 250100, length 11.8 mm.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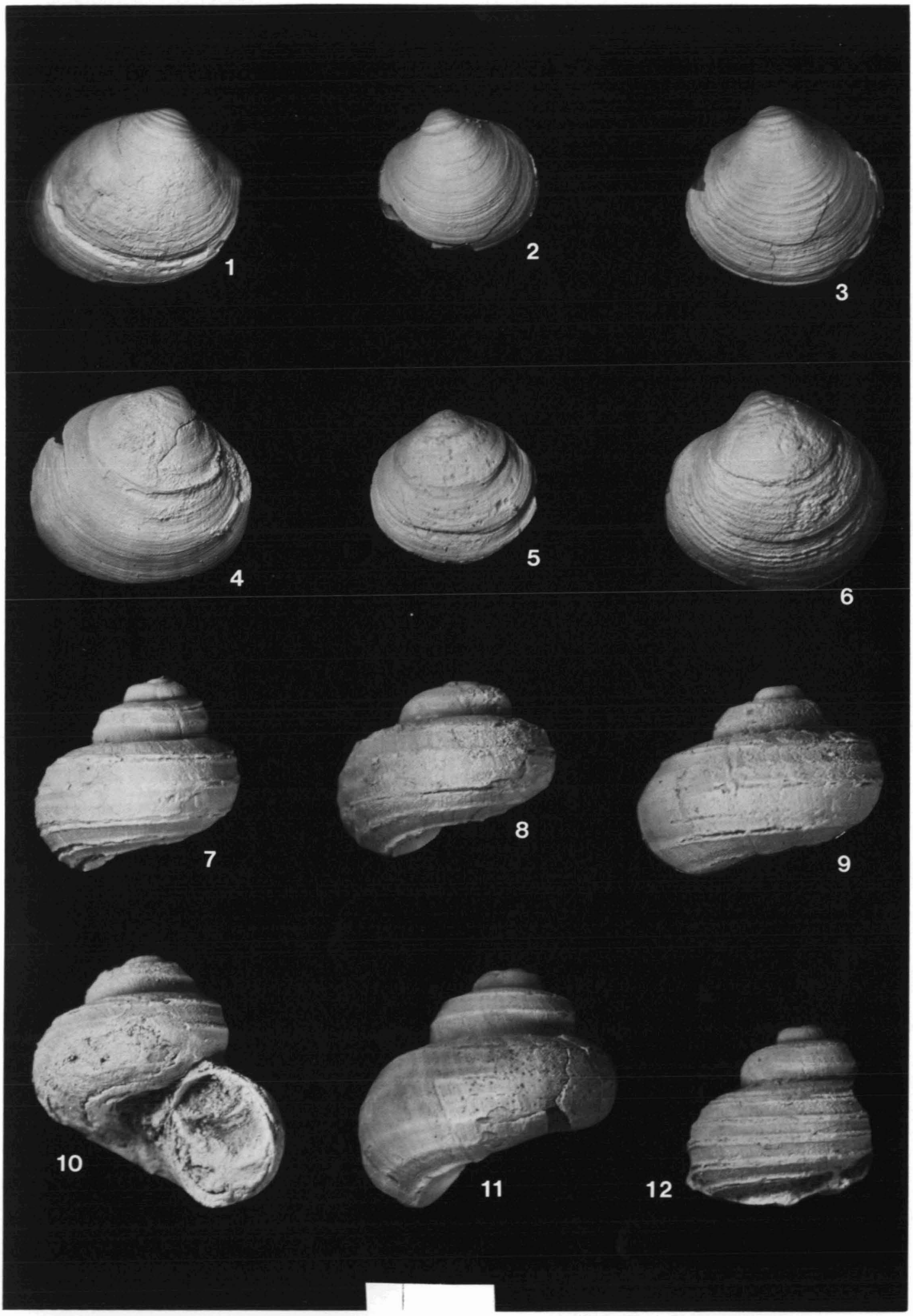
EXPLANATION OF PLATE 3

Fossil molluscs from Mopung Hills

Figures 1–6 —*Sphaerium nevadense* Taylor, n. sp., locality B. (1) type, UMMZ 250102, length 8.7 mm, height 7.8; (2) UMMZ 250103, length 6.4 mm, height 5.8; (3) UMMZ 250103, length 7.5 mm, height 7.2; (4) UMMZ 250103, length 8.8 mm, height 8.0; (5) UMMZ 250103, length 6.8 mm, height 6.1; (6) UMMZ 250103, length 8.8 mm, height 8.0.

Figures 7–12 —*Valvata nevadensis* Taylor, n. sp., locality C. (7) UMMZ 250105, width 4.2 mm; (8) UMMZ 250105, width 4.6 mm; (9) UMMZ 250105, width 4.9 mm; (10, 11) type, UMMZ 250104, width 5.3 mm; (12) UMMZ 250105, width 3.9 mm.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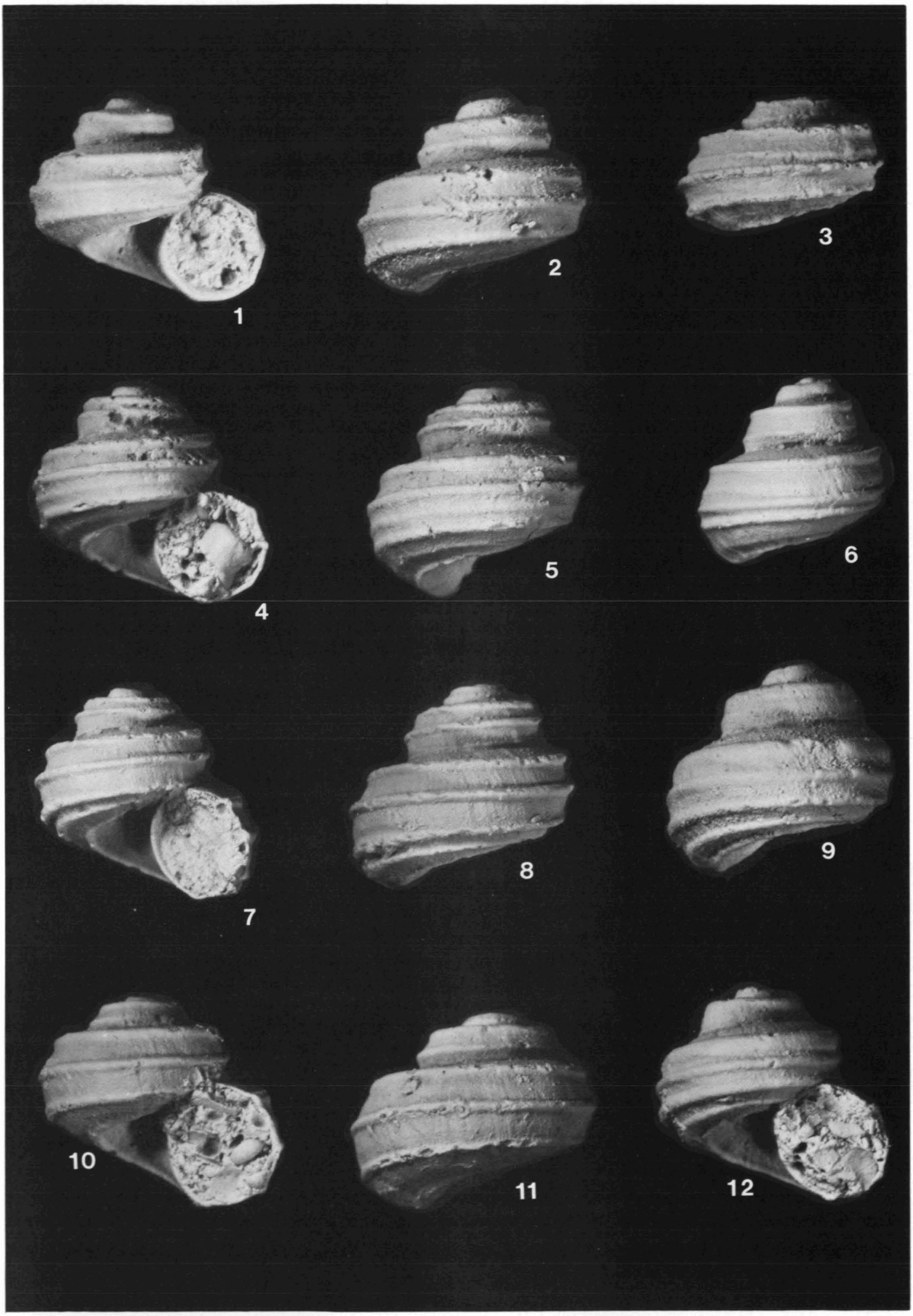
EXPLANATION OF PLATE 4

Valvata idahoensis Taylor, n. sp. from Salt Lake Group, Idaho. (1, 2) holotype, USNM 559943, width 4.7 mm; (3) paratype, USNM 559944, width 4.2 mm; (4, 5) paratype, USNM 559944, width 4.8 mm; (6) paratype, USNM 559944, width 3.9 mm; (7, 8) paratype, USNM 559944, width 4.7 mm; (9, 12) paratype, USNM 559944, width 4.8 mm; (10, 11) paratype, USNM 559944, width 5.2 mm.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EXPLANATION OF PLATE 5

Lutrilimnea polyskelidis Taylor, n. sp., from Mopung Hills. (1–3, 7) type, UMMZ 250106, locality C, length 36 mm; (4, 5) UMMZ 250108, locality A, length 27 mm; (6, 8, 11) UMMZ 250108, locality A, length 44 mm; (9) UMMZ 250107, locality C, length 44 mm; (10, 12, 13) UMMZ 250107, locality C, length 43 mm; (14, 15, 18) UMMZ 250108, locality A, length 7.1 mm; (16, 17) UMMZ 250108, locality A, length 39 mm.


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EXPLANATION OF PLATE 6

Lutrilimnea polyskelidis Taylor, n. sp., from Mopung Hills. (1, 2) UMMZ 250109, locality B, length 11.5 mm; (3, 9) UMMZ 250108, locality A, length 11.2 mm; (4) UMMZ 250109, locality B, length 15.3 mm; (5, 6) UMMZ 250109, locality B, length 7.4 mm; (7) UMMZ 250109, locality B, length 5.8 mm; (8, 10, 11) UMMZ 250109, locality B, length 7.5 mm.


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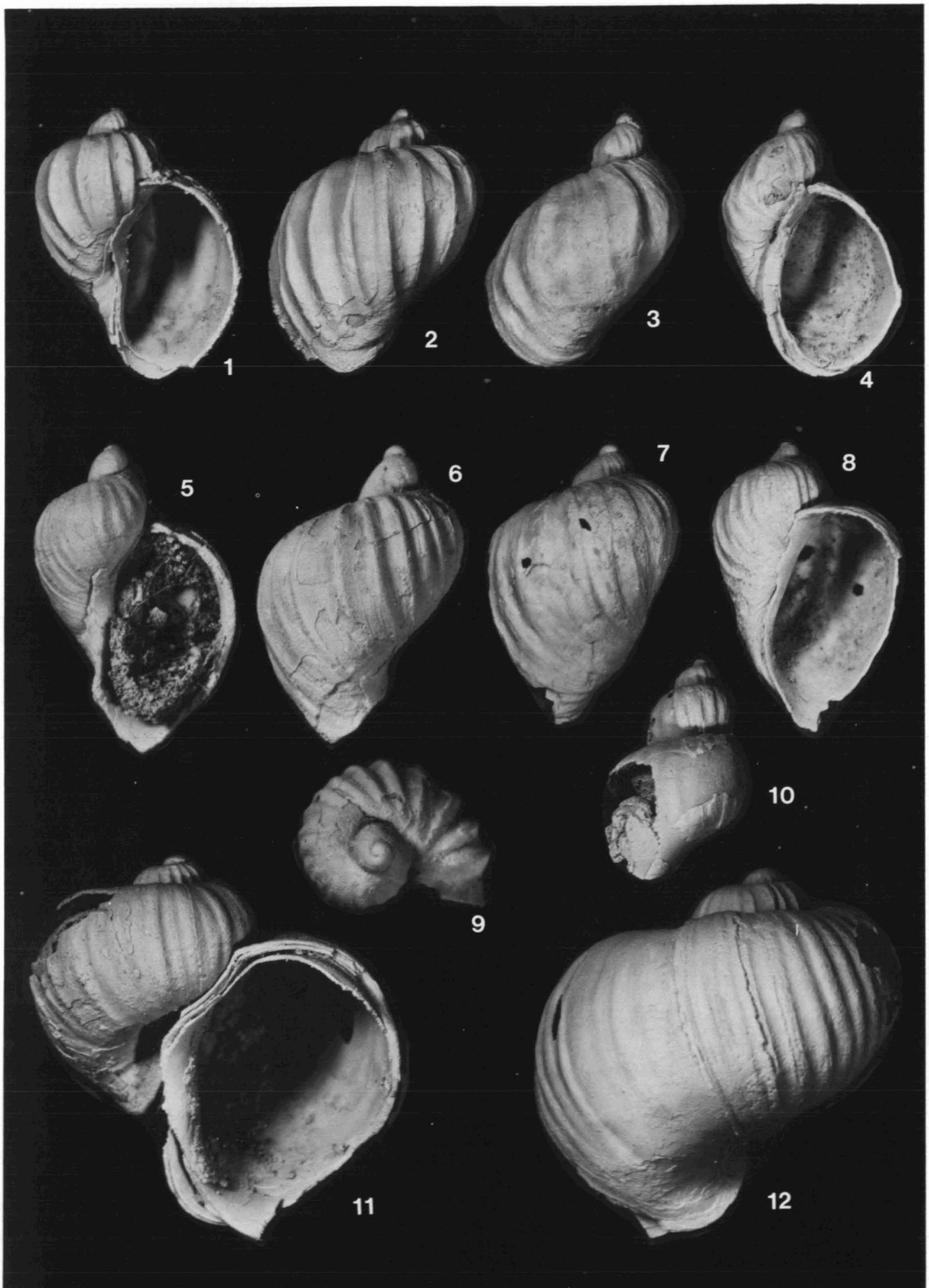
EXPLANATION OF PLATE 7

Lutrilimnea polyskelidis Taylor, n. sp., from Mopung Hills. (1, 2) UMMZ 250108, locality A, length 10.5 mm; (3, 4) UMMZ 250108, locality A, length 10.2 mm; (5, 6, 9) UMMZ 250108, locality A, length 6.0 mm; (7, 8) UMMZ 250108, locality A, length 11.3 mm; (10) UMMZ 250109, locality B, length 9.2 mm; (11, 12) UMMZ 250108, locality A, length 15.3 mm.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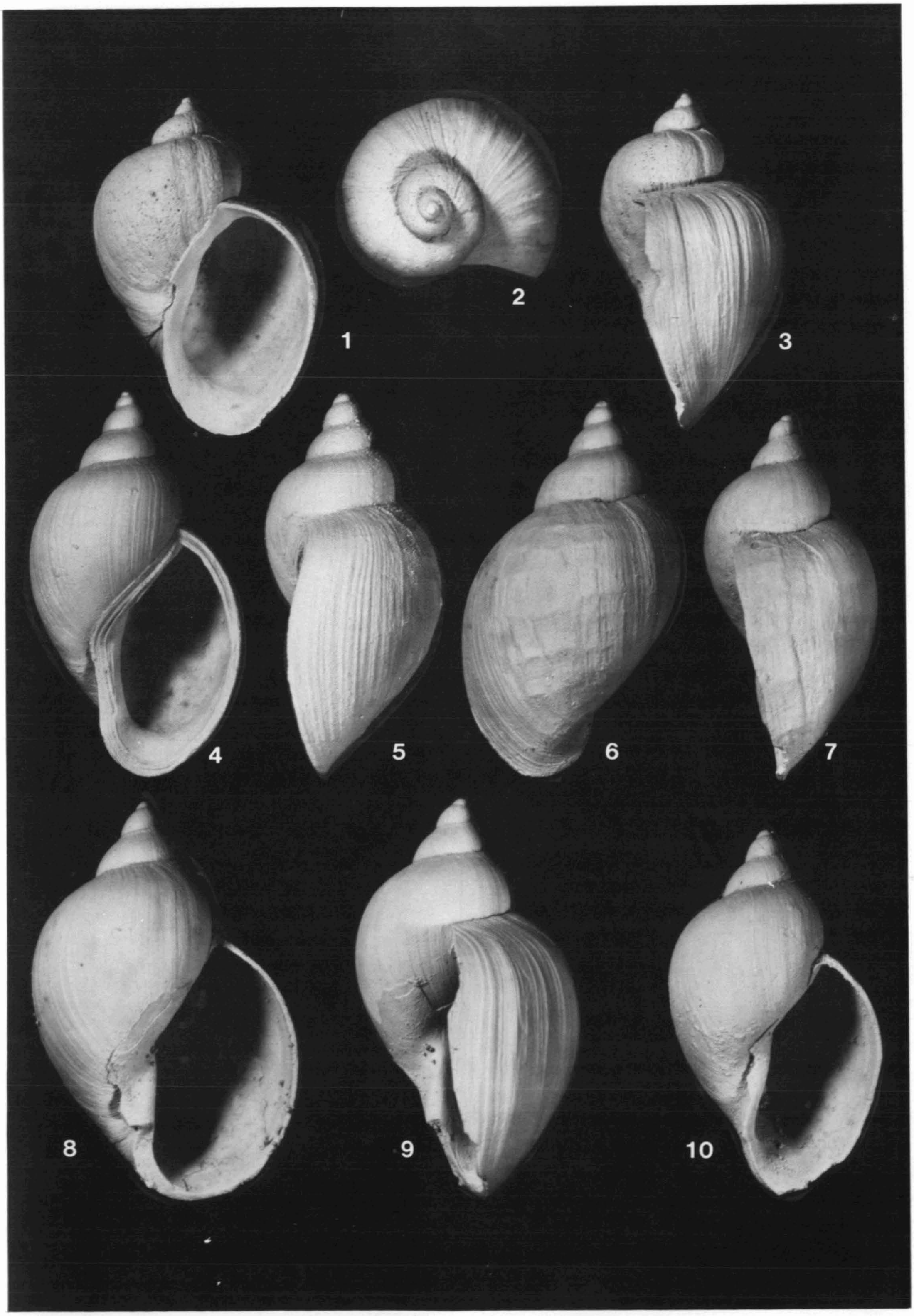
EXPLANATION OF PLATE 8

Lutrilimnea gentilis Taylor, n. sp., Pleistocene, Thatcher basin, Idaho. (1–3) UMMZ 250111, locality MC-6, length 13.3 mm; (4, 5) type, UMMZ 250110, locality Hanks 3, length 15.2 mm; (6, 7, 10) UMMZ 250112, locality Hanks 2, length 14.4 mm; (8, 9) UMMZ 250112, locality Hanks 2, length 16.0 mm.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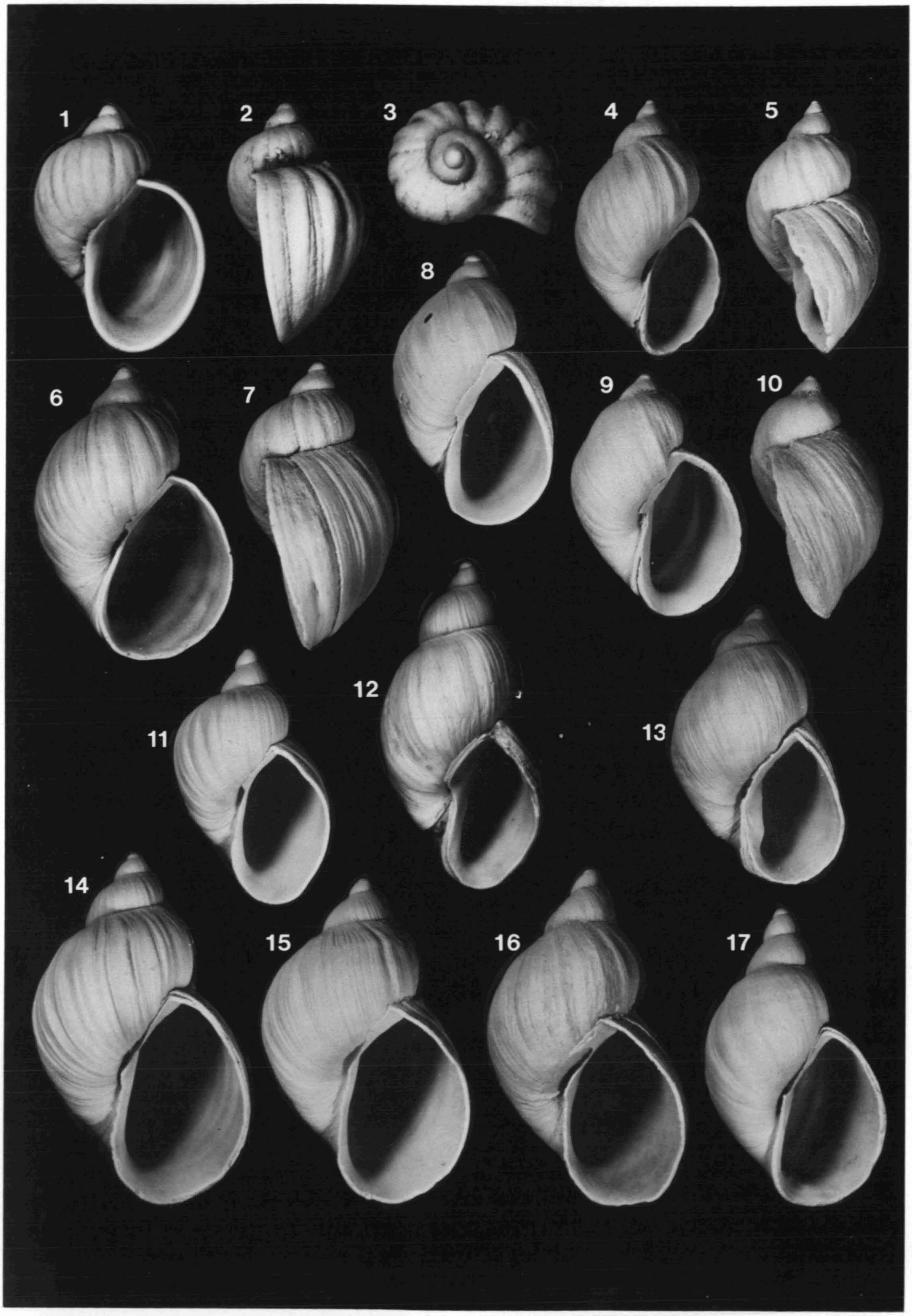
EXPLANATION OF PLATE 9

Lutrilimnea ursina Taylor, n. sp., Holocene, Bear Lake, Utah. (1–3) UMMZ 250114, length 10.0 mm; (4, 5) UMMZ 250114, length 10.1 mm; (6, 7) UMMZ 250114, length 11.6 mm; (8) UMMZ 250114, length 10.8 mm; (9, 10) UMMZ 250114, length 9.7 mm; (11, Broken after illustration); (12) UMMZ 250114, length 13.1 mm; (13) UMMZ 250114, length 10.9 mm; (14) type, UMMZ 250113, length 14.1 mm; (15) UMMZ 250114, length 12.9 mm; (16) UMMZ 250114, length 13.5 mm; (17) UMMZ 250114, length 11.9 mm.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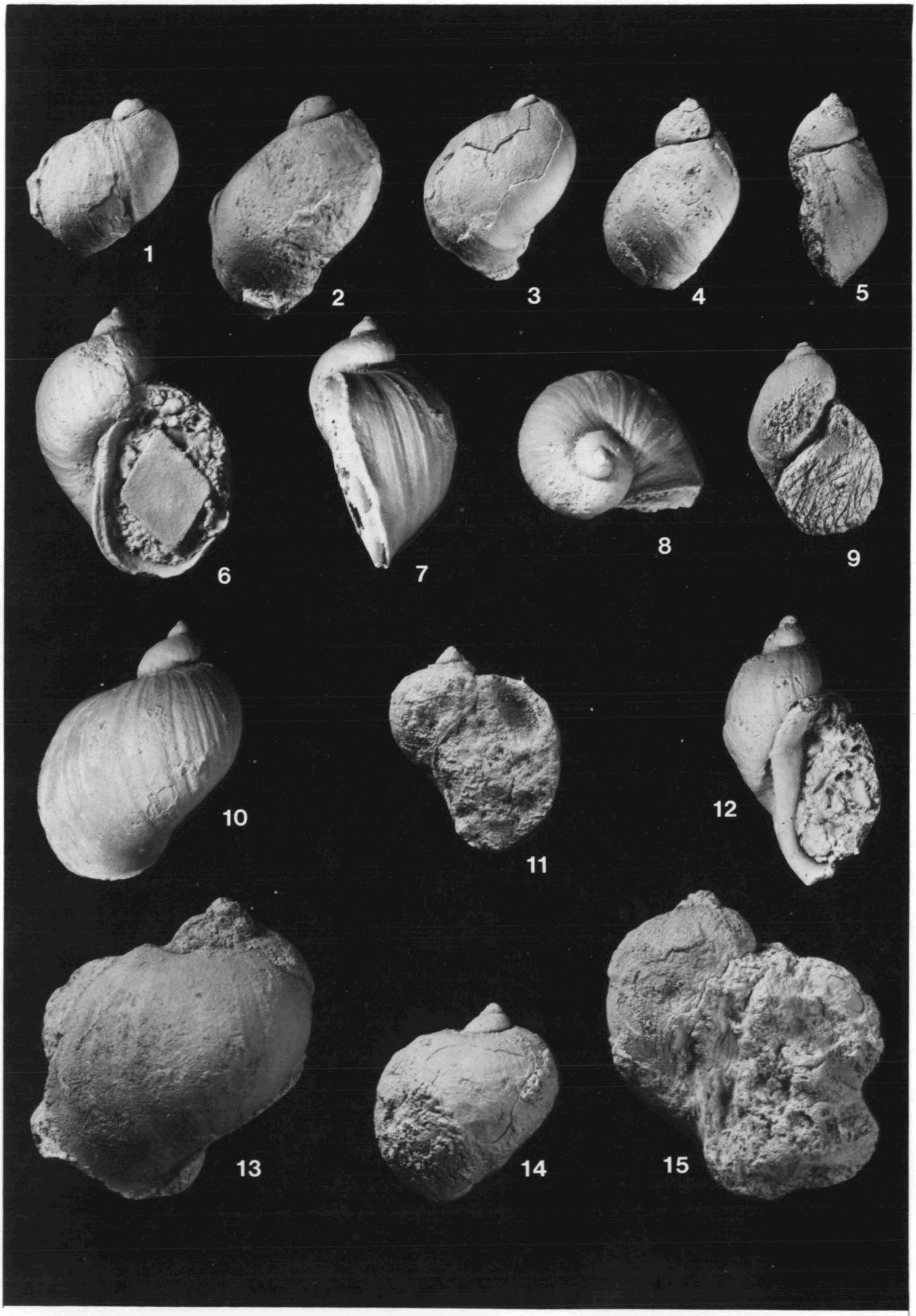
EXPLANATION OF PLATE 10

Fossil Lymnaeidae. *Radix venusta* (Russell, 1938), Oligocene, Antero Formation, Colorado. (1) USNM 305771, length 11.1 mm; (2) USNM 305772, length 15.2 mm; (3) USNM 305773, length 12.6 mm; (4, 5, 9) holotype, USNM 497658, length 12.8 mm. *Radix intermontana* Taylor. (6–8, 10) holotype, USNM 559955, Miocene, Salt Lake Formation, Idaho, length 10.4 mm; (11, 14) USNM 644857, Miocene, Allison Ranch, Nevada, figured by Taylor (1966), length 13.6 mm; (12) USNM 559957, Miocene, Salt Lake Formation, Idaho, length 10.3 mm; (13, 15) USNM 644858, Miocene, Allison Ranch, Nevada, figured by Taylor (1966), length 21 mm.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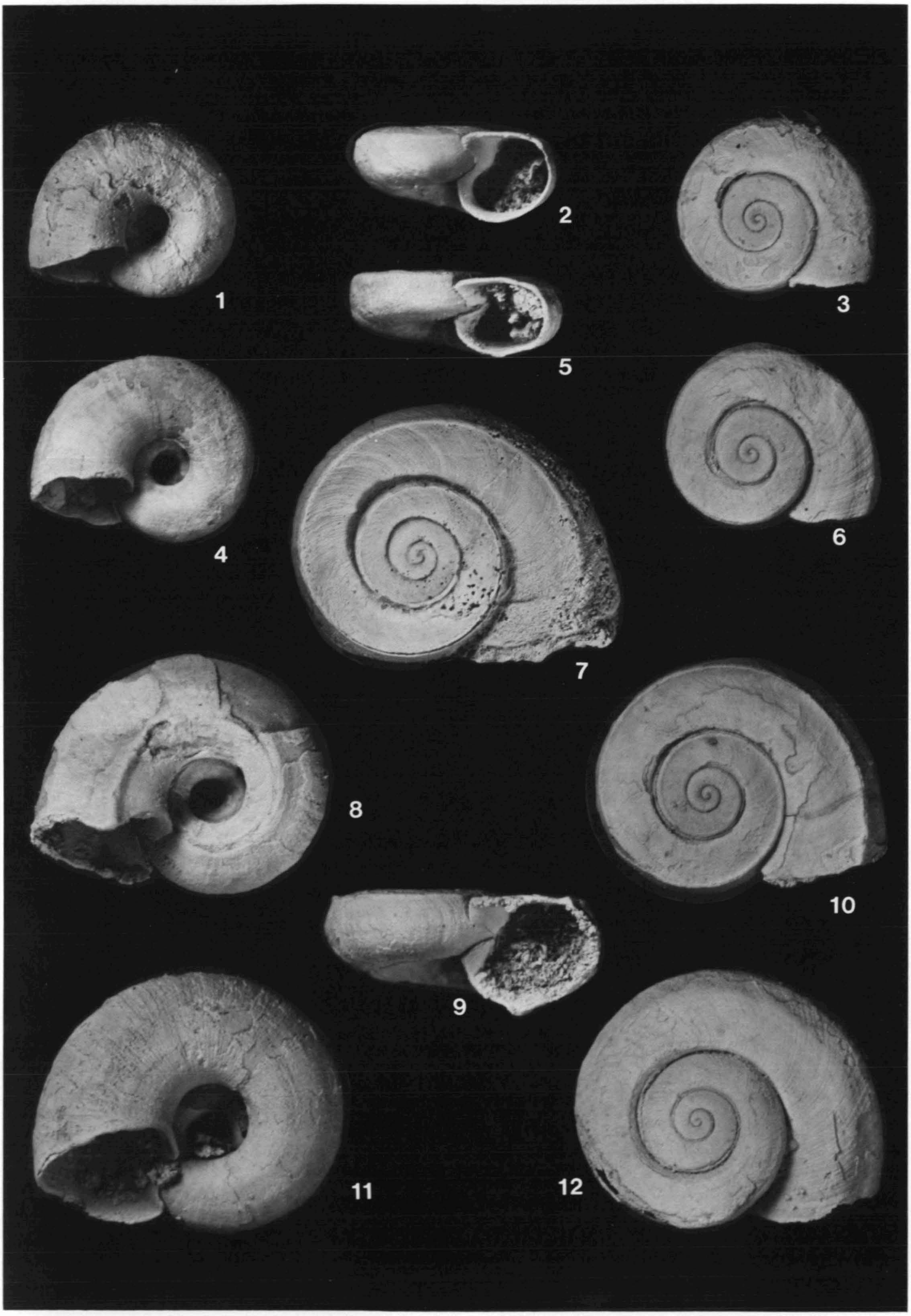
EXPLANATION OF PLATE 11

Menetus carinifex Taylor, n. sp., from Mopung Hills. (1–3) UMMZ 250116, locality A, width 4.4 mm; (4–6) UMMZ 250116, locality A, width 4.6 mm; (7) UMMZ 250117, locality C, width 6.8 mm; (8–10) UMMZ 250116, locality A, width 6.2 mm; (11, 12) UMMZ 250115, type, locality A, width 6.6 mm.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EXPLANATION OF PLATE 12

Menetus carinifex Taylor, n. sp., from Mopung Hills, Locality A. (1–3, 6) UMMZ 250116, width 5.8 mm; (4, 5, 7) UMMZ 250116, width 5.2 mm; (8–11) UMMZ 250116, width 6.7mm.


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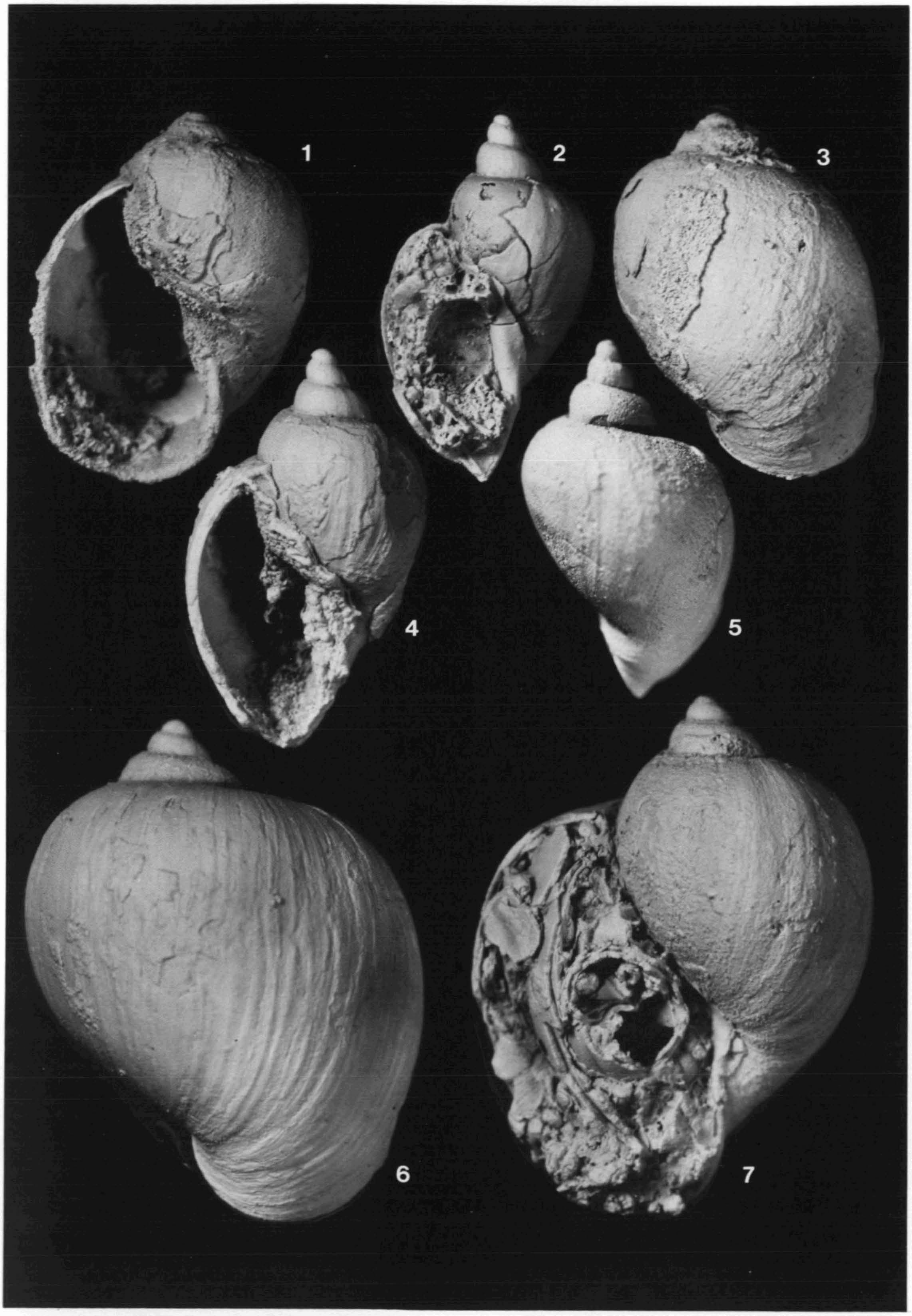
EXPLANATION OF PLATE 13

Physa humboldtiana Taylor, n. sp., from Mopung Hills. (1, 3) UMMZ 250119, locality A, height 7.8 mm; (2, 5) UMMZ 250120, locality B, height 7.1 mm; (4) UMMZ 250120, locality B, height 8.0 mm; (6, 7) UMMZ 250120, locality B, height 10.3 mm.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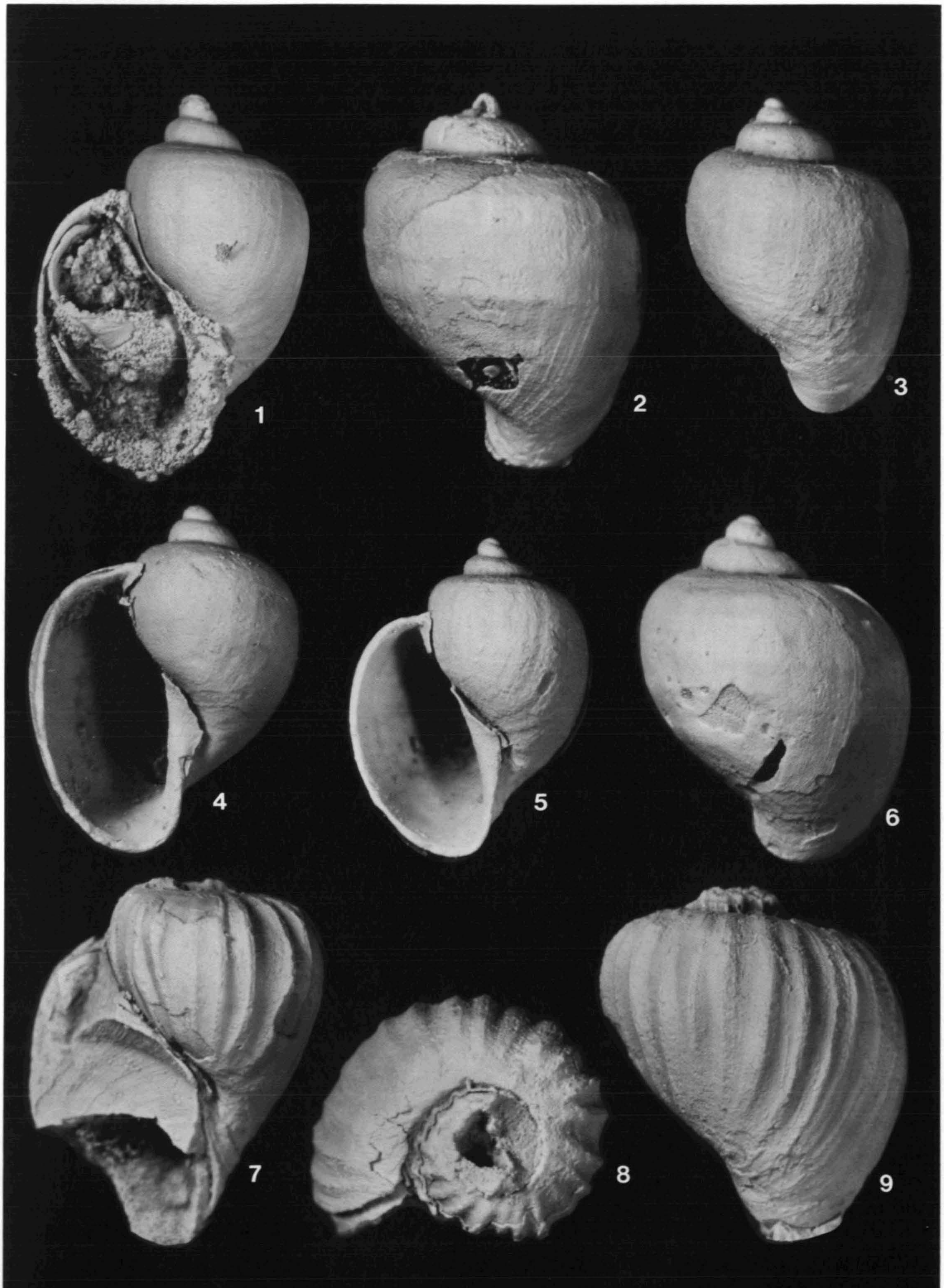
EXPLANATION OF PLATE 14

Physa humboldtiana Taylor, n. sp., from Mopung Hills, locality A. (1, 2) UMMZ 250119, height 7.5, 7.3 mm; (3, 5) UMMZ 250119, height 6.2 mm; (4, 6) UMMZ 250119, height 6.9 mm; (7–9) type, UMMZ 250118, height 7.5 mm as preserved.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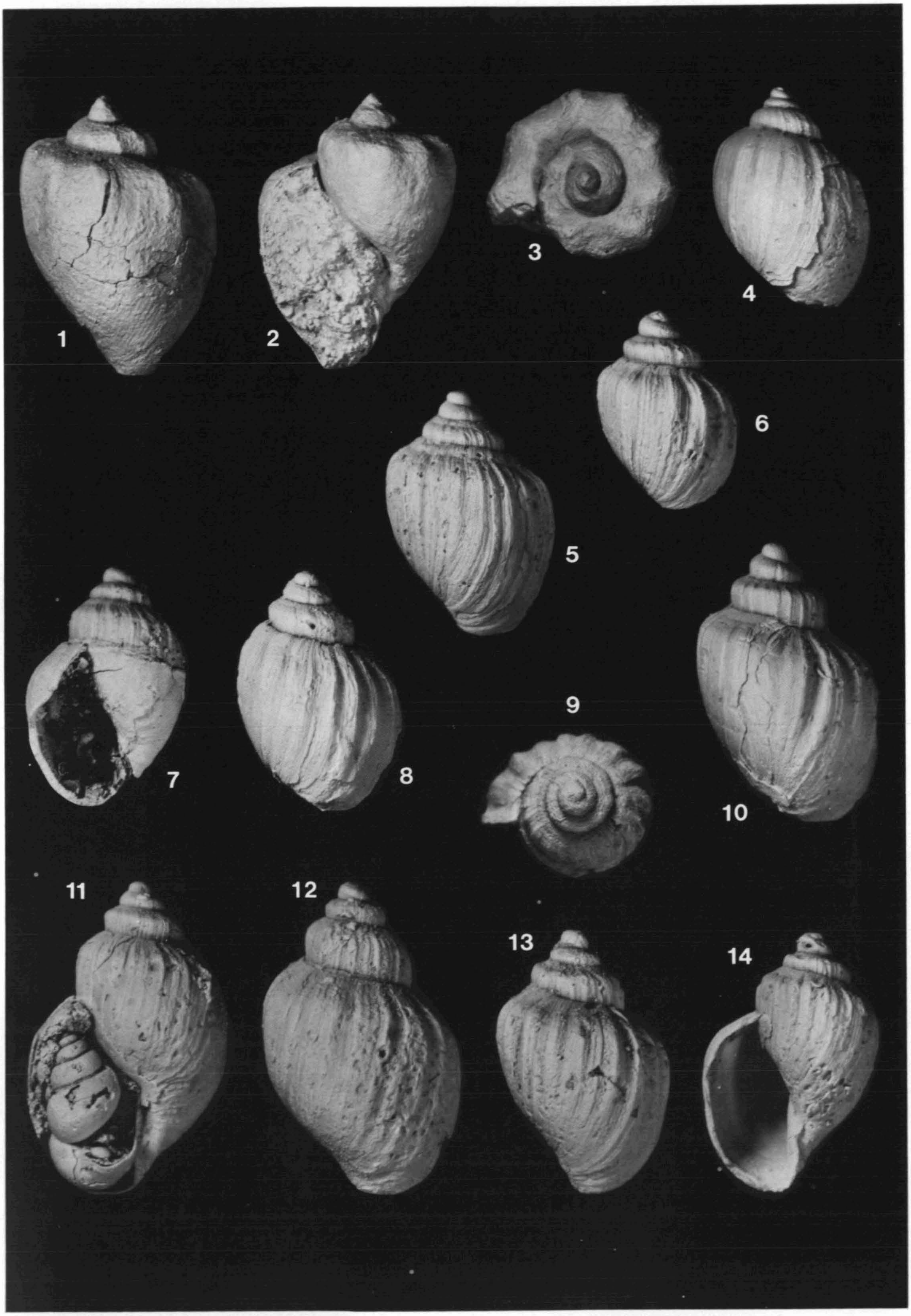
EXPLANATION OF PLATE 15

Physa wattsi Arnold, Pliocene, Kettleman Hills, California. Figs. 1–4, U. S. Geological Survey Locality 12556. (1–3) USNM 305774, height 11.0 mm; (4) USNM 305775, height 8.8 mm. Figs. 5–14, U. S. Geological Survey Locality 12479. (5) USNM 305776, height 4.9 mm; (6) USNM 305777, height 4.0 mm; (7–9, fragmented after photographing); (10, fragmented after photographing); (11, 12) USNM 305778, height 6.2 mm; (13, 14) USNM 305779, height 5.3 mm.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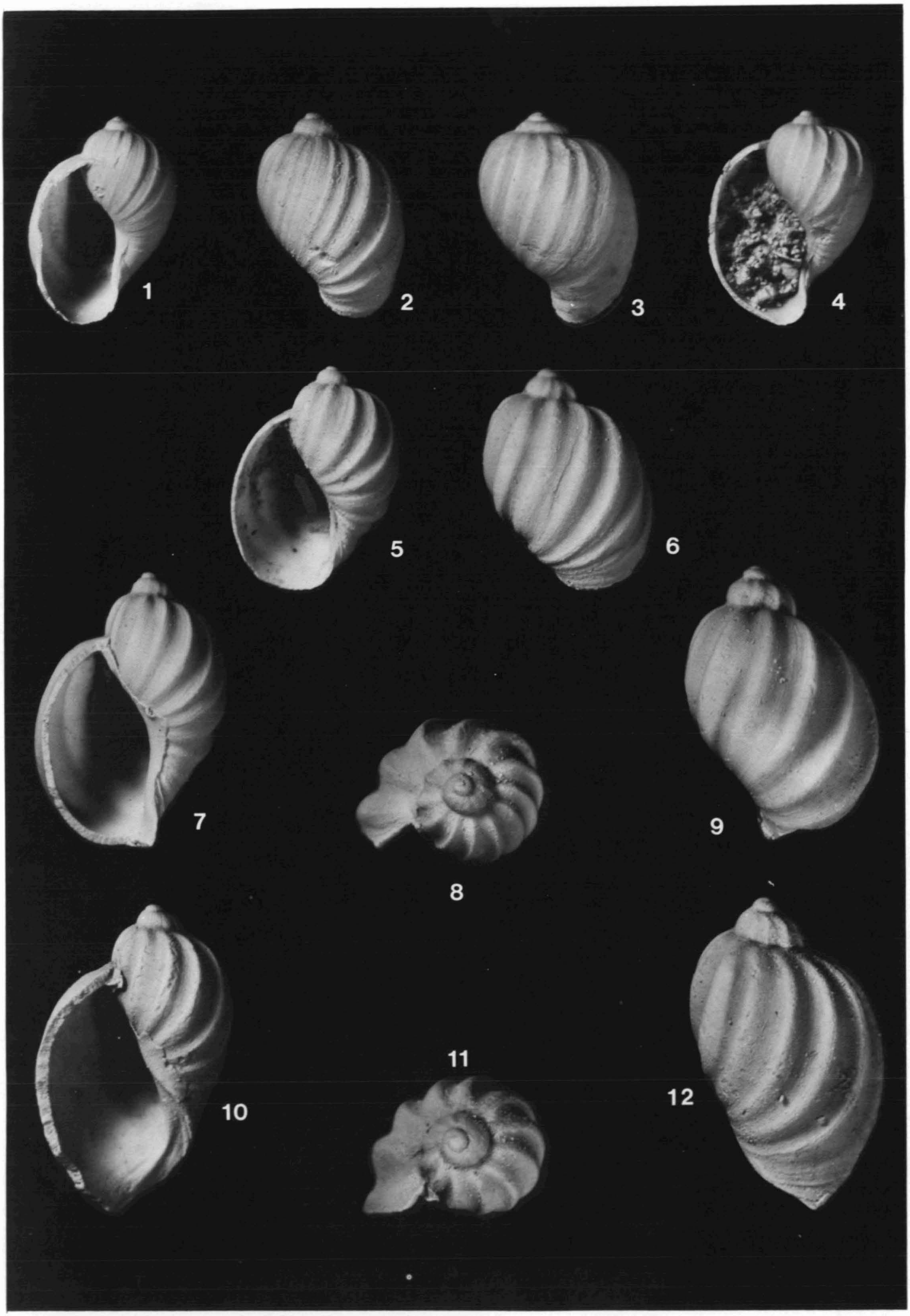
EXPLANATION OF PLATE 16

Physa harpa Taylor, n. sp., Pliocene, Cache Valley Formation, Utah. (1, 2) USNM 305780, height 4.2 mm; (3, 4) USNM 305781, height 4.2 mm; (5, 6) USNM 305782, height 4.5 mm; (7–9) USNM 305783, type, height 5.5 mm; (10–12) USNM 305784, height 6.4 mm.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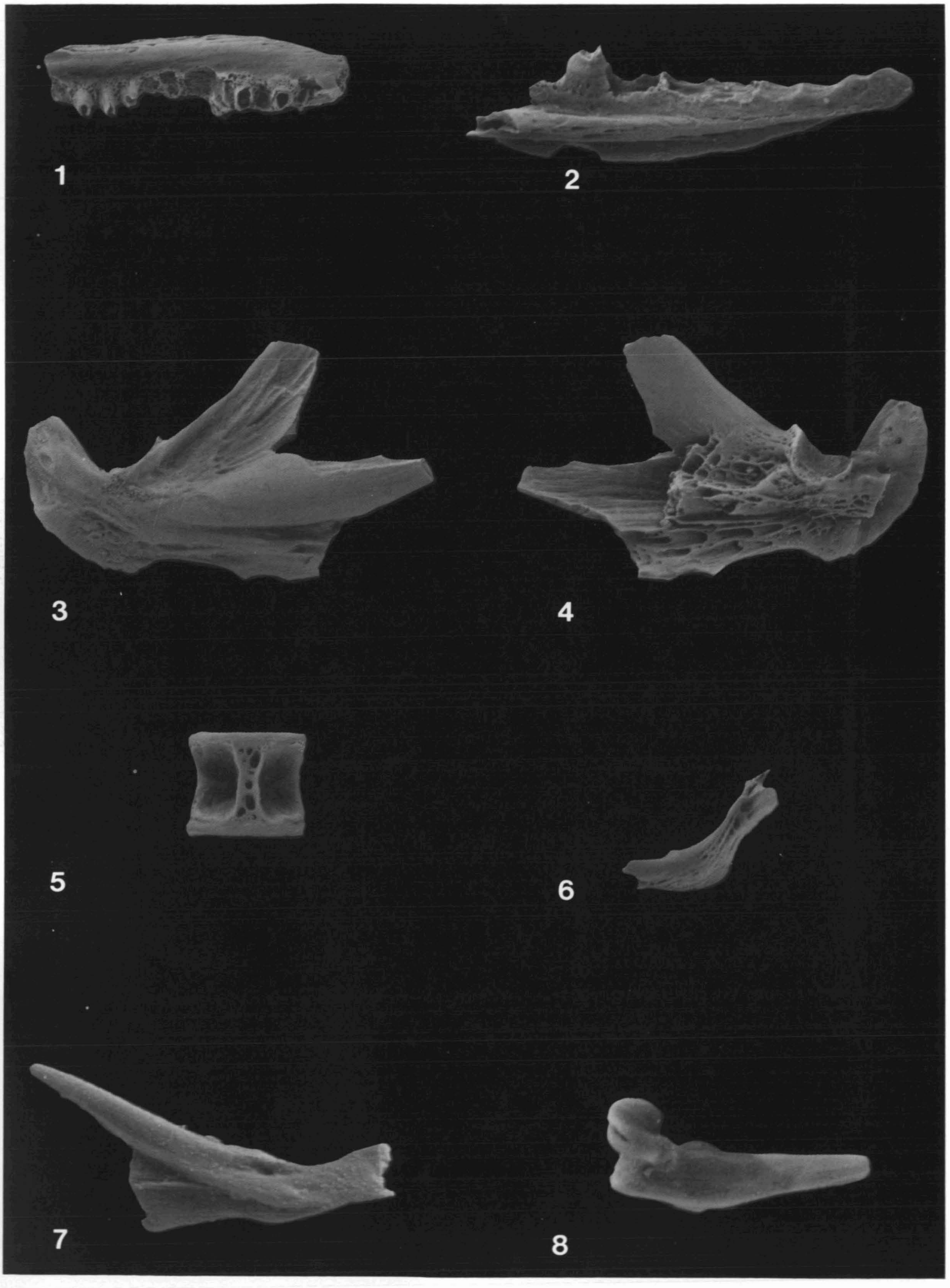
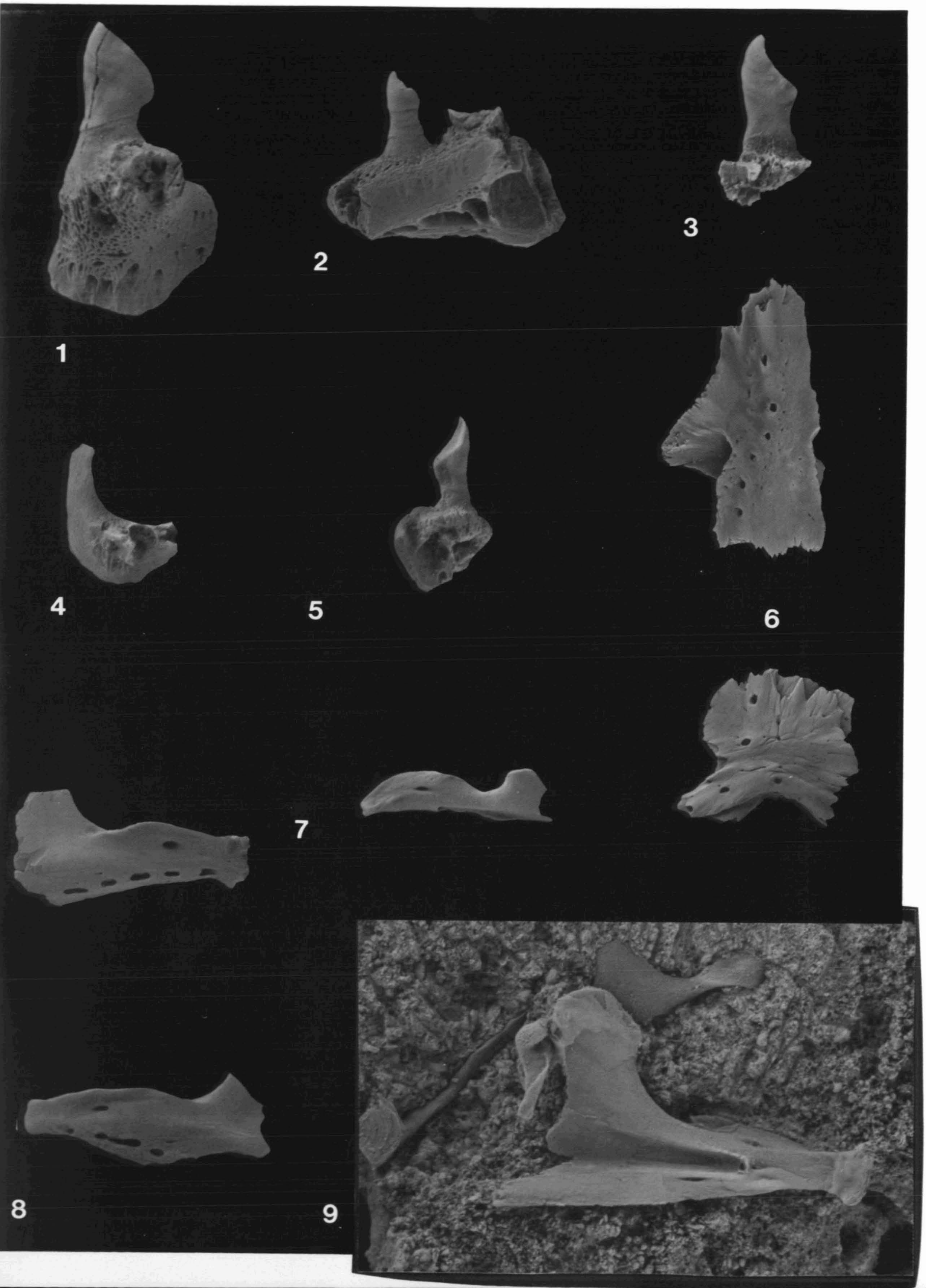
EXPLANATION OF PLATE 17

(1) Mesial view of partial right maxilla of *Rhabdofario* sp., UMMP V 74712, from locality B, Honey Lake; (2) mesial view of partial right dentary of *Salmo* sp., UMMP V 74720, X4, from Mopung Hills; (3, 4) lateral and mesial views of partial right angular-articular of *Salmo* sp., UMMP V 74720, from Mopung Hills; (5) dorsal view of a thoracic vertebra of *Salmo* sp., UMMP V 74720, X4, from Mopung Hills; (6) lateral view of partial left cleithrum of *Cottus* cf. *C. beldingi*, UMMP V 74721, X4, from Mopung Hills; (7) ventral view of left palatine (anterior to the right) of *Cottus* cf. *C. beldingi*, UMMP 74721, X16, from Mopung Hills; (8) mesial view of anterior end of right maxilla of *Cottus* cf. *C. beldingi*, UMMP V 74721, X16, from Mopung Hills.



EXPLANATION OF PLATE 18

(1) Right pharyngeal, with second tooth, of *Gila* sp., UMMP V 74705, X4, from locality B, Honey Lake; (2) left pharyngeal, with second tooth and base of first minor tooth, of *Gila* sp., UMMP V 74705, X4, from locality B, Honey Lake; (3) left third tooth of *Gila (Siphateles)* sp., UMMP V 74723, X8, from Mopung Hills; (4) posterior part of left pharyngeal arch, showing single row of teeth, of *Gila (Siphateles)* sp., UMMP V 74723, X4, from Mopung Hills; (5) right second tooth of *Gila (Siphateles)* sp., UMMP V 74723, X8, from Mopung Hills; (6) left frontal and parietal of *Gila* sp., UMMP V 74713, X3, from locality B, Honey Lake; (7) right dentaries (lateral and dorsal views) of *Gila* sp., UMMP V 74714, X4, from locality B, Honey Lake; (8) left dentary (lateral view) of *Gila (Siphateles)* sp., UMMP V 74724, X4, from Mopung Hills; (9) right maxilla, left dentary, and first centrum with rib of *Gila (Siphateles)* sp., UMMP V 74725, X4, from Mopung Hills.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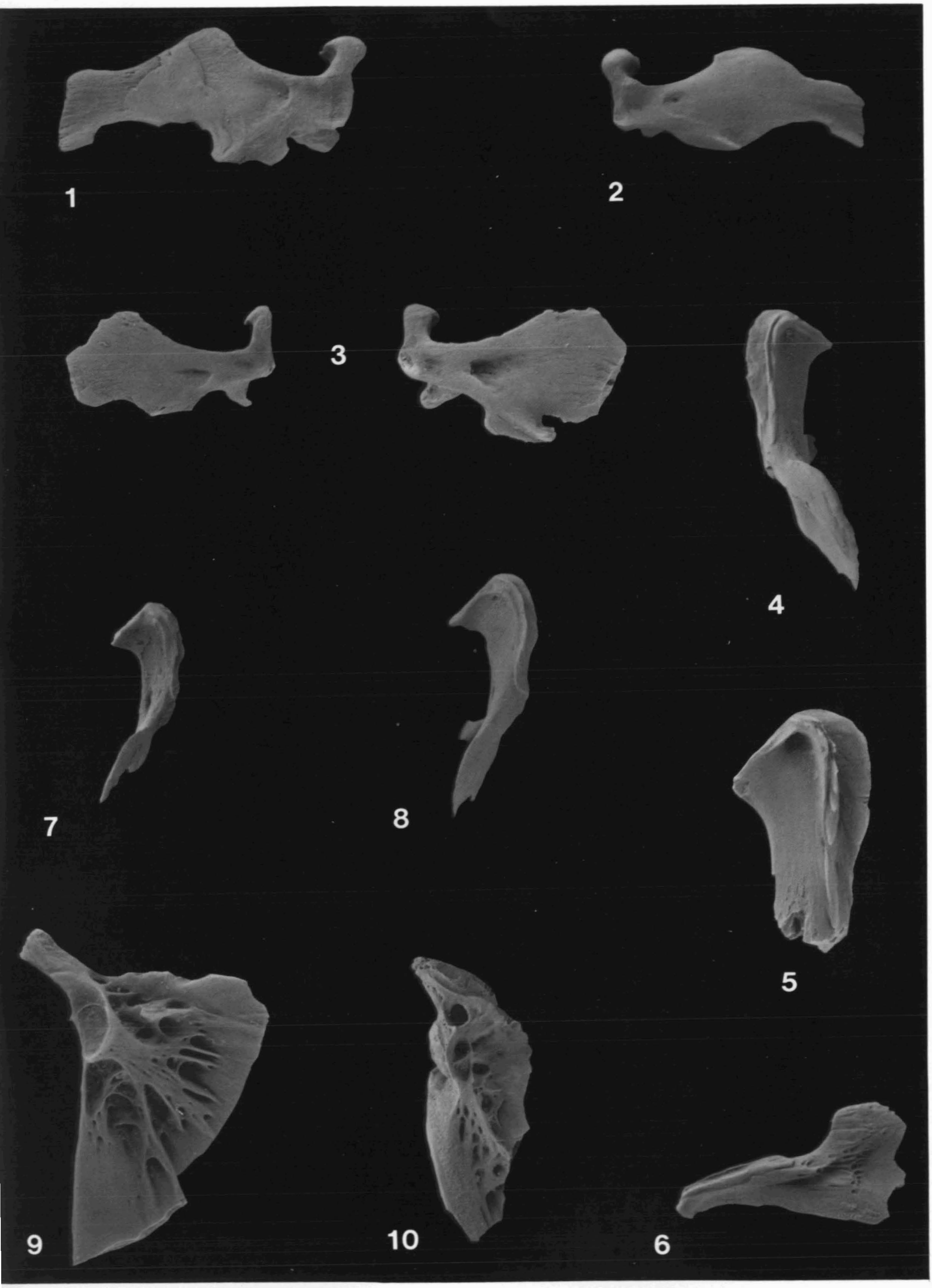
EXPLANATION OF PLATE 19

(1) Right maxilla (lateral view) of *Catostomus* cf. *C. tahoensis*, UMMP V 74722, X4, from Mopung Hills; (2) left maxilla of *Catostomus tahoensis*, UMMZ 174437, X3, from Pyramid Lake; (3) right and left maxillae of *Catostomus* sp., UMMP V 74704, X4, from locality B, Honey Lake; (4) left dentary (dorsal view), X3, (5) right dentary, X5, and (6) left dentary (lateral view), X5, of *Catostomus* sp., UMMP V 74703, from locality B, Honey Lake; (7) Right dentary of *Catostomus* cf. *C. tahoensis*, UMMP V 74722, X4, from Mopung Hills; (8) right dentary of *Catostomus tahoensis*, UMMZ 174437, X4, from Pyramid Lake; (9) right opercle (mesial view) of *Chasmistes* sp., UMMP V 74462), X4, from locality B, Honey Lake; (10) left hyomandibular (mesial view) of *Chasmistes* sp., UMMP V 74461, X2, from locality B, Honey Lake.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