Nonmarine Mollusks From Barstow Formation of Southern California

By DWIGHT W. TAYLOR

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

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Descriptions and illustrations of new and already-described mollusks of late Miocene age, and a discussion of their environment

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By DWIGHT W. TAYLOR

ABSTRACT

A molluscan fauna of eleven species is described from the continental upper Miocene Barstow formation near Barstow, in southern California. It is associated with the type fauna of vertebrate paleontologists' Barstovian Age, and is the first nonmarine mollusk fauna of Tertiary age reported from the southern Great Basin. Four species are described as new: *Lymnaea mohaveana, Menetus? micromphalus, Craterarion pachyostracon* (new genus and species) and *Helminthoglypta alfi.*

The fauna is most closely related to the one now living in the same region and is not known to occur in other areas. Other late Tertiary nonmarine molluscan faunas show geographic localization also. Correlation over the western United States by means of these faunas is impossible at the present time, but practicable within areas of localization.

INTRODUCTION

This report describes a small late Miocene nonmarine molluscan fauna from the Barstow formation of Southern California, and presents certain conclusions concerning it and other molluscan faunas of western North America.

Several late Miocene molluscan assemblages are known, although not well, from western North America. The Barstow fauna is the first Tertiary nonmarine fauna from the southern Great Basin. The large number of associated vertebrates provide an accurate age determination for the mollusks.

The author is grateful to the following persons for advice and aid in the study and in the preparation of the report: Mr. R. M. Alf, Webb School, Claremont, Calif.; Dr. S. S. Berry, Redlands, Calif.; Dr. J. W. Durham, University of California; Mr. S. C. Gifford, Redlands, Calif.; Dr. W. O. Gregg, Los Angeles, Calif.; Dr. D. F. Hewett, U. S. Geological Survey and California Institute of Technology; Dr. A. M. Keen, Stanford University; Dr. Thane McCulloh, California Institute of Technology; Mr. M. C. McKenna, University of California; Dr. D. E. Savage, University of California; the late Dr. Chester Stock, California Institute of Technology; and Dr. A. O. Woodford, Pomona College.

The following abbreviations are used to indicate collections: B, S. Stillman Berry; G, W. O. Gregg; P, Pomona College; S, Stanford University Paleontological Type Collection; T, D. W. Taylor; UC, University of California Museum of Paleontology Invertebrate Type Collection; USNM, United States National Museum.

PREVIOUS WORK

Mollusks were first collected from the Barstow formation by parties from the University of California in 1911. From this material Hannibal (1912, p. 157) described *Planorbis mojavensis;* additional species were listed by Merriam (1919, p. 450). Other collections made by subsequent University of California parties are detailed in the systematic part of this report. More recent collecting, principally by R. M. Alf and parties from the Webb School, and by the writer, has yielded additional localities and species of mollusks.

FAUNA

The known molluscan fauna of the upper Miocene Barstow formation consists of the following species. Asterisks indicate terrestrial forms; others are freshwater.

Gonidea n. sp.?
Lymnaea mohaveana Taylor, n. sp.
L. megasoma Say
Helisoma? sp.
Planorbula mojavensis (Hannibal)
Menetus? micromphalus Taylor, n. sp.
**Vallonia* sp. cf. *V. cyclophorella* Sterki
**Craterarion pachyostracon* Taylor, n. gen. and sp.
**Pristiloma chersinellum* (Dall)
**Hawaiia minuscula* (Binnery)
**Helminthoglypta alfi* Taylor, n. sp.

FAUNAL ANALYSIS

1. *Gonidea*, n. sp.? The genus is found only in the Pacific Coast drainage of North America, from Southern California north to British Columbia and east to Idaho (Gregg, 1947, p. 18). The one living species occurs in "rapid streams and rivers with considerable current, * * * sloughs, sluggish creeks, and slow-moving rivers," seldom in lakes (Hannibal, 1912, p. 128).

Other described fossil species of *Gonidea* are as follows: *a. G. coalingensis* Arnold (1909, p. 92, pl. 30, fig. 11; including *G. c.* var. *cooperi* Arnold, 1909, p. 93, and *Margaritana subangulata* Cooper, 1894, p. 166, pl. 14, figs. 1–4 (not *Anodonta angulata* var. *subangulata* Hemphill [a recent *Gonidea*], 1891, p. 325, pl. 10, figs. 1–2)) described from the Tulare formation (Pliocene and Pleistocene) in Kings County, California. Hannibal (1912, p. 127) also listed this species from the "Pliocene * * * Santa Clara, and Cache Lake beds,

California." These beds are now known as the Santa Clara formation (Pliocene and Pleistocene) and the Cache formation (Pleistocene).

b. G. hemphilli Hannibal (1912, p. 128, pl. 7, fig. 19), described from "Miocene: Contra Costa Lake beds, California. Water-tunnel, head of Telegraph Cañon, Berkeley Hills, California." This locality is in what is now considered the type Orinda formation (lower Pliocene in chronology of vertebrate paleontologists; upper Miocene of marine sequence).

c. G. sp., listed by Woodring, Stewart, and Richards (1940, p. 40, 92) from the San Joaquin formation (Pliocene) in Kings County, California.

2. *Lymnaea mohaveana* Taylor, n. sp. The nearest apparent relative of this species, *L. palustris* (Müller), is circumboreal. The common western American form of the latter, *L. p. nutalliana* Lea, is found from Southern California and Arizona (at high altitudes) northward.

Found plentifully in bodies of water of greater or less size, on floating sticks and submerged vegetation, on stones and on the muddy bottom. Inhabits both clear and stagnant water, but prefers a habitat in which the water is not in motion. (Baker, 1911, p. 311).

3. *Lymnaea megasoma* Say. Found living from northern New England and the Great Lakes area northward to Hudson Bay (Baker, 1911, p. 188).

At Tomahawk Lake, Wisconsin, *megasoma* lives in swampy portions of sheltered bays where the water is quiet. The bottom of such a habitat is boggy and the water is so shallow that frequently little boggy islands are formed, and on these *megasoma* may be found, one or two specimens on each island * * * It would seem that the characteristic habitat of *megasoma* is a swamp or marshy pond or bay (Baker, 1911, p. 190).

Other fossil occurrences are in the lower Pleistocene Sand Draw fauna of Brown County, Nebraska, and in the lower Pliocene Laverne formation, Beaver County, Oklahoma. The present relatively restricted range may indicate a change in ecologic tolerance since its former wide distribution, so that this species cannot be used for fine habitat differentiation in the Barstow fauna.

4. *Helisoma*? sp. The genus is widely distributed in North and Central America, in quiet or slow moving water.

5. *Planorbula mojavensis* (Hannibal). The genus is found living from Louisiana and Georgia north into Canada (Baker, 1945, p. 176). One form, "*Planorbula armigera* is largely a species of swales or of small and stagnant bodies of water" (Baker, 1928, p. 358). Other fossil species are known in the middle Pleistocene of the High Plains (Leonard, 1950, p. 17–18) and in the Oligocene of Washington.

6. *Menetus*? *micromphalus* Taylor, n. sp. The subgenus *Menetus s. s.*, to which this species may belong, is found living along the Pacific Coast from British Columbia to Southern California (at high altitudes). *Menetus* usually inhabits quiet or slow-moving shallow waters with abundant vegetation. Fossil species are known from the Tulare formation (Pliocene and Pleistocene) of the Kettleman Hills, California (Pilsbry, 1934, p. 568), and from Pliocene deposits in Malheur County, Oregon (Henderson and Rodeck, 1934, p. 268).

7. *Vallonia* sp. cf. *V. cyclophorella* Sterki. The living species is widely distributed in the western United States, west of the High Plains (Pilsbry, 1948, p. 1035–1036). In Southern California it lives under stones, logs, etc. in damp leaf mold, usually at higher elevations. No previous records of fossil occurrence have been found.

8. *Craterarion pachyostracon* Taylor, n. gen. and sp. The genus is not closely related to either of the two other genera of the subfamily, *Binneya* and *Hemphillia*, although it has characters of both. *Binneya* lives in in the semiarid areas of Santa Barbara Island, off Southern California, Baja California near San Quentin Bay, and Guadalupe Island, off Baja California (Pilsbry, 1948, p. 733–737). *Hemphillia* is now found in the cool moist areas of Washington and Oregon to western Montana (Pilsbry, 1948, p. 738). The number of Specimens of *Craterarion* found may indicate a riparian habitat.

9. *Pristiloma chersinellum* (Dall). This species is found living from Southern California (at high altitudes) north to southern Oregon; possibly also in Montana (Pilsbry, 1946, p. 413–415). In Southern California it lives under bark, logs, etc. on damp ground in the higher mountains. No previous record of its occurrence as fossil has been found.

10. *Hawaiia minuscula* (Binney). This common and widely distributed species is found living from Alaska and Maine south to Costa Rica (Pilsbry, 1946, p. 421). In Southern California it lives under stones, bark, etc. on damp ground, but may occur at lower elevations and under less moist conditions than *Vallonia cyclophorella* and *Pristiloma chersinellum*. Leonard and Franzen (1944, p. 29) reported it from the lower Pliocene Laverne formation of Oklahoma.

11. *Helminthoglypta alfi* Taylor, n. sp. The nearest living relative is found around Victorville, California, about 35 miles from the Barstow Hills; all members of the sub-generic group (Pilsbry's "Mohave Desert Series") are found in the Mohave Desert region. *Helminthoglypta* lives around Victorville on dry, rocky, mountain slopes, among boulders and in rock slides, or under rocks and leaves beneath cottonwood trees along the Mohave River.

PALEOECOLOGY

From the discussion of the habitats of the Barstow mollusks or their living relatives it is seen that they may be classed in four groups, as follows:

1. Aquatic species living in a pond or slow-moving stream with some aquatic vegetation.

Gonidea n. sp.?
Lymnaea mohaveana
L. megasoma
Helisoma? sp.
Planorbula mojavensis
Menetus? *micromphalus* (possibly)

2. Land snails living under logs, bark, stones, etc., on moist leaf mould. In Southern California they now live only in the cooler, moister high altitude areas.

Vallonia sp. cf. *V. cyclophorella*
Pristiloma chersinellum
Hawaiia minuscula

3. Land snails living in a fairly dry habitat, under rocks among brush and leaves, perhaps beside a stream or pond.

Helminthoglypta alfi
Craterarion pachyostracon (possibly)

4. Extinct species of uncertain significance.

Menetus? *micromphalus*
Craterarion pachyostracon (may possibly belong to group 3 above)

Ecologic interpretation of the individual species can be supplemented profitably by contrasting the fauna with the living Mohave Desert mollusks. Although the mollusks known from the Barstow fauna almost certainly represent but a fraction of the total molluscan fauna of that time, the comparison shows differences which appear significant.

The Mohave Desert as here considered is bounded on the north by a line passing east from the Sierra Nevada through the southern ends of the Argus, Slate, Panamint and Black Mountains; on the east by the watershed of the Colorado River; on the south by the San Gabriel, San Bernardino, Little San Bernardino, and Pinto Mountains, and by an arbitrary line passing thence east to the Colorado watershed; and on the west by the Tehachapi Mountains and the southern Sierra Nevada. These limits thus exclude the north-south parallel ranges from Owens Valley to Death Valley, which seem more characteristic of the Great Basin in the strict sense, and also exclude the region of large Pleistocene lakes (Thompson, 1929, p. 5–7).

The Mohave Desert is an arid plateau of interior drainage lying in the Basin and Range Province in easternmost Kern County, northeastern Los Angeles County, and San Bernardino County, California, and in southernmost Clark County, Nevada. It is characterized by evaporation potentially in excess of rainfall, which is approximately three to five inches per year over most of the desert and falls almost entirely in the winter. Most of the area lies north of the climatically significant boundary of 100° F. mean maximum temperature for three months (Russell, 1926).

Topography is typical basin and range type. It is controlled chiefly by mechanical, rather than chemical, weathering because of the aridity and the cloudburst nature of much of the rain. Mountain ranges at first rising from the desert floor gradually become buried in alluvium (see Gilluly, Waters, and Woodford, 1951, fig. 15–3).

The vegetation is characterized by "large woody shrubs with a sage (half-shrub) understory" (Axelrod, 1950, p. 262). Annuals flourish briefly after a winter of adequate rain. Cottonwoods and other riparian plants grow in the rare spots with permanent water.

In such an arid region the number of habitats available for mollusks is necessarily restricted. They may be divided broadly into two types: mountain slopes with rockslides where land snails can remain protected through the hot summers, and sites of permanent water with attendant vegetation as food and cover for aquatic and terrestial mollusks.

The known Recent molluscan fauna of the Mohave Desert is listed below. Excluded from consideration are the mollusks of the mountains bordering the desert and of Clark Mountain, which seem to be better grouped elsewhere.

Sphaeriidae
Pisidium casertanum (Poli)
Musculium truncatum (Linsley)
Amnicolidae
Hydrobia sp.
Lymnaeidae
Lymnaea bulimoides cassi Baker
Planorbidae
Gyraulus parvus williamsoni (Dall)
Helisoma tenue californiense Baker
H. ammon (Gould)
Physidae
Physa osculans Haldeman
Ancylidae
Ferrissia fragilis (Tryon)
Limacidae
Deroceras monentolophus Pilsbry
Helminthoglyptidae
Helminthoglypta mohaveana Berry
H. graniticola Berry
H. g. arida Pilsbry and Field
H. crotalina Berry
H. jaegeri Berry
H. greggi Willett
H. fisheri (Bartsch)
Micrarionta rowelli acus Pilsbry
M. r. unifasciata Willett
M. r. bakerensis Pilsbry and Lowe
M. r. amboiana Willett
M. argus (Edson)

Sonorelix rixfordi (Pilsbry)
S. avawatzica (Berry)
S. melanopylon (Berry)
Sonorella micrometalleus (Berry)

The habitats of these various species are as follows:

1. Rocky slopes of the mountains. The snails of this ecologic niche are generally found among the rocks and boulders on the lower slopes of the mountains, among the loose detritus in crevices, in rockslides, etc. All the helminthoglyptid snails have about the same habitat.

2. Among rocks and boulders beside the Mohave River. Here a colony of *Helminthoglypta mohaveana* is found under rocks among leaves about six feet from the river, among the riparian stand of trees. This species also occurs in habitat (1) above.

3. Damp habitats beside the Mohave River. In such places, under logs and stones on damp ground, the slug *Deroceras* occurs.

4. Edges of the Mohave River. Out of the main current of the river, along the edge, in a narrow border of slow-moving water, mud bottom, and aquatic vegetation, or in marshy patches beside the river, the following occur: *Pisidium*, *Musculium*, *Lymnaea*, *Ferrissia*, *Gyraulus*, *Helisoma*, and *Physa*.

5. Springs. The only permanent springs in the desert which have been visited by the writer are just north of the San Bernardino Mountains: Rabbit, Cottonwood, and Old Woman Springs. All contain *Physa*, and Old Woman Springs adds *Hydrobia*.

6. Ponds. There are several small ponds, at least one of which is natural, in the vicinity of Palmdale and Lancaster. In these occur *Gyraulus*, *Helisoma*, and *Physa*.

The significant differences between the Barstow fauna and the living mollusks of the Mohave Desert appear to be the presence in the Barstow fauna of small land snails now found in Southern California only in the high mountains (*Vallonia*, *Pristiloma*, *Hawaiia*); the relative dominance in the living fauna of Helminthoglyptidae; and the presence in the Barstow fauna of large aquatic species (*Gonidea*, *Lymnaea*), but only small to medium-sized forms in the living fauna.

None of the smaller land snails of the Barstow formation occurs along the Mohave River, although these and other species are living in the San Bernardino Mountains. Their absence may be due to lack of moisture, because only a narrow strip of ground is kept damp by the river. It is possibly due also to high temperature, for in larger damp areas of similar climate these small snails are also missing. The amount of rainfall in the San Bernardino Mountains and in the Mohave River area indicates that these species might have survived in a riparian habitat with 15 inches of rain annually.

The present dominance of Helminthoglyptidae is probably due to the local extinction of much of the Miocene fauna. There may have been as many Miocene as Recent species of Helminthoglyptidae in the Mohave Desert, but judging from the Barstow fauna they were relatively less abundant. The subsequent drier climate of the area has presumably eliminated essentially all land mollusks but the Helminthoglyptidae. This selection may well be connected directly with body size.

Large aquatic species in the Barstow fauna probably indicate a larger volume of habitable water than is now present in the desert. This in turn implies greater rainfall.

Concerning the Miocene vegetation of the southern Great Basin, Axelrod (1950, pp. 231, 234) wrote:

> The principal types of vegetation included live oak and conifer woodland, chaparral, arid subtropical scrub ('thorn forest') coastal sage, and plains grassland * * *. In the more southerly parts of the area, where climate was warmer, we may infer that woodland and chaparral rose to somewhat higher levels as the tropical zone was approached, much as these vegetation types do today.

According to M. C. McKenna (oral communication) the large numbers of species and individuals of the grazing animals, such as horses, camels, and antilocaprids, and the variety of carnivores of the Barstow fauna are strongly reminiscent of the present fauna of the African savannas, with grassy plains and scrub forest.

Axelrod (1950, p. 238) summarized his conclusions from Miocene floras for southeastern California as follows:

> The Madro-Tertiary Flora, dominated by live oak woodland, chaparral, and thorn forest vegetation, was thriving under a semiarid climate of 15 to 25 inches of yearly rain distributed biseasonally, hot summers, and mild, frostless winters.

Faunal evidence is consistent with this picture. Mollusks indicate that the area of deposition of the Barstow formation included a slow-moving stream or pond, in which lived freshwater snails and clams, and nearby vegetation furnishing leaf mould habitats for land snails.

AGE AND CORRELATION

The age of the Barstow formation was determined as late Miocene by Merriam (1911, 1919) on the basis of the mammalian fauna. The Barstow fauna is used as the vertebrate paleontologists' standard for the late Miocene Barstovian provincial age of North America (Wood and others, 1941, p. 12). Late Tertiary nonmarine mollusks are known too poorly for substantiation or contradiction of this age; thus the Barstow mollusks are dated by the associated vertebrates.

Correlation of late Tertiary nonmarine molluscan

faunas is made difficult by geographic localization of species. Of the eleven Barstow mollusks, including four living species, only two have been reported previously as fossils. Both *Lymnaea megasoma* and *Hawaiia minuscula* are Recent species known also from the lower Pliocene Laverne fauna of Oklahoma. *Hawaiia minuscula* is a widespread, tolerant form considered not significant in this case; it is also known from several Pleistocene faunas in the High Plains. *L. megasoma* lives today under conditions widely different from those inferred from the Barstow and Laverne faunas, so that its significance is uncertain. Axelrod (1950, p. 234) noted a similarity of floras in the region from the Mohave Desert to Texas and Oklahoma; the presence of *Lymnaea megasoma* in the two places may reflect a similarity of environment.

DISTRIBUTIONAL RELATIONS OF THE BARSTOW FAUNA

Mollusks of the Barstow fauna may be grouped according to their distributional relations as follows:

1. Southern California element. The following species or their relatives are now living in Southern California.

Gonidea n. sp.?
Lymnaea mohaveana
Helisoma? sp.
Vallonia sp. cf. *V. cyclophorella*
Pristiloma chersinellum
Hawaiia minuscula
Helminthoglypta alfi

2. Locally extinct element. The following species or their relatives live elsewhere in the United States, but occurred in Southern California in Miocene time.

Lymnaea megasoma
Planorbula mojavensis

3. Uncertain element. The following species are of uncertain distributional relationship.

Menetus? *micromphalus*
Craterarion pachyostracon

The above data show that the Barstow fauna is most closely related to the one now living in Southern California. This geographic localization, persistent in time, helps to explain the difficulties in correlation of late Tertiary nonmarine mollusks.

Other West American molluscan faunas of approximately the same age as the Barstow fauna may be divided into groups as follows:

1. Northern Great Basin faunas with few if any living species and several extinct genera otherwise known only from the Neocene of Europe (*Orygoceras, Papyrotheca,* etc.). The faunas are characterized particularly by the association of these European forms with the extinct American genera *Pilsbryus, Pliopholyx, Anculopsis, Vorticifex, Pompholopsis, Payettia,* etc., as well as extinct species of *Fluminicola, Carinifex, Lanx,* etc. Amnicolidae and Planorbidae are relatively abundant.

a. Malheur Co., Oregon; Pliocene (Henderson and Rodeck, 1934).
b. Idaho formation, Idaho; Pliocene (Dall, 1924; Yen, 1944).
c. Collinston, Utah; Pliocene (Chamberlin and Berry, 1933).
d. Pliocene assemblage from the Salt Lake formation, northern Utah (Yen, 1947).
e. Miocene assemblage from the Salt Lake formation, southeastern Idaho (Yen, 1946).
f. Truckee formation, Nevada; Pliocene (Yen, 1950).

2. Western Nevada faunas at least partly from the Esmeralda formation. They are characterized by the presence of *Viviparus* and *Perrinilla,* not surely known elsewhere in the western United States, of *Lanx* and species of "*Melania*" or "*Goniobasis*" occurring also in Group 1, and by the absence (so far as known) of the other forms listed under that group. No living species occur in the faunas.

a. Nye and Esmerelda Counties, Nev.; Esmerelda formation, Pliocene (Hannibal, 1912; Turner, 1900, p. 203; Buwalda, 1914, p. 351).
b. Tonopah fauna, Miocene, in Esmerelda formation?, north of Tonopah, Nev. (Henshaw, 1942, p. 88–89).

3. John Day Basin faunas, Oregon. The original descriptions of most of these species do not reveal whether the specimens are from the Oligocene and Miocene John Day formation, or the upper Miocene Mascall formation. For the present purpose they are treated as a unit, as listed by Henderson (1935, p. 45). The fauna shows no relationship to any other fossil fauna, but seems to be related to that now living in the humid coastal strip from Washington to Northern California. The fauna is characterized by the presence of *Monadenia, Vespericola, Polygyrella, Ammonitella,* and *Oreohelix* (Pilsbry, 1939, p. 35, 416, 560; 1940, p. 892–893).

4. Deep River beds, upper Miocene, Meagher County, Mont. This fauna, which consists of 17 terrestrial species, is in process of description by Dr. S. S. Berry. It seems to be most closely related to that of Idaho and western Montana, but contains a few genera now found in the Mississippi Valley. This fauna also seems to be unrelated to the contemporary assemblages.

Of all these faunas only the Barstow has both land and freshwater species in any abundance. The other Great Basin faunas are entirely freshwater, the Deep River fauna wholly terrestrial, and the John Day Basin group of species essentially so. This combination of geographic localization and incomplete faunal representation effectively prohibits correlation over the western United States at the present time, but within an area such as the northern Great Basin correlation should be practical.

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LOCALITIES

Accurate topographic maps of the Barstow Hills have not yet been published. Locality descriptions are composed of the better-known local names and airline distances taken from aerial photographs.

Locality 1. Three outcrops of whitish volcanic ash in a straight line in the northwest corner of Rainbow Basin, about one hundred yards west of the road. Shell material is mostly gone, the snails being chiefly represented by molds, although a few are well preserved.

Locality 2. A stratum of light green volcanic ash exposed along the north bank of a westward-trending wash for nearly two hundred yards. This locality lies north of the western wall of Rainbow Basin, along the first wash north of the cliffs. The deposit is apparently fluviatile. The fossils are poorly preserved.

Locality 3. "Lake Bed Horizon" in the canyon next south from Pirie Canyon. The gently dipping stratum is exposed along the north canyon wall for about two hundred yards, in the middle of the SE ¼ of sec. 15, T. 11 N., R. 2 W. The exposure is straight except at the east end, where the bed is sharply upturned and truncated. The abundant shells are generally well preserved, but some are slightly crushed.

Locality 4. Gray mudstone northwest of the relatively undissected plain north of Rainbow Basin. One shell, crushed but otherwise well preserved, from a nodule, collected by Thane McCulloh.

Locality 5. "Carnivore Basin," 1.7 miles N. 62 degrees E. of the junction of Pirie Canyon and its principal northern tributary.

Locality 6. 1.63 miles N. 51 degrees E. of the junction of Pirie Canyon and its principal northern tributary.

Locality 7. 1.7 miles N. 57 degrees E. of the junction of Pirie Canyon and its principal northern tributary.

In addition, there are old localities not yet relocated in the field. The type series of *Planorbula mojavensis* with the vague locality designation "near Barstow" comes from a place not recognized by the author. The University of California collections contain one specimen of *Gonidea* and two of *Helminthoglypta* that probably represent at least one more locality. The Stanford University collection has a specimen of *Menetus*? indicating a probably distinct locality. Merriam (1919, p. 445) refers to the occurrence of *Anodonta*? (=*Gonidea*) at rare horizons.

Occurrence of Barstow mollusks

Species	Locality							
	1	2	3	4	5	6	7	?
Gonidea n. sp.?		?						x
Lymnaea mohaveana			x		?			
L. megasoma			x	?			x	
Helisoma?		x						
Planorbula mojavensis		x	x			x		x
Menetus? *micromphalus*			x					x
Vallonia sp. cf. *V. cyclophorella*			x					
Craterarion pachyostracon			x					
Hawaiia minuscula			x					
Helminthoglypta alfi	x		x		x			x

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA
Family UNIONIDAE
Subfamily ANODONTINAE
Genus GONIDEA Conrad, 1857
Gonidea n. sp.?

Anodonta?, Merriam, 1919, Univ. California Pub. Bull. Dept. Geology, v. 11, p. 450.

Diagnosis.—Probably a new species of *Gonidea*, characterized by its long, narrow shape and markedly anterior beak.

Description.—Shell long and narrow, suboval at the ends, slightly arcuate along the roughly parallel dorsal and ventral margins. Beaks about one-fifth the length behind the anterior end. A conspicuous, nearly straight ridge extending from beaks to ventroposterior edge. No sculpture or hinge characters shown on the one available mold.

Measurements.—The complete specimen would probably have measured (in millimeters): length, 75; height, 31; width, 24.

Material.—

Catalog No.	Number of specimens	Locality	Remarks
UC 34184	1	"Barstow"	Described specimen.
T 3170	1	2	Identifiable as unionid only.

Remarks.—Compared with specimens of the recent *Gonidea angulata* (Lea), the Barstow species is narrower and more elongate, with the margins more nearly parallel and the beaks more anterior. It differs from the narrower forms of *G. coalingensis* Arnold of the Tulare formation (Pliocene and Pleistocene) by its posteriorly slightly narrower shell and arcuate ventral margin. The Barstow species differs from *G. hemphilli* Hannibal of the Orinda formation (Pliocene) by its larger size and more elongate shape.

Although the specimen described is sufficiently well preserved to name, the author refrains from so doing for the following reasons. (1) The exact locality is unknown. (2) It is desirable to learn the characters of the hinge before description, and therefore waiting for more specimens seems the best course. (3) Merriam (1919, p. 445) indicated that *Gonidea* occurs at more than one locality.

Class GASTROPODA

Family LYMNAEIDAE

Genus LYMNAEA Lamarck, 1799

Subgenus STAGNICOLA Jeffreys, 1830

Lymnaea mohaveana Taylor, n. sp.

Plate 20, figures 1, 2.

Diagnosis.—A species of the *L. palustris* group, distinguished by the wide expansion of the aperture and the consequently very broad body whorl.

Holotype.—S 8077, loc. 3, west end of Barstow Hills, 7 miles north of Barstow, San Bernardino County, California. "Lake Bed Horizon" in the canyon next south from Pirie Canyon. Middle of SE ¼ sec. 15, T. 11 N., R. 2 W. Barstow formation, upper Miocene. R. Tedford and R. Schultz, 1949. Paratypes, T 1785, 2035, S 8078, USNM 561488, UC 34194–34197.

Description.—Shell thin, elongate, narrowly conic, base strongly expanded; spire acute, approximately three-fifths the total shell length; whorls seven, only a little convex on the spire; suture slightly constricted; body whorl widely expanded, giving an almost obtusely rounded appearance. Aperture effuse, elongate-oval; outer lip thin, expanded; parietal lip appressed to form a heavy callus; columella twisted to form a conspicuous, thick plait; umbilical chink generally closed, sometimes narrowly open. Shell smooth except for numerous irregular, close growth lines.

Measurements of holotype (in millimeters).—Length, 27.3; width, 12.4; length of aperture, 13.2; width of aperture, 7.6; whorls 6. It is slightly broken, and probably would have measured, whole: length, 28.5; width, 13; length of aperture, 13.8; width of aperture, 8; whorls 7.

Material.—

Catalog No.	Number of specimens	Locality	Remarks
S 8077	1	3	Holotype.
S 8078	14	3	
T 1785	24	3	Poor specimens.
T 2035	6	3	
UC 34194–34197	4	3?	
UC	11	3?	
USNM 561448	15	3	
T 2444	2	5	Do.
T3136	3	5	Do.

The material from locality 3 is composed about equally of molds in compacted volcanic ash and specimens in which most of the shell remains. *Lymnaea mohaveana* is the commonest snail at its type locality. It is more abundant than the above figures would indicate, but the great majority of specimens collected are badly eroded molds, barely identifiable.

Remarks.—*Lymnaea mohaveana* appears closest to *L. palustris* (Müller), from which it differs in the broadened body whorl and expanded aperture.

Subgenus BULIMNEA Haldeman, 1841

Lymnaea megasoma Say

Plate 20, figure 3.

Material from the Barstow formation was compared with the many Recent specimens in the University of Michigan collection, but no differences were found.

Material.—

Catalog No.	Number of specimens	Locality	Remarks
T 3171	2	2	Poor specimens.
T 1786	9	3	Do.
T 2036	11	3	
T 2037	10	3	Do.
UC 34190–34193	4	3?	
UC	3	3?	
T 2039	1	4	Do.

Remarks.—In studying the Barstow specimens comparison was made with *Lymnaea lavernensis* Leonard and Franzen (1944, p. 22, pl. 4, fig. 11), of the lower Pliocene Laverne formation of Oklahoma. This species was compared by Leonard and Franzen with the Recent *L. (Stagnicola) magister* Baker, but not with *L. (Bulimnea) megasoma* Say, with which it appears synonymous. *L. lavernensis* agrees with *L. megasoma* in several significant respects: The shell is large, ovate-conic, with a relatively short spire and convex whorls. The nuclear whorl is relatively large, larger than in *Stagnicola, Fossaria, Pseudosuccinea,* etc. Sculpture consists of numerous, irregular, coarse, low, rounded growth lines, which on the earlier whorls are cut by subobsolete spiral striae. These characters appear to place *L. lavernensis* definitely in *Bulimnea.* Comparison of the many Recent as well as fossil specimens in the University of Michigan collections (including paratypes of *L. lavernensis*) shows their specific identity.

Lymnaea (Bulimnea) petaluma Hanna (1923, p. 37, pl. 2, figs. 3, 7) may or may not be distinct from *L. megasoma;* the material seen is inconclusive.

Family PLANORBIDAE

Subfamily HELISOMATINAE

Genus HELISOMA Swainson, 1840

Subgenus PIEROSOMA Dall, 1905

Helisoma? sp.

A large planorbid from locality 2 (T 3172) may be referable to this group.

Subfamily PLANORBULINAE

Genus PLANORBULA Haldeman, 1840

Planorbula mojavensis (Hannibal)

Plate 20, figures 10–15.

Planorbis (*Segmentina*) *Mojavensis* Hannibal, 1912, Proc. Malacol. Soc. London, v. 10, p. 157, 200, pl. 8, figs. 24a, b (not 27).

Planorbis mohavensis Hannibal, Merriam, 1919, Univ. California Pub. Bull. Dept. Geology, v. 11, p. 450.

Diagnosis.—A *Planorbula* characterized by its relatively large upper palatal and small lower palatal lamella, and by the apparent absence of a basal lamella.

Holotype.—UC 34178? (not surely identified). "Rosamond Series, California. Near Barstow, Mojave Desert, California (J. C. Merriam, C. L. Baker)." Paratypes, B 8924, S 5460, UC 34179–34182.

Description.—Shell discoid, biconcave, presumably ultra-dextral, of moderate size. Whorls about five, convex, regularly rounded; sutures strongly impressed. Sculpture of fine, oblique growth lines. Aperture reniform, lamellate. Umbilicus and spirepit wide, shallow, about equal in size. Dentition as follows: a large, sigmoid, obliquely transverse parietal lamella, about ½ mm high along most of its length, sharply descending at the ends, highest in the middle, distal end about 1 mm from the left suture; a small tubercular subparietal lamella about halfway between distal end of parietal lamella and left suture, slightly behind end of lamella; a small, elongate suprapalatal lamella in the center of the right side of the whorl; a medium sized, slightly curved upper palatal lamella intermediate between the suprapalatal and lower palatal lamellae; and a small, tubercular lower palatal lamella at the periphery.

Measurements, in millimeters, without allowance for wear.—

Major diameter	Minor diameter	Height	Original number of whorls	Catalog No.
6. 2	5. 5	2. 0	4½	UC 34178
10. 0	6. 7	3. 5	5	B 8924

Material.—

Catalog No.	Number of specimens	Locality	Remarks
P 129	1+	2	In matrix.
T 2040	5	2	Poor specimens.
T 3173	2	2	Do.
T 1788	5	3	Juvenile.
T 3134	3	6	
B 8924	1	"Near Barstow".	Paratype.
S 5460	4	do	Do.
UC 34178	1	"Barstow"	Holotype?
UC 34179–34182	4	do	Paratypes.
UC	11	do	Do.

Remarks.—Unfortunately the holotype has not yet been identified with certainty. A specimen labelled "Type" in Hannibal's handwriting (UC 34178) does not agree well with the original figures of the specimen designated as type (Hannibal, 1912, p. 210).

A paratype of *Planorbis mojavensis* (S 8080) is referred to *Menetus? micromphalus.*

Planorbula mojavensis differs from other species of the genus by its relatively large upper palatal lamella and relatively small lower palatal lamella, and by the apparent absence of a basal lamella. In the original description Hannibal indicates the presence of a supraparietal lamella, but none of the specimens available show it.

Segmentina durhami Hanna and Hertlein (1938, p. 109, pl. 21, figs. 3–5), from the Oligocene of Washington, was considered to be related to *S. armigera* (Say), now called *Planorbula. P. mojavensis* differs from *P. durhami* by its smaller size, lesser height, and biconcavity. The lamellae of *P. durhami* were not preserved well enough for comparison.

Genus MENETUS H. and A. Adams, 1855

Menetus? micromphalus [1] Taylor, n. sp.

Plate 20, figures 4–9.

Diagnosis.—A medium sized *Menetus*-like planorbid with rapidly increasing whorls and a peripheral subangulation.

Holotype.—T 2038a, loc. 3, west end of Barstow Hills, 7 miles north of Barstow, San Bernardino County, California. "Lake Bed Horizon" in the canyon next south from Pirie Canyon. Middle of SE 1/4, sec. 15, T. 11 N., R. 2 W. Barstow formation, upper Miocene. D. W. Taylor and M. C. McKenna, 1–II–1950. Paratypes, T 2038, S 8079, USNM 561451.

Description.—Shell moderately large, discoid, biconcave, presumably ultradextral. Whorls about 4½, the last rapidly expanding, rounded at the aperture but variably angular from about the second to the fourth whorl. Aperture semicircular, oblique, slightly expanded; lip thickened. Umbilicus small and shallow; spire pit deep and broad. The slightly imperfect material shows no sculpture.

Measurements (in millimeters, with allowance for damage), of holotype.—Major diameter, 12; minor diameter, 8.5; height, 4; whorls 4 1/2.

Material.—

Catalog No.	Number of specimens	Locality
S 8079	5	3
S 8080	1	"Near Barstow."
T 2038	6	3
T 2038a	1	3
USNM 561451	8	3

[1] Gr. *micros*, small, and *omphalus*, umbilicus.

Remarks.—The paratype of *Planorbis mojavensis* here referred to *Menetus*? *micromphalus* (S 8080) has a series of low, broad grooves on the periphery of the third whorl, giving it an undulatory appearance. They become less prominent coarse growth lines on the left side of the body whorl The specimen is a mold, and thus it is uncertain whether these lines are coarse growth striae or a series of internal shell thickenings only. The holotype of *M.*? *micromphalus* does not show coarse striae on the preserved parts of the shell

Family VALLONIIDAE

Genus VALLONIA Risso, 1826

Vallonia sp. cf. V. cyclophorella Sterki

Plate 20, figures 24–26.

One specimen (T 1792) with the lip absent compares favorably with this recent species in size, excentricity of body whorl, and sculpture. The chief difference noted is that the fossil has a relatively gradual increase of whorls, while in recent *Vallonia cyclophorella* the last whorl expands more rapidly.

Material.—

Catalog No.	Number of specimens	Locality
T1792	1	3

Family ARIONIDAE

Subfamily BINNEYINAE

Genus CRATERARION [2] Taylor, n. g.

Characters those of the type and only known species.

Craterarion pachyostracon [3] Taylor, n. sp.

Plate 20, figures 16–20.

Diagnosis—A very thick, convex subspiral, long-oval slug plate.

Holotype.—S 8073, loc. 3, west end of Barstow Hills, 7 miles north of Barstow, San Bernardino County, California. "Lake Bed Horizon" in the canyon next south from Pirie Canyon. Middle of SE ¼, sec. 15, T. 11 N., R. 2 W. Barstow formation, upper Miocene. D. W. Taylor, X1–1950. Paratypes, T. 1791, S 8074, B 19936, G 5924, UC 34183, USNM 561449.

Description.—Shell long-oval, thick and heavy, convex. Nucleus hemispherical, situated nearly at the posterior margin and slightly to the right of the median line; deflected to the right so that the shell has about one-tenth of a whorl. Right posterior margin bearing a small projection, often slightly curved to the left. Left posterior margin in larger specimens also showing a small tubercle. Edges thickened, with later growth apparently taking place only dextrally and anteriorly. Dorsal surface roughened by irregular growth wrinkles; a few faint raised longitudinal lines are visible toward the anterior margin of the best specimens. Ventral surface without growth lines or any sort of sculpture, irregularly concave, callused slightly at the posterior end.

Measurements, in millimeters.—

Catalog No.	Length	Width	Thickness
S 8073	8. 5	5. 3	3. 5
T 1791A	8. 0	5. 1	1. 4
T 1791B	7. 4	4. 6	1. 9
B 19936	6. 8	4. 2	2. 0

Material.—

Catalog No.	Number of specimens	Locality	Remarks
B 19936	1	3	Paratypes.
G 5924	2	3	Do.
S 8073	1	3	Holotype.
S 8074	6	3	Paratypes.
T 1791	11	3	Do.
UC 34183	1	3?	Do.
USNM 561449	6	3	Do.

Remarks.—Craterarion has characters of the two recent genera *Binneya* and *Hemphillia* but is close to neither. Its shell shows a tendency toward spiral coiling, as in *Binneya*, and the weak raised spiral lines are reminiscent of the embryonic sculpture of *Binneya*. The coiling is however, not strong, and in this respect approaches *Hemphillia*. *Craterarion* differs radically from both in the extreme thickness of the shell, the degree of coiling, and the possession of the posterior "hook" in young specimens. In this character it is similar to some species of *Deroceras*.

Slugs are known from the Miocene of Europe, but this is apparently the earliest record for any slug in North America. The only other pre-Pleistocene slug known from America is *Deroceras aenigma* Leonard (1950, p. 38), described from the type section of the upper Pliocene Rexroad formation of Smith, 1940, revised by Hibbard, 1950, in Meade County, Kansas.

Family ZONITIDAE

Subfamily ZONITINAE

Genus PRISTILOMA Ancey, 1887

Subgenus PRISCOVITREA H. B. Baker, 1931

Pristiloma chersinellum (Dall)

Plate 20, figures 27–29.

Comparison of the Barstow specimens was made with a lot of *P. chersinellum* from Cottonwood Camp,

[2] Gr. *crater*, a basin, and *Arion*, type genus of the family. Named for its occurrence in the Great Basin.

[3] Gr. *pachy*, thick, and *ostracon*, shell.

Elizabeth Lake Canyon, Los Angeles County, California. Neither W. O. Gregg nor the writer could find any differences between the two sets.

Material.—

Catalog No.	Number of specimens	Locality
T 1790	7	3

Genus HAWAIIA Gude, 1911

Hawaiia minuscula (Binney)

Plate 20, figures 21–23.

One slightly imperfect specimen is referred to this living species. Characters shown by the fossil agree with recent specimens, but better material might show differences.

Material.—

Catalog No.	Number of specimens	Locality
T 1792a	1	3

Family HELMINTHOGLYPTIDAE

Subfamily HELMINTHOGLYPTINAE

Genus HELMINTHOGLYPTA Ancey, 1887

Helminthoglypta alfi Taylor, n. sp.

Plate 20, figures 30–32.

Diagnosis.—One of Pilsbry's "Mohave Desert Series" of *Helminthoglypta*, closely related to *H. graniticola* and *H. g. arida*. It differs from these in its smaller size, intermediate height of the spire, and subcircular aperture.

Holotype.—S 8075, loc. 1, Barstow Hills, 7 miles north of Barstow, San Bernardino County, California. A series of three outcrops of a stratum of whitish volcanic ash lying in a straight line in the northwest corner of Rainbow Basin. Barstow formation, upper Miocene. D. W. Taylor, 8–II–1948. Paratypes, B 15373, 19935, G 5925, S 8076, T 1107, 1108, 1417, 1439, 3137, 3138, USNM 561450.

Description.—Shell helicoid, small for the genus, slightly to moderately elevated; whorls four to five, evenly rounded, regularly increasing; suture slightly impressed; body whorl conspicuously descending to the lip in approximately the last twelfth of its turn. Aperture oblique, and, except for the excision made by the preceding whorl, oval, though nearly circular; lip somewhat thickened and slightly reflected. Umbilicus small, contained five to six times in the diameter of the shell, steep-sided, permeable to the apex, but little if at all covered by the reflection of the lip. Later whorls smooth except for the irregular, oblique growth lines; no spiral sculpture.

Measurements (in millimeters) of adult specimens.—

Catalog No.	Height	Diameter	Diameter of umbilicus	Number of whorls
S 8075	5. 8	10. 6	2. 4	4. 1
S 8076	6. 4	11. 4	1. 9	5. 0
S 8076	6. 4	11. 5	2. 0	4. 5
S 8076	6. 4	11. 9	2. 0	4. 6
USNM 561450	6. 0	10. 1	2. 0	4. 2
USNM 561450	5. 3	9. 3	1. 7	4. 2

Material.—

Catalog No.	Number of specimens	Locality
B 15373	1	1.
B 19935	4	1.
G 5925	2	1.
S 8075	1	1.
S 8076	8	1.
T 1107	1	1.
T 1108	8	1.
T 1417	4	1.
T 1439	5	1.
T 3137	24	1.
T 3138	84	1.
USNM 561450	6	1.
T 1789	7	3.
T 2445	6	5.
T 3135	2	5.
UC 34185–34189	5	"Barstow."

Remarks.—In general shape immature (3½–4 whorls) specimens of *Helminthoglypta alfi* and *H. graniticola arida* are the same, except that the body whorl of the latter is higher, relative to the width of the shell. Adult shells of *H. g. arida* are larger, more depressed, have a lower spire, a more oval aperture, and a proportionately broader body whorl. In addition *H. alfi* has the very last portion of the body whorl strongly deflected, whereas in *H. g. arida* the deflection of the body whorl is more gradual, and takes up about an eighth of the whorl. *H. alfi* differs from *H. graniticola* sensu stricto in being more depressed, although it can be matched by a few specimens of the latter in this respect, and in being smaller. It also has a proportionally higher body whorl and a more nearly circular aperture. The deflection of the body whorl is more conspicuous than in *H. graniticola*.

Only one specimen (T 3135) shows clearly the embryonic sculpture. The first half-whorl has numerous

oval or tear-drop-shaped papillae arranged radially on a background of irregular, fine radial wrinkles. These wrinkles alone are present on the second half-whorl, and thereafter become fine, irregular growth lines. This sculpture shows that the specimen cannot belong to *Micrarionta* (*Eremarionta*), but must be placed in *Helminthoglypta*.

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[Italic numbers indicate descriptions]

PLATE 20

PLATE 20

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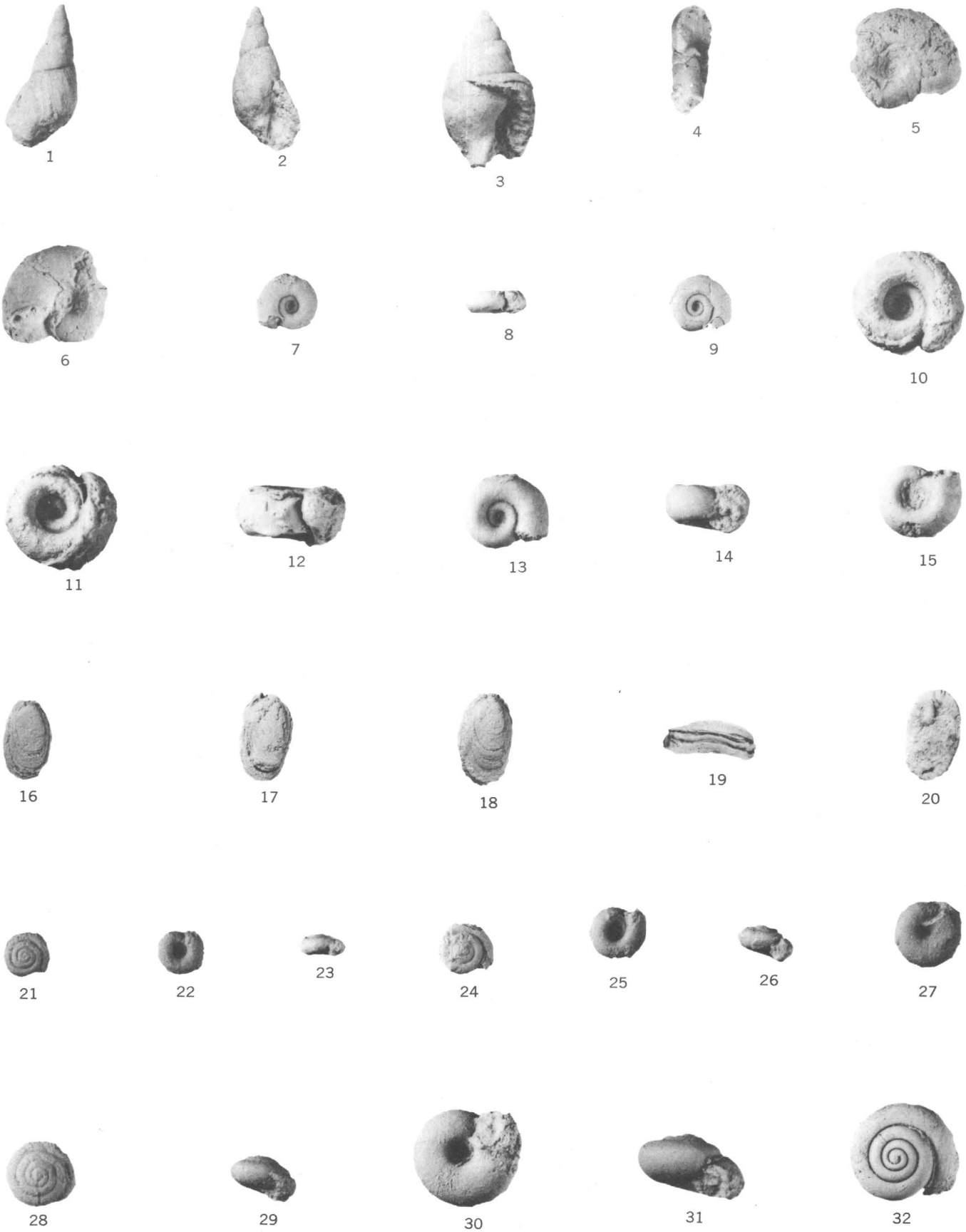

NONMARINE MOLLUSKS FROM THE BARSTOW FORMATION