

UPPER WOLFCAMPIAN (?) MOLLUSCA FROM THE ARROW CANYON RANGE, CLARK COUNTY, NEVADA

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ABSTRACT—An abundant and diverse silicified fauna comprised mostly of gastropods, but including pelecypods, scaphopods, chitons, small orthoconic nautiloids, sponges, ostracodes, a trilobite species, and foraminifers, occurs in association with the alga *Mizzia* in a structurally isolated portion of the upper Bird Spring Group (BS. Unit). At least three gastropod species, *Amaurotoma zappa*, *Glyptospira arelela*, and *Anomphalus jaggerius*, are new. The assemblage resembles, in some respects, that described by Chronic (1952) from the Kaibab Formation (Leonardian-Guadalupian) of Arizona as well as undescribed assemblages from the Loray Formation (upper Leonardian) of eastern Nevada and the Bird Spring Group (middle Wolfcampian ?) of the Providence Mountains in southwestern Nevada. The fauna is tentatively assigned an uppermost Wolfcampian age on the basis of *Schwagerina* cf. *S. crassitectoria* Dunbar & Skinner, which occurs several hundred feet above the mollusk-bearing bed, as well as on the occurrence of *Mizzia* cf. *M. yabei* (Karpinski), previously reported from Middle to Late Permian rocks.

Color markings are preserved on some of the gastropods, a chiton and a nautiloid.

INTRODUCTION

THIS study is part of an intensive investigation of the stratigraphy, paleontology, and geology of the Arrow Canyon Range, Clark County, Nevada, being conducted by staff and students of the Geology Department of the University of Illinois at Urbana. The fossils herein discussed were found during mapping in 1967 by R. L. Langenheim, Jr. After preliminary examination of the small initial sample indicated a rich and well-preserved fauna, additional collecting was undertaken in January and December, 1968. Because of the large size of the fauna and the limited time available, only a few species are considered in detail at this time. It is hoped that the entire assemblage will be thoroughly studied in detail in later work.

I wish to express my gratitude to D. B. Blake, who provided valuable assistance in all phases

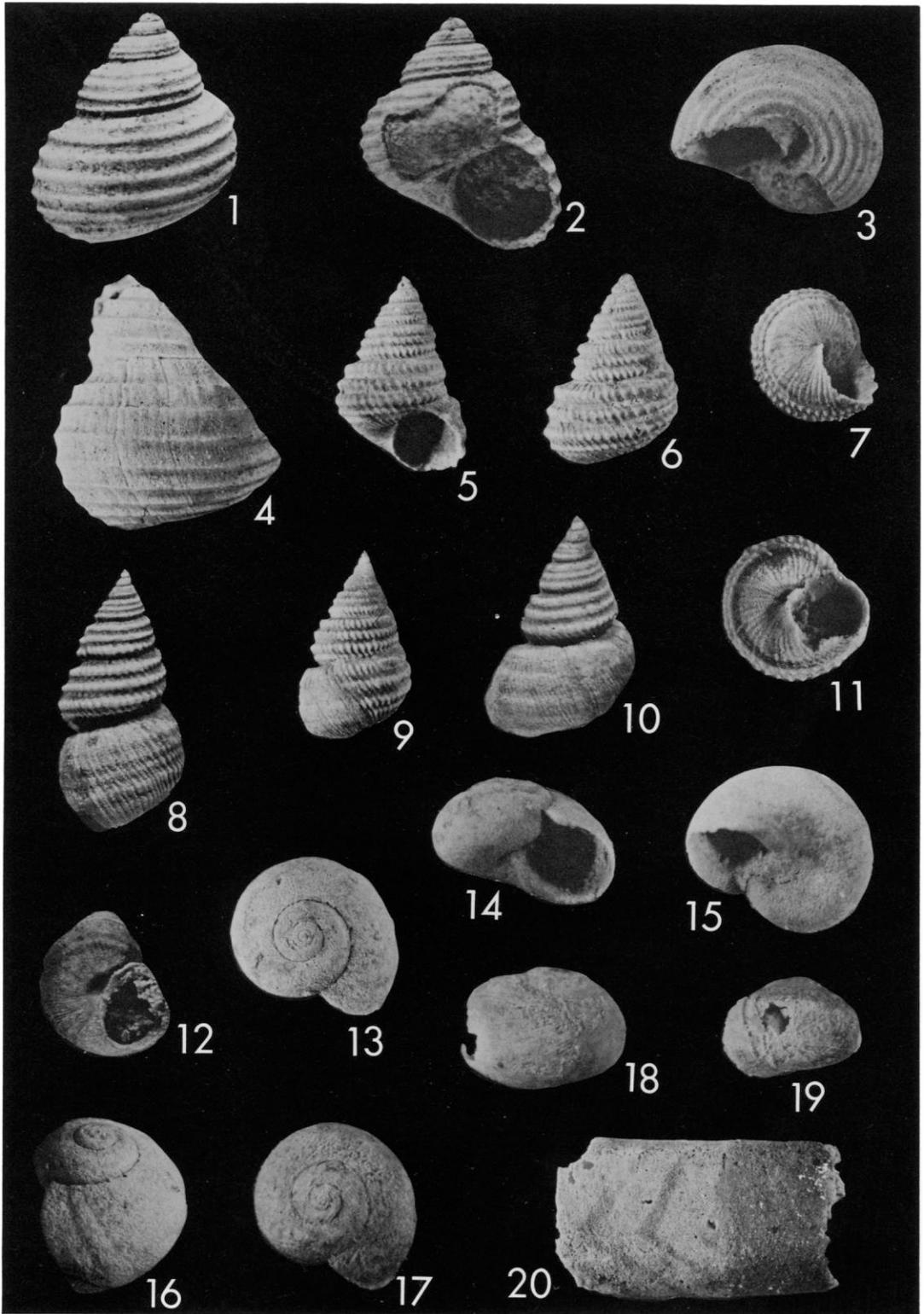
of the preparation of this paper; especially in the systematic studies. R. L. Langenheim, Jr., donated the original material, provided geologic and stratigraphic advice, and aided in final manuscript preparation. R. W. Pierce assisted in photography. E. L. Yochelson shared his knowledge of Permian gastropods and provided enthusiastic advice and support. Thanks are also due T. E. Yancey for stimulating critical discussions of Permian molluscan paleoecology.

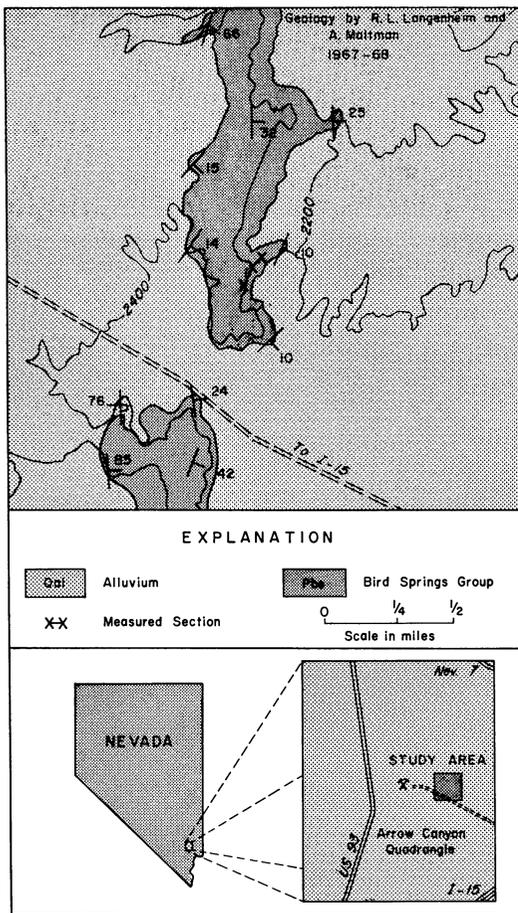
The Arrow Canyon Quadrangle, which includes the Arrow Canyon Range, is bounded by Lat. 36° 30' N., 36° 45' N., Long. 114° 45' W., and 115° 00' W., and is about 60 miles northeast of Las Vegas in Clark County, Nevada (Text-fig. 1). The measured stratigraphic sections and localities from which material was collected for this study are on the easternmost ridge of the range. The base of the measured

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EXPLANATION OF PLATE 1

- FIGS. 1-4—*Amaurotoma zappa* n. sp. 1-3, abapertural, apertural and basal views of holotype X-3339, $\times 4.0$; 4, abapertural view of paratype X-3345 showing sutural ramp and growth lines, $\times 4.0$.
5-12—*Glyptospira arelela* n. sp. 5-7, apertural, abapertural and basal views of holotype X-3346, $\times 4.0$; 8-10, abapertural views of paratypes X-3363, X-3364, and X-3366 showing smooth body whorl form, $\times 4.0$; 11, basal view of paratype X-3365 showing basal color band, $\times 4.0$; 12, basal view of paratype X-3366, $\times 4.0$.
13-19—*Anomphalus jaggerius* n. sp. 13-16; apical, apertural, basal and oblique views, the latter showing growth lines, of holotype X-3408, $\times 4.0$; 17, apical view of paratype X-3409 showing silicification threads, $\times 4.0$; 18, abapertural view of paratype X-3410 showing silicification threads, $\times 3.5$; 19, abapertural view of paratype X-3411 showing silicification threads, $\times 3.3$.
20—Orthoconic nautiloid, dorsal (?) view showing color banding, $\times 4.0$.





TEXT-FIG. 1—Index map showing location of measured section.

section presented here (Text-fig. 2) was marked in the field by a large red "4" painted on a low ledge about one-half mile north of the point where the road from Ute to the range front passes through the gap between Lookout Hill and the ridge to the north (Text-fig. 1). The low, medium-gray, massive limestone ledge which yielded the silicified fauna crops out 74 feet stratigraphically above this section marker and was marked with a red "I." This unit is six to seven feet thick and crops out for about 200 yards along and near the top of the ridge and for about the same distance along the east side of Lookout Hill. Blocks selected for apparent abundance of fossils were collected along the entire extent of the outcrop. Some blocks were etched with hydrochloric acid and some with acetic acid with no noticeable difference in results.

GEOLOGY AND STRATIGRAPHY

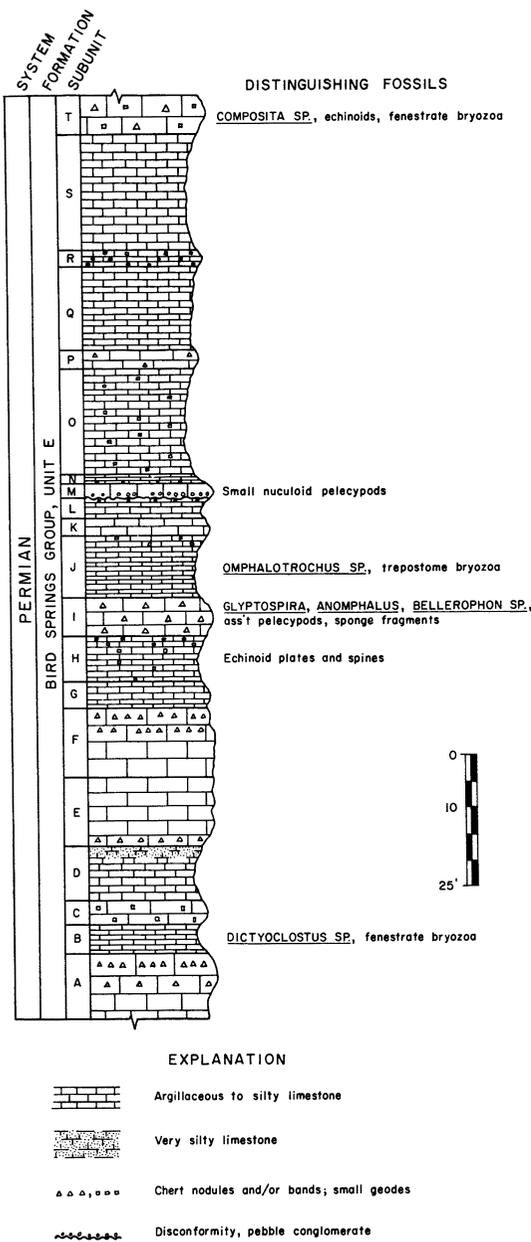
The geology and stratigraphy of the Arrow Canyon Range are summarized by Longwell, et al., (1965) and Langenheim, et al., (1962). Rocks in the vicinity of the measured section are limestones of Langenheim's (1962) BS_e Unit of the Bird Spring Group, which here strikes about N. 10° E. and dips 35° to 70° eastward (Text-fig. 1). The ridge is part of the west limb of a north-trending syncline on the downthrown side of the Dry Lake Thrust (Longwell, et al., 1965), but the outcrops are surrounded by caliche cemented Tertiary and Quaternary gravel and thus are isolated from the rest of the range so that physical correlation has not been possible. Furthermore, numerous minor normal and reverse faults deform the rocks of the ridge.

The Bird Spring Group in the Arrow Canyon Range has been described by Langenheim & Langenheim (1965), Lane & Webster (1966), Cassity & Langenheim (1966), Coogan (1964), and Webster (1969). These reports, however, deal only with exposures in Arrow Canyon, at Battleship Wash and at the south end of the range which do not include the uppermost portion of the Bird Spring Group and its contact with younger Permian or Triassic rocks. The sequence described in this report was not recognized within the Arrow Canyon or Battleship Wash outcrops, and, on the basis of geologic mapping completed to date, appears to be stratigraphically higher in the section.

STRATIGRAPHY

Rocks exposed in the vicinity of the section measured in January, 1968, are about 500 feet thick, but only 168 feet (Text-fig. 2) were measured and described in detail at that time. During a brief visit in December, 1968, a section about 500 feet thick was measured on the north end of Lookout Hill.

The first measured section consists of alternating tan and medium gray weathering limestone beds ranging from 1.4 to 22 feet thick. The tan rocks are generally thinner bedded and more silty and cherty than the massive, argillaceous gray rocks. Recognition of specific units on lithologic grounds is difficult, although unit "M," a three foot thick, massive, ledge-forming limestone containing scattered small compositid brachiopods, is distinctive. This unit is prominent throughout the exposure, capping hills and ridges, and is readily recognized on Lookout Hill.



TEXT-FIG. 2—Measured section showing horizons from which fossils were collected.

Unit "I," which contained the fossils treated in this report, is perhaps the most distinctive because of its abundant mollusks. Weathered surfaces display iron-stained, silicified specimens of *Glyptospira arelela* n. sp., *Anomphalus jaggerius* n. sp., *Bellerophon deflectus* Chronic (?), and many other gastropods and pelecypods. Lithistid sponge fragments are also generally

present and, when sufficiently abundant, give a reticulate pattern to weathered surfaces. The rock is silty and argillaceous and ranges from tan to gray with weathered surfaces generally medium gray. The uppermost one foot of the unit appears to have a lesser variety and number of gastropods, the most abundant being *Bellerophon*, which occurs in small groups rather than uniformly distributed. Such clustering is not limited to the top of the unit. This phenomenon has been reported by McKee (1938, p. 55) in facies 4 of the Kaibab Alpha Unit.

The section measured in December, 1968, includes a similar alternating sequence of thin-bedded, tan and massive gray units to about 250 feet above unit "I," at which point there is a transition to massive, three to six foot units of gray limestone containing many large echinoid fragments and some large *Pinna*-like pelecypods. At about 350 feet above unit "I," fusulinids (tentatively identified as *Schwagerina* cf. *S. crassitectoria*) and corals (*Ptolemaia* (?)) occur. A single specimen of *Glyptospira arelela* n. sp. was obtained from a richly fossiliferous unit 20 feet above the fusulinids.

CORRELATION

The youngest previously reported Permian rocks in the Arrow Canyon Range belong to the *Schwagerina* sp., *Pseudoschwagerina* sp., and *Paramillerella* sp. [*sic*] zone of Welsh (1959, unpub. PhD dissertation, Univ. Utah, Salt Lake City) in Arrow Canyon and the crinoid horizon of Lane & Webster (1966, p. 3-4) in Battleship Wash which is reported to contain *Pseudoschwagerina texana* Dunbar & Skinner and *Parafusulina* sp. These middle to upper Wolfcampian rocks are considered to be stratigraphically below the present molluscan assemblage on the basis of physical dissimilarity of those sequences to that containing the mollusks. Admittedly, the considerable local irregularity in depositional environments during this time makes such a conclusion tenuous, but the little available other evidence is not conflicting.

An upper Wolfcampian age has been assigned to the unit "I" fauna for several reasons. *Schwagerina* cf. *S. crassitectoria* Dunbar & Skinner, which is described from the Wolfcamp-Leonard boundary in the Hueco Mountains (Williams, 1963, p. 29), occurs several hundred feet above unit "I," strongly suggesting an upper Wolfcampian age. *Mizzia* cf. *M. yabei*, a middle to upper Permian alga, reinforces this conclusion. Unfortunately, the preservation of the staffellid fusulinid does not permit precise

identification and thus it is not helpful stratigraphically. Finally, *Omphalotrochus* has a range to the Middle Permian (Knight, et al., 1960, p. 1196) and characterizes latest Wolfcampian rocks in the western states.

Comparison of the mollusks to other described and undescribed assemblages from the Great Basin is not very informative in the stratigraphic sense because of the lack of knowledge of evolutionary rates and trends. The Kaibab fauna (Leonardian-Guadalupean) described by Chronic (1952) contains many genera in common with unit "I" assemblage (*Bellerophon*, *Glyptospira*, *Pleurophorous*, *Astartella*, etc.) but this may only reflect environmental similarity. An as yet undescribed fauna from the Loray Formation, late Leonardian of eastern Nevada, stratigraphically near that described by Yancey (1969) contains a species of *Glyptospira* apparently intermediate between that described here and Chronic's *G. cristulata*, which suggests that this fauna is probably older than late Leonardian. Finally, a sequence of middle (?) Wolfcampian rocks in the Providence Mountains in southeastern California contains *Amaurotoma zappa*, n. sp., as well as species of *Glyptospira* and *Anomphalus*, both of which are strikingly distinct from those of unit "I" (M. Kaasa, personal communication). The *Glyptospira* from the Providence Mountains is very dissimilar to any of the other three noted above and any speculation as to its stratigraphic or phylogenetic significance would be difficult. Knight (1948) presented a report on two species and seven subspecies, which presently would be placed in *Glyptospira*, and indicated a range of Wolfcampian to Guadalupean for the genus and commented on the evolutionary significance of the carinae. Unfortunately, the exact significance was not stated in the published abstract.

PALEONTOLOGY

The unit "I" fauna (Table 1) is dominated by the ornate, turbiniform gastropod, *Glyptospira arelela*, n. sp., with *Anomphalus jaggerius*, n. sp., a rotelliform, smooth gastropod, second in abundance. Beyond this, the order of abundance of the gastropods is less obvious, with at least 20 other species present. There are at least 12 species of pelecypods, but they are much less abundant than the gastropods. The pelecypods, however, are more susceptible to breakage and their apparent relative abundance thus may be reduced. Scaphopods are fairly plentiful, being represented mostly by individuals of the large smooth genus *Plagioglypta*, and less abun-

dantly by *Prodentalium*. Chitons are relatively numerous and about 50 valves, probably representing two species, were obtained from about 75 pounds of rock. The most abundant of the two belongs to an undescribed genus possessing a tail valve which is concave in lateral outline, a unique feature among chitons (A. G. Smith, 1968, personal communication). One specimen of this genus, comprising the posterior four articulated valves and three other closely associated valves, indicates a possible length of 2.5 cm. A species of the wide-ranging genus *Helminthochiton* is represented by three or four valves which belonged to individuals probably less than 4.0 cm long. Cephalopods are represented by scattered small, straight nautiloids as much as 13 cm long and by one badly broken nodose, coiled nautiloid.

Ostracodes are abundant and well-preserved with at least two species of bairdiids and one kirkbyid. Trilobites are fairly rare with one species of *Phillipsia* present. Trilobites apparently do not silicify readily, and their apparent scarcity could result from lack of preservation.

Of considerable numerical importance are *Staffella* sp., *Mizzia* cf. *M. yabei* (Karpinski), and lithistid sponge debris, which, along with *Glyptospira* and *Anomphalus*, constitute the major part of the insoluble residues from unit "I."

Echinoderms, brachiopods, and bryozoans are notably scarce. Scattered interambulacral plates less than 2 mm in diameter and very small spines of *Archeocidaris* (?) occur along with a few crinoid columnals that are less than 1 mm in diameter. Very small (3 to 4 mm long) brachiopods, probably referable to *Composita* and *Dielasma*, also occur in limited quantity. Small fragments of cryptostome bryozoa of several species are sparsely represented in the assemblage.

A few *Spirorbis* worm tubes occur on *Glyptospira* shells with no more than one or two per shell where present.

Very small, unsilicified fish vertebrae and other parts are also present in limited numbers.

PALEOECOLOGY

The sea bottom during unit "I" deposition appears to have been of soft calcareous mud including much broken and unbroken biogenous material along with terrigenous clay and silt. Locally, the rock has a higher silt content and generally these areas have large, poorly preserved specimens of *Bellerophon*, perhaps indicating a channel or similar slightly more

TABLE 1—Composition of the Unit "I" assemblage.

Major Group	Taxon	Frequency of Occurrence
Algae	<i>Mizzia</i> cf. <i>M. yabei</i> (Karpinski)	A
Foraminifers	<i>Staffella</i> sp.	A
Sponges	Lithistid debris	A
	Monaxon spicules	F
Bryozoans	Cryptostomes of several types	R
Brachiopods	<i>Composita</i> sp.	R
	<i>Dielasma</i> sp.	R
Echinoderms	<i>Archaeocidaris</i> sp. columnals	R R
	<i>Spirorbis</i> sp.	R
Chitons	<i>Helminthochiton</i> sp. New genus, new species	R F
Scaphopods	<i>Plagioglypta</i> sp.	R
	<i>Prodentalium</i> sp.	R
Pelecypods	<i>Allorisma</i> sp.	R
	<i>Astartella subquadrata</i> Girty	C
	<i>Bakewellia</i> spp.	R
	<i>Conocardium</i> spp.	R
	<i>Grammatodon</i> sp.	R
	<i>Nuculana</i> sp. or <i>Polidevcia</i> sp.	R
	<i>Paleonucula levatiformis</i> Walcott	C
	<i>Parallelodon</i> sp.	F
	Pectinoids, two spp.	R
	<i>Schizodus</i> sp.	R
	Gastropods	<i>Amaurotoma zappa</i> , n. sp.
<i>Anomphalus jaggerius</i> , n. sp.		A
<i>Apachella</i> spp.		C
<i>Bellerophon deflectus</i> (?) Chronic		C
<i>Colpites</i> sp.		R
<i>Glyptospira arelela</i> , n. sp.		A
<i>Goniasma</i> spp.		C
<i>Meekospira</i> spp.		C
<i>Naticopsis</i> sp.		R
<i>Omphalotrochus</i> sp.		R
<i>Orthonema</i> spp.		C
<i>Paleostylus</i> sp.		C
<i>Platyworthenia</i> sp.		C
<i>Sallya</i> sp.		F
<i>Soleniscus</i> sp.		R
<i>Straparollus</i> sp.		R
<i>Trachydomia</i> sp.	F	
Cephalopods	Orthoconic nautiloid	R
	Coiled nautiloid	R
Ostracodes	Bairdiid spp.	A
	Kirkbyid sp.	C
Trilobites	<i>Phillipsia</i> sp.	R
Fish	Vertebrae, etc.	R

A—more than 25 specimens

F—5–10 specimens

C—10–25 specimens

R—less than 5 specimens

current-swept environment, with the more abundant silt somehow inhibiting subsequent silicification. The presence of articulated pelecypods (*Paleonucula*, *Pleurophorus*, *Conocardium*, and *Astartella*—although these are infaunal and would be less subject to disarticulation), an articulated chiton, non-disaggregated *Mizzia* segments (as many as four), and the generally random orientation, lack of sorting and abrasion all indicate a relatively quiet environment with slow deposition. Scattered coquinoïd accumulations of larger fossils and angular fossil fragments could result from concentration and breakage during storms. In addition, breakage and limited concentration may result from burrowing and scavenging organisms. The absence of distinct bedding also suggests the activity of burrowing organisms or, perhaps, of continuous, uniform sedimentation. The likelihood of considerable biological activity on the sea floor, coupled with the presence of clay and silt, could produce enough turbidity close to the bottom to discourage filter feeders such as corals, bryozoa, brachiopods and crinoids. The scarcity of echinoids could also be attributed to unsatisfactory conditions as they apparently preferred coarser substrates as evidenced by their presence in coarsely silty units above and below unit "I."

The abundant algae and the presence of terrigenous material suggests a shallow environment. Scattered concentrations of both *Mizzia* and sponge framework probably mark the site of semi-isolated colonies of these organisms. Concentrations of staffellid foraminifers are less abundant. These accumulations could result from physical sorting but may arise from clusters attached to seaweed or from benthonic aggregations. Stevens (1966, p. 128) has interpreted *Spirorbis* as indicating a very shallow (0-5 m), possibly euryhaline, environment. Its presence in the unit "I" fauna appears consistent with this conclusion, although the precision of the depth range is uncertain.

I assume that chitons were washed in from a nearby rocky area as this is the environment of many living chitons. All other indicators, however, militate against the nearby occurrence of rocky bottom and it is conceivable that Paleozoic chitons may have been adapted for locomotion on a muddy bottom. The large insertion plates characteristic of most recent taxa were not well-developed until the Mesozoic and Cenozoic and their appearance may have marked some change in the chitons' mode of life. Also, the chitons may have been attached to other invertebrates or, as suggested by A. G. Smith

(1968, personal communication), they could have lived on the holdfasts of large algae.

Chronic (1952, p. 109) suggests that gastropods with thick, smooth shells (*Bellerophon*, etc.) in her Arizona assemblages lived on the bottom as burrowers or crawlers in contrast to the ornate types which lived clinging to the algae and falling to the bottom after death. Her idea of a seaweed forest would be equally applicable to the unit "I" fauna and is supported by the abundance of *Mizzia* in the assemblage. Such a forest would further dampen wave agitation and reduce shell abrasion. Scattered blocks of limestone containing specimens of *Glyptospira* almost exclusively may mark the location of unpreserved colonies of other algae.

Probable infaunal elements include scaphopods and the pelecypods *Paleonucula*, *Conocardium*, *Nuculana* (or *Polidervcia*) and *Astartella*. One specimen of the scaphopod, *Prodentalium*, about 3.5 cm long was found in life position.

Individuals of *Parallelodon* and *Astartella* with holes bored in the umbonal area may indicate that at least one gastropod species was predatory on pelecypods. Molnia (1971), however, has demonstrated that such holes may arise through mechanical abrasion.

As in most paleoecological interpretations, it is difficult to quantify such factors as depth, salinity and turbidity. Stevens (1966) attempted to assign depth ranges to his various communities based on comparison of Permian and Recent taxa. The unit "I" fauna resembles most closely his Euphemitid Community to which he assigned a depth range of 0 to 4 meters. The major qualification in regard to comparing the unit "I" fauna and the Euphemitid Community of Stevens is the absence of *Euphemitopsis* in the Bird Spring assemblage. Examination of material from the Loray Formation in the collections of the University of California at Berkeley, apparently the source of Stevens' collections, indicates that restrictive conditions are necessary for the presence of *Euphemitopsis*, and, where present, it occurs in great numbers. Moore (1964), described some late Pennsylvanian assemblages from Kansas and cited two molluscan assemblages, comparing favorably with that of unit "I." His Drum and Beil assemblages, although they are dominated by gastropods and pelecypods, contain appreciable numbers of brachiopods, crinoids, and echinoids; all of which suggests slightly differing ecologic conditions from those of the "I" fauna. It appears that the irregularity of depositional environments during latest Paleozoic

time in the Great Basin caused development of many different nearshore communities, and that the closest described approximation to the environment of unit "I" is that of locality 3 of Chronic (1952). This assemblage, however, did not contain lithistid sponge material although most other faunal elements are present in common, at least at the generic level.

SHELL COLORATION

Many unit "I" specimens retain original color patterns in spite of silicification. *Glyptospira arelela*, n. sp., is most striking, with about 80% of the individuals showing some coloration in the form of revolving bands adjacent to the carinae. Generally, a distinct brown band is present just abapical to the fourth carina of the body whorl (Pl. 1, fig. 11). Pigmentation occurs less generally between other carinae. In some specimens of *G. arelela* the pigment is localized in a deposit which seems to fill flat-bottomed grooves between the carinae rather than being dispersed in the shell substance itself. This may result from a different mode of silicification of the pigmented shell material. Perhaps the pigment granules interfere with formation of a continuous silica lattice, causing the "shell proper" and pigmented material to appear as separate entities. Yonge, (1960, p. 123-125) stated that melanin, a pigment that may be preserved for long periods of time, is intimately associated with conchiolin in the outer shell layer, and that soluble shell pigments occur in the calcium carbonate of the shell. This statement is an oversimplification and is also misleading since insoluble pigments, possibly melanin, are intimately associated with the shell material of gastropods. In any event, the pigmented material preserved in the Nevada specimens of *Glyptospira* probably was not contained in the outer sheath of conchiolin, which generally deteriorates rapidly after death and is only a thin veneer, whereas the pigment in *Glyptospira* extends well into the shell. In some mollusks, pigmented conchiolin encloses each prism of calcium carbonate within the shell, and this may be the case in *Glyptospira*.

In addition to coloration in *Glyptospira*, one poorly preserved individual of *Sallya* sp. has transverse blotches on the upper whorl surface and a small slightly flattened orthoconic nautiloid (Pl. 1, fig. 20) bears asymmetric "V"-shaped lines pointing toward the aperture. Inasmuch as only half of the cone is preserved, it is not known whether the pattern was bilaterally symmetrical or whether it is confined to the dorsum of the conch. Teichert (1964, p.

K23-K24) states that if coloration is limited to one side of a cephalopod shell, it is on the dorsum. One chiton valve may retain some color in the form of two longitudinal stripes near the center of the valve, but these are very indistinct. Finally, the generally brownish tinge of the trilobites and ostracodes may result from retention of some organic material in their originally chitino-calcareous shells.

Foerste (1930, p. 145) indicates that distinct and striking color designs occur only on organisms inhabiting shallow waters and that the more distinct the markings, the shallower the water inhabited. This observation supports the idea that the unit "I" mollusks were shallow water dwellers, but does not provide a basis for estimating the actual depth.

SYSTEMATIC PALEONTOLOGY

The terminology and classification is that of the Treatise on Invertebrate Paleontology, Part I (Knight, et al., 1960).

Phylum MOLLUSCA

Class GASTROPODA Cuvier, 1797

Order ARCHAEOGASTROPODA Thiele, 1925

Suborder PLEUROTOMARIINA Cox & Knight, 1960

Superfamily TROCHONEMATACEA Zittel, 1895

Family TROCHONEMATIDAE Zittel, 1895

Genus AMAUROTOMA Knight, 1945

Type species.—*Amaurotoma subsinuata* (Meek & Worthen, 1861)

AMAUROTOMA ZAPPA, n. sp.

Pl. 1, figs. 1-4

Diagnosis.—Small, turbiniform, with rounded whorls, moderately impressed suture, small umbilicus, and about 13 to 18 angular carinae separated by shallow concave furrows; carinae evenly developed adapical to periphery, smaller and closer spaced abapical to periphery.

Description.—Shell small, turbiniform, dextral, as many as 5 whorls; umbilicus narrow; protoconch poorly known, probably 2½ smooth, simple whorls; whorl profile rounded in most individuals, larger specimens with sutural ramp, giving whorls an angular aspect; aperture nearly circular, slightly elongate axially, very thin parietal inductura on upper portion of inner lip, not extending beyond aperture; inner lip slightly reflexed around umbilicus; apertural lip crenulate, reflecting spiral ornament; spiral ornament 13 to 18 angular carinae separated by shallow concave furrows; 5 to 6 carinae regu-

TABLE 2—Measurements of *Amaurotoma zappa*, n. sp. (in mm).

Specimen	Shell height	Shell width	Aperture height	Aperture width	Number of whorls
X-3339*	9.2	7.9	4.7	4.6	5
X-3340	8.6	8.2			5
X-3341	3.2	3.1	2.0	1.8	5
X-3342	6.4	6.1	3.5	3.5	4
X-3343	14.1	10.3	6.5	6.1	5+
X-3344	4.1	3.9			4

* Holotype

larly spaced on upper whorl surface near suture to just below periphery, 7 to 10 progressively smaller, more closely spaced carinae from just below periphery to base, but not inside of umbilicus; larger individuals generally with single fine lira between carinae; axial ornament of faint threads across adapical 3 carinae but not across entire whorl; growth lines opisthocyrts adapically, becoming prosocyrts at about third carina; opisthocyrts portion of growth line outlining very shallow sinus; pleural angle from 45° to 65° with lower angles in larger individuals; maximum dimensions observed on an unbroken specimen, unfigured paratype X-3345—height of shell, 14.1 mm; width, 10.3 mm; height of aperture, 6.5 mm; width of aperture, 6.1 mm; number of whorls, 5; pleural angle 45°. Table 2 gives measurements of other paratypes and the holotype.

Discussion.—*Amaurotoma zappa*, n. sp., resembles *A. subsinuata* (Meek & Worthen) and *Yunnania termieri* Mansuy. The resemblance to *A. subsinuata*, a Pennsylvanian species redescribed by Knight (1933, p. 50) is marked. The major differences are the size of the individual and the shape of the growth line. Maximum dimensions reported by Knight (1933, p. 50) for a gerontic "plesiotype" of *A. subsinuata* are height of shell, 10.0 mm, width of shell, 6.0 mm, and pleural angle, 40°. The size difference, however, is not as important as the fact that the aperture of some individuals of *A. subsinuata* has a shallow sinus high on the whorl at about the third carina, which produces "V"-shaped growth lines at this carina. *A. zappa* has an apparently similar sinus, but it is extremely shallow and smoothly concave, resulting in an opisthocyrts rather than "V"-shaped growth line (Pl. 1, fig. 4). Difficulty in differentiation of these two species may arise because Knight reports that the sinus is not uniformly evident in the Pennsylvanian material, and I note that it is obscure in much of the Permian material.

A. zappa differs from *Yunnania termieri* Mansuy being umbilicate, lacking prosocline growth lines, and in its thinner shell.

The sutural ramp in larger individuals of *A. zappa* (Pl. 1, fig. 4) further distinguishes the species although it is not uniformly present and its significance is unknown.

Knight, et al., (1960, p. 1225) state that a trend toward loss of the right ctenidium in the Trochonematacea causes subsequent progressive loss of the channel or sinus in the apertural lip. The extremely shallow sinus of *A. zappa* in contrast to that of *A. subsinuata*, an older species, may reflect this trend.

Specimens apparently referable to *A. zappa* occur in the Bird Spring Group of the Providence Mountains and in the Loray Formation in eastern Nevada.

Name.—The specific name, *zappa*, honors Frank Zappa.

Hypodigm.—Holotype, X-2229; figured paratype, X-3345; and five unfigured paratypes, X-3340 through X-3344, in the collections of the Department of Geology, University of Illinois, Urbana, Illinois.

Suborder TROCHINA Cox & Knight, 1960

Superfamily MICRODOMATACEA Wenz, 1938

Family MICRODOMATIDAE Wenz, 1938

Genus GLYPTOSPIRA Chronic, 1952

Type species.—*Glyptospira cristulata* Chronic, 1952.

GLYPTOSPIRA ARELELA, n. sp.

Pl. 1, figs. 5–12

Diagnosis.—Small, turbiniform, with three equally developed carinae on upper whorl surface and one weak carina just below periphery.

Description.—Shell small, turbiniform, dextral, moderately high-spired, as many as 8 whorls; aperture slightly elongate axially, 0.3 to 0.4 height of shell; umbilicus minute; suture moderately deep, impressed; protoconch 2½ to

TABLE 3—Measurements of *Glyptospira arelela*, n. sp. (in mm).

Specimen	Shell height	Shell width	Aperture height	Aperture width	Pleural angle	Number of whorls
X-3346*	7.5	5.4	3.3	2.9	49°	6
X-3367	9.0	6.0	3.9	3.6	47°	6+
X-3368	8.3	5.5	3.7	3.0	40°	7
X-3369	8.2	5.6	3.0	2.9	45°	6
X-3370	7.5	5.2	3.0	3.2	52°	6+
X-3371	7.5	5.0	3.0	2.8	46°	5
X-3372	7.2	5.3	3.3	3.0	55°	
X-3373	7.2	5.3	2.9	2.9	58°	6
X-3374	7.0	5.4	2.7	2.8	48°	5+
X-3375	7.0	5.0	3.1	3.0	55°	6
X-3376	6.9	4.8	2.7	2.9	51°	6+
X-3377	6.9	4.4	2.9	2.5	48°	6
X-3378	6.8	4.5	2.9	2.5	51°	
X-3379	6.6	4.6	2.9	2.7	53°	
X-3380	6.6	4.6	2.9	2.6	43°	5
X-3381	6.5	4.6	2.8	2.4	50°	6
X-3382	6.5	4.8	2.8	2.7	40°	6
X-3383	6.5	4.6	3.0	2.8	54°	
X-3384	6.3	4.9	2.8	2.7	61°	6
X-3385	6.1	4.2	2.8	2.3	50°	6
X-3386	5.9	4.0	2.2	2.8	48°	6+
X-3387	5.9	4.3	2.8	2.3	48°	5+
X-3388	5.9	4.1	2.7	2.4	55°	5+
X-3389	5.8	4.0	2.4	2.4	46°	6
X-3390	5.8	4.3	2.3	2.3	52°	6+
X-3391	5.8	4.0	2.1	2.0	53°	5.5
X-3392	5.7	4.1	2.5	2.4	57°	5+
X-3393	5.4	3.8	2.4	2.2	50°	5
X-3394	5.2	3.8	2.4	2.0	62°	6
X-3395	5.1	3.6	1.9	2.1	43°	5+
X-3396	5.0	4.0	2.0	2.0	53°	5+
X-3397	4.9	3.7	2.2	2.2	53°	5+
X-3398	4.8	3.5	2.0	1.8	52°	6
X-3399	4.5	3.5	1.9	1.8	52°	5
X-3400	4.6	3.4	2.2	1.8	59°	4+
X-3401	4.6	3.6	2.0	1.9	50°	5
X-3402	4.1	3.5	1.9	1.9	69°	5+
X-3403	3.8	2.9	1.9	1.6	59°	5
X-3404	3.4	2.7	1.7	1.6	59°	4+
X-3405	2.9	2.3	1.3	1.3	66°	4+
X-3406	2.5	1.9	1.1	1.1	67°	4
X-3407	2.5	2.0	0.8	0.8	61°	4

* Holotype

3 smooth, simple whorls; spiral ornament 3 strong carinae adapical on whorl, one weak carina just below periphery and close to third strong carina; strong carinae equally spaced in juvenile whorls, but first and second closer than second and third in more mature whorls; spiral ornament appearing on third whorl, abapical strong carina first, then upper two, all present by fifth whorl; transverse ornament of fine, closely-spaced, prosocline, collabral threads or growth lines rendering carinae rasplike; spire

whorl profile angular, adapical carina forming small shoulder and sutural shelf at top of whorl; body whorl gently convex abapically to third carina; inner lip reflexed slightly about umbilicus; height to width ratio ranging from 1.2 in juveniles to 1.5 in adults; pleural angle ranging from 40° to 70° with larger angles generally on smaller individuals.

Coloration has been discussed in general account. Table 3 lists measurements of the holotype and paratypes.

Discussion.—The angular whorl profile of *G. arelela*, as well as its single weak carina near the periphery, serves to distinguish it from *G. cristulata* Chronic, from the Kaibab Formation at Walnut Canyon, Arizona, the only other described species. That species has 5 to 6 weak carinae below the periphery and a rounded whorl profile. It is also generally higher spired, having a height to width ratio ranging from 2.1 to 1.1 and pleural angles ranging from 50° to 25°.

An undescribed species of *Glyptospira* from the Loray Formation at Ward Mountain near Ely, Nevada, differs from the others in that the fourth carina tends to be adapical to the suture and generally more than one weak carina is abapical to the three strong ones.

Another undescribed species of *Glyptospira* from the Bird Spring Group of the Providence Mountains, California, is distinct in having irregularly developed carinae on the upper whorl surface. The abapical carina is most strongly developed, the adapical is less developed, and the central carina is very weak.

Five to ten percent of *G. arelela* individuals have a distinct ontogenetic change in ornament and body whorl development. The spiral carinae become extremely subdued, though distinguishable, color bands, where present, are wider and more diffuse than in "normal" specimens, the body whorl is almost disjunct, and the suture may be sinuous (Pl. 1, figs. 8–10, 12). Growth lines also apparently become more closely spaced. These conditions may develop gradationally or abruptly and the exact size of the individual in which these changes first appear differs substantially, but generally the condition is more likely in the larger sizes (Table 4). This suggests that the changes are associated with reductions in growth and may be gerontic features. The absence of such changes in many large individuals, however, implies that the condition is not characteristic and may either be a recessive character or a pathologic condition. In addition, one specimen has the carinae greatly reduced over the entire shell, with gently convex carinae crossed by normal growth lines which dominate the ornamentation. This individual may represent some extreme of genetic recombination or may be merely an artifact of silicification.

Name.—The specific name, *arelela*, is derived from the initials of R. L. Langenheim, Jr.

Hypodigm.—Holotype, X-3346, and paratypes, X-3347 through X-3407, are in the collections of the Department of Geology, University of

TABLE 4—Dimensions of smooth body whorl variety of *G. arelela*, n. sp. (in mm).

Specimen	Height of normal development	Total height
X-3347	6.2	8.5
X-3348	6.5	8.8
X-3349	6.3	8.7
X-3350	8.3	11.1
X-3351	7.7	10.3
X-3352	6.3	7.1
X-3353	8.8	11.0+
X-3354	7.6	9.6
X-3355	6.5	6.9
X-3356	6.2	3.0
X-3357	6.9	8.2
X-3358	5.9	6.1
X-3359	6.1	6.4
X-3360	5.7	7.9
X-3361	5.5	6.5
X-3362	6.0	6.1

Illinois, Urbana. Many hundreds of individuals were studied.

Superfamily ANOMPHALACEA Wenz, 1938

Family ANOMPHALIDAE Wenz, 1938

Genus ANOMPHALUS Meek & Worthen, 1867

Type species.—*Anomphalus rotulus* Meek & Worthen, 1867.

ANOMPHALUS JAGGERIUS, n. sp.

Pl. 1, figs. 13–19

Diagnosis.—Small, very low-spired, cryptomphalus, with elliptical whorl profile.

Description.—Small, smooth, dextral, rotelliform, with as many as 5 whorls, protoconch smooth, simple, very low-spired; whorls oppressed; suture distinct, not impressed; hemiomphalus in individuals as large as 28.0 mm high; crytomphalus in larger sizes, with small crescentic callus just filling umbilicus but leaving a depression at its site; whorls with a constant moderate curvature from suture to periphery, curvature increasing at periphery for short distance, flattening at base and curving gently inward near umbilical area; aperture round; apertural lip thickened at juncture with penultimate whorl, thinning toward periphery, thickening again at juncture with columellar lip forming roughly crescentic, callused columella, upper part of which fills umbilicus; growth lines indistinct, prosocline; average height to width ratio about 0.73; Table 5 gives measurements of the holotype and paratypes.

TABLE 5—Measurements of *Anomphalus jaggerius*, n. sp. (in mm).

Specimen	Height of shell	Width of shell
X-3408*	5.2	7.0
X-3409	5.3	6.7
X-3410	5.6	7.7+
X-3411	5.0	6.8
X-3412	5.5	7.2
X-3413	5.2	7.1
X-3414	6.4	8.6
X-3415	5.5	7.5
X-3416	5.2	7.0
X-3417	4.3	5.4
X-3418	2.7	4.1+
X-3419	2.0	3.0
X-3420	3.8	5.3
X-3421	3.9	5.5
X-3422	5.4	7.4
X-3423	5.7	7.9
X-3424	5.4	7.3

* Holotype

Discussion.—*A. jaggerius* differs from *A. vanescens* Yochelson, from the Hueco Formation, Texas, and *A. studiosus* Yochelson, from the Word and Leonard Formations, Texas, the other described Permian species, in that it is cryptomphalus through most of its life and generally larger. *A. jaggerius* is also higher spired, with a height to width ratio of 0.73 as compared to 0.56 for *A. vanescens* and 0.54 for *A. studiosus* (ratios based on data in Yochelson, 1956, p. 253, 255). The only other cryptomphalous species, *A. rotulus* Meek & Worthen, and *A. verruculiferous* (White), both of Pennsylvanian age, are generally much smaller than *A. jaggerius* (Yochelson, 1956, p. 253).

Many individual *A. jaggerius* display very fine, siliceous threads beginning at the suture and spiraling outward and downward to the periphery of the whorl where they join a series of similar threads following the periphery. All threads below the periphery parallel it (Pl. 1, figs. 17–19). These structures are limited to the outer shell layer and characteristically occur on less well-preserved individuals. Yochelson (personal communication, 1968) suggests that the threads result from crystallization of the silica along rows of aragonite crystals in the original shell. This structure has been observed also in specimens of *Naticopsis* sp. from unit "I."

Name.—The specific name, *jaggerius*, honors Mick Jagger.

Hypodigm.—Holotype, X-3408, and paratypes, X-3409 through X-3424, are in the collections of the Department of Geology of the University of Illinois.

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