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## Early Triassic Gastropods from the Sinbad Member of the Moenkopi Formation, San Rafael Swell, Utah

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### ABSTRACT

The Sinbad gastropod fauna is important because it is the most diverse Early Triassic fauna known, with 16 genera and 26 species, 22 of which are new. It is not a typical offshore marine fauna like those found in the post-Scythian. It consists of enormous numbers of embryonic shells and small-size species in coquinal limestones. Pelecypods are equally abundant but are poorly preserved and show even less diversity. Ammonoids, important as index fossils, are present but rare. Sponges, echinoderms, algae, and conodonts are also represented by scattered individuals. All other rocks of Scythian age have yielded just a few species

representing conservative, long ranging genera such as *Worthenia*, *Coelostylina*, *Naticopsis*, or *Omphaloptychia* also found in the Sinbad. In addition, the Sinbad fauna contains the trochids *Boutillieria*, *Natiria*, and *Chartronella*; the neritids *Vernelia* and *Neritaria*; the loxonematids *Zygopleura*, *Kittliconcha*, and *Anoptychia*; the cerithid *Promathilda*; the subulitid *Strobeus*, and the opisthobranch *Cylindrobullina*. Sedimentary evidence suggests that the Sinbad fauna was distributed in a subtidal lagoonal environment in an arid climate.

### INTRODUCTION

The gastropod fauna of the Sinbad Limestone consists of enormous numbers of embryonic shells and small-size species of mostly unrecognizable taxa in coquinas. In a few localities there are some well-preserved specimens of both large and small-size species. This study is of one such locality, near Windowblind Butte (AMNH Locality #3026).

Pelecypods are also present in substantial numbers but the diversity is less than that of the gastropods. Ammonites, important index fossils, are represented by scattered individuals. Sponges and echinoderms (crinoid stems and echinoid spines and plates) are present, but uncommon. Conodonts are fairly abundant, but have not been studied.

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### STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT

The most detailed study of the Sinbad Limestone member of the Moenkopi Formation of the San Rafael Swell is that of Blakey (1974). He named, for the first time, the underlying Black Dragon Member and the overlying Torrey Member. Within the Sinbad Member Blakey recognized three facies: a basal skeletal calcarenite (the fossil-bearing unit from which our collection was made), a middle silty, peloidal calcilutite, and an upper dolomitized calcarenite. There is much interfingering of the lower and upper boundaries, which decreases the thickness from 100 ft to about 50 ft west to east across the San Rafael Swell (Blakey, 1974, pp. 23–25). Fossil-bearing Sinbad has been identified as far east as the Salt Valley anticline in Grand County. The Sinbad obviously represents the most extensive transgression of the Early Triassic seas into central Utah.

Blakey's conclusions regarding the depositional environment of the skeletal calcarenite follows:

The dolomitized calcarenite facies was deposited in a variety of shoreline and nearshore environments. In the Island in the Sky area (about 35 miles southeast of the San Rafael Swell) stromatolite heads, oncholites, and laminated mats of algal origin are common. These features are composed of intraclasts, pellets and oolites with subordinate terrigenous material and gypsum in veins and pockets. According to Logan *et al.* (1964), flat to crinkly-laminated algal mats are suggestive of the supratidal or high intertidal zone, while discrete "cabbage heads" like those in the Sinbad suggest an intertidal environment with a substantial tidal range, and algal balls or oncholites suggest low intertidal or subtidal zones with more constant agitation. The small amount of sand and silt is attributed to low relief and absence of a nearby terrigenous source and distributing agents (rivers) in an arid climate. The above characteristics suggest marine carbonate shoreline sedimentation in an arid climate (Blakey, 1974, p. 55).

Dean (1981) subdivided the Sinbad Limestone into five lithofacies units representing subtidal to supratidal deposits in the Capitol Reef area of south-central Utah. The section in the Windowblind Butte area is about 100 ft thick and contains most of the facies de-

scribed by Dean. The snails are from the lower five ft of a dark weathering oolitic packstone unit that is about 20 ft thick in the middle portion of the section. This unit is lithofacies B of Dean, representing a subtidal lagoonal environment of an encroaching sea.

### AMMONOIDS AND CORRELATION

Ammonoid shells constitute a small but significant fraction of the Sinbad Limestone coquinas. Mostly, these show preburial breakage, as do other fossils, but a few are preserved well enough for identification. Stewart *et al.* (1972) summarized all reported finds from the Sinbad prior to 1972. They listed *Meekoceras gracilitatis*(?), *Meekoceras*(?) sp., *Parannites* sp., *Anasiberites* sp., *Xenocelites* sp., and *Hemiprionites* sp. J. S. Dean (1981), from observations of the Sinbad Limestone of the Teasdale Dome, about 50 miles south of the San Rafael Swell collecting site, reports as follows: "Collections (of ammonoids) are dominated by *Meekoceras* sp., probably *M. gracilitatis*, followed by *Wyomingites* sp. Part of a coarsely ribbed conch similar to *Wasatchites* sp. was also recovered." Blakey's (1974) collection contains *Wyomingites* cf. *W. whiteanus*, *Dienoceras knechi*, *D. spathi*, and *Arctoceras tuberculatum*. A small collection made by Stokes from AMNH Locality 3026 contains *Meekoceras gracilitatis* and *Arctoceras mushbackanum* (Bernard Kummel, personal commun.).

Zonation of Triassic ammonoids has been discussed by Tozer (1971). He shows all known Sinbad taxa clustered in or near the Smithian Substage of the Nammalian Stage of the Early Triassic. The evidence is coherent; *Anasiberites*, characteristic of the Smithian, is found in the Sinbad, as is *Wasatchites*; these are worldwide guides to the same interval. In terms of the recently proposed Decade of North American Geological Time Scale (Palmer, 1984), the Smithian, near the middle Scythian, is dated at approximately 242–244 million years.

### THE GASTROPODS

The Sinbad Limestone is a correlative of the Siusi Member of the Werfen Formation of northern Italy (Broglia *et al.*, 1983) which is also an oolitic packstone containing a di-

verse microgastropod fauna of *Worthenia*, *Coelostylina*, *Naticopsis*, *Bellerophon*, *Omphaloptychia*, and "*Holopella*." Beds below the Siusi Member contain brachiopods and other groups that are mixed Triassic and Permian.

There is no other comparable gastropod fauna known except in the Triassic Anisian beds of Guizhou Province, China, and in the Virgin Limestone member of the Moenkopi. The Virgin Limestone thus far has not yielded the diversity seen in the Sinbad. Most other lower Triassic gastropods are reported as isolated species in faunal lists. Larson's (1966) study of the Virgin Limestone of Nevada does report 3 brachiopod species, 12 clam species, and 9 gastropod species. In addition to his species, we are describing *Omphaloptychia laevisphaera*, n. sp., *O. homolirata*, n. sp., *Coelostylina costata*, n. sp., *Naticopsis* (*Naticopsis*) *virginensis*, n. sp., and *Anoptychia eotriassica*, n. sp., which are found in both the Sinbad and Virgin Limestones. There are distinct differences between these gastropod faunas. The most common forms in the Sinbad are the immature specimens of several *Naticopsis* species along with *Anoptychia* and *Cylindrobullina*; these are absent or very rare in the Virgin. The commonest forms in the Virgin appears to be a species of *Coelostylina* (called *Omphaloptychia* by Larson) and a species of *Trachynereita*.

The Anisian fauna (which is younger than the Sinbad) of Guizhou Province of China (Yin and Yochelson, 1983a) is the earliest Triassic fauna which appears to have most elements of a normal marine fauna, but even it lacks some of the predominant Paleozoic genera that occur in the Ladinian or higher stages of the Triassic. It is interesting that in the Guizhou fauna most species are represented by one or several specimens and no species has astronomical numbers of individuals—in sharp contrast to the Sinbad.

The Sinbad and the Guizhou faunas are interesting because of what they do not contain. The Sinbad fauna lacks the diverse pleurotomarians and euomphalids seen in the Guizhou or the higher Ladinian. They both lack the mesogastropods and neogastropods (such as the mathildids, purpurinids, or aporhaidids) so common to the later faunas. We suspect that the Sinbad lacks these important

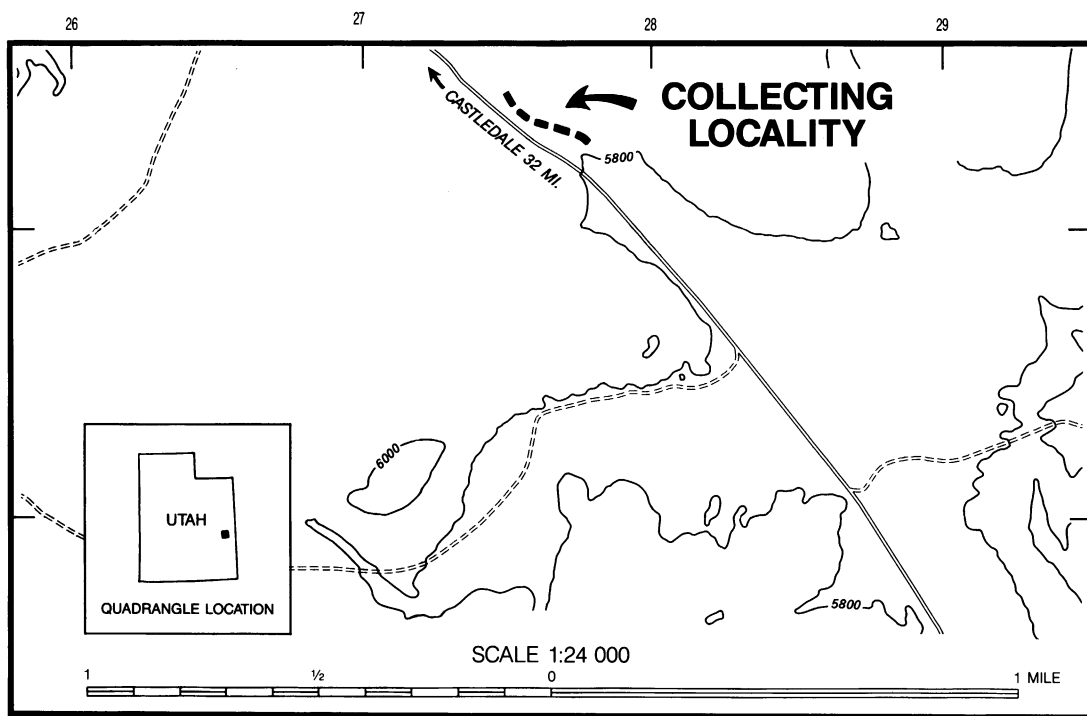
elements because of the ecological conditions (high-energy environment) of the San Rafael Swell region. The pleurotomarians and euomphalids, in particular, are found in low-energy, offshore sediments in the late Paleozoic.

The Guizhou fauna, like the Sinbad, is dominated by small-size species (the average less than 0.75 cm high). Although the Guizhou fauna lacks a number of groups that are dominant in the Ladinian, since it does contain a diverse pleurotomarian and euomphalid fraction of the fauna, we feel it is deficient owing to a preservation phenomenon. Both faunas are decidedly Paleozoic rather than Mesozoic in appearance (Yin and Yochelson, 1983c, p. 1101). The Scythian of China (Pan, 1980) from the Guizhou Province and Tibet also has a Paleozoic aspect containing bellerophonitids and trochids similar to those seen in the Northeastern Asia Lower Triassic, but it lacks diversity.

#### MATERIALS AND METHODS

All Sinbad Limestone specimens were collected at locality AMNH 3026 in the lower 5 ft of a dark weathering oolitic limestone unit (containing bands of sandstone 20 ft thick) which is about 50 ft up from the base of the Sinbad. The Sinbad is about 100 ft thick at this locality. The section is on the road at top of the main Dry Canyon just below a limestone bench capping the canyon. It is 4½ miles south-southeast of Windowblind Butte (1 mile northeast of the center of T21S, R11E), Stinking Spring Quadrangle, northeast Utah (see index map).

The preservation of the fossils is quite variable. Many of the pectinid clams have fine elements of the shell structure preserved, while other clam and snail shells are recrystallized or dissolved completely so that only internal molds are left. Most of the fossil shells are preserved as calcitic pseudomorphs after aragonite. In most cases, the specimens can be freed from the matrix by needles, but in many specimens either the outer shell layer or the entire shell is feathered in so that the shell layers remain locked into the matrix when the rest of the shell is freed. In those cases the ornament and growth lines, necessary for recognition of the genera and species,



CONTOUR INTERVAL 40 FEET  
NATIONAL GEODETIC VERTICAL DATUM OF 1929

### INDEX MAP

FROM THE U.S. GEOLOGICAL SURVEY NW¼  
WICKOP QUADRANGLE, UTAH - EMERY CO.

are not available for study. This further reduces the opportunity to observe the real diversity of the fauna.

### ACKNOWLEDGMENTS

We would like to thank Ms. Lauren Duffy for assisting us in producing SEM micrographs that were used in this study. Mr. Peter Harries and Amy Adelson photographed specimens illustrated in this paper. We also thank Drs. Richard D. Hoare and Harold B. Rollins for reviewing the manuscript.

### ABBREVIATIONS

AMNH, American Museum of Natural History  
H, shell height  
W, shell width  
SPANG, spiral angle  
SD, subsequent designation

### SYNOPTIC CLASSIFICATION

#### Class Gastropoda

#### Suborder Pleurotomariina

Family Lophospiridae Wenz, 1938  
*Worthenia windowblindensis*,  
new species (97)\*

*Worthenia* cf. *canalifera* (Mün-  
ster), 1841 (2)

#### Suborder Trochina

Family Turbinidae Rafinesque,  
1815

Subfamily Homalopomatinae  
Keen, 1960

*Boutillieria sinbadensis*, new  
species (5)

Subfamily Colloniinae Cossmann,  
1916

*Natiria striatocostata* (Mün-  
ster), 1841 (1)

\* The figures in parentheses are sample sizes.

- Natiria aequicostata*, new species (4)
- Family Paraturbinidae Cossmann, 1916
- Chartronella unicostata*, new species (3)
- Chartronella*, species (1)
- ? *Chartronella pagina*, new species (1)
- Suborder Neritopsina
- Family Naticopsidae Gray, 1847
- Naticopsis depressispirus*, new species (93)
- Naticopsis utahensis*, new species (56)
- Family Neritidae Rafinesque, 1815
- Subfamily Neritinae Rafinesque, 1815
- Neritaria costata*, new species (4)
- Vernelia fenestravella*, new species (14)
- Order Mesogastropoda
- Superfamily Loxonematacea Koken, 1889
- Family Zygopleuridae Wenz, 1938
- Zygopleura haasi*, new species (66)
- Zygopleura rugosa*, new species (10)
- Kittliconcha sciaphostera*, new species (25)
- Anoptychia eotriassica*, new species (273)
- Family Coelostylinidae Cossmann, 1909
- Coelostylina costata*, new species (4)
- Coelostylina virginensis*, new species (13)
- Coelostylina* cf. *angulifera* (White), 1877 (1)
- Coelostylina* species a (7)
- Coelostylina* species b (4)
- Omphaloptychia hormolira*, new species (55)
- Omphaloptychia laevisphaera*, new species (25)
- Superfamily Cerithiacea
- Family Mathildidae Wenz, 1938
- Promathilda spirocostata*, new species (6)

- Superfamily Subulitacea Lindström, 1884
- Family Subulitidae Lindström, 1884
- Subfamily Subulitinae Lindström, 1884
- Strobeus* cf. *paludinaeformis* (Hall), 1869 (187)
- Class Opisthobranchia Milne Edwards, 1848
- Superfamily Acteonacea d'Orbigny, 1842
- Family Acteonidae d'Orbigny, 1842
- Cylindrobullina convexa*, new species (132)

## SYSTEMATIC DESCRIPTIONS

### SUBCLASS PROSOBRANCHIA

### ORDER ARCHEOGASTROPODA

### SUBORDER PLEUROTOMARIINA

### SUPERFAMILY PLEUROTOMARIACEA

### FAMILY LOPHOSPIRIDAE WENZ, 1938

### SUBFAMILY RUEDEMANNIINAE KNIGHT, 1956

### *Worthenia* deKoninck, 1883

TYPE SPECIES: *Turbo tabulatus* Conrad, 1835, p. 267.

DISCUSSION: *Worthenia* is a fairly conservative genus which originated during the Mississippian. It is represented by eight species: five in Europe, two in North America, and one that is cosmopolitan during the Carboniferous. It tends to be high-spired or tabulate with both spiral and collabral ornament present in various combinations. The two American species, *W. tabulata* and *W. speciosa*, are widely distributed and fairly common in Mississippian and Pennsylvanian faunas. The fairly conservative morphological patterns parallel that of *Glabrocingulum* Thomas, 1940, and *Ananias* Knight, 1945, during the upper Paleozoic and show some degree of homeomorphy (Eldredge, 1968).

In the Permian these genera underwent rapid diversification, which is most evident in shell shapes, height of spires, whorl profiles, and ornament patterns. Some 16 species of *Worthenia* are recognized (Batten, ms). Many of the morphotypes represented by these species persist into the Triassic in Europe and Asia (Zardini, 1978; Yin and Yoch-

elson, 1983a). In North America only four Triassic species have been recognized, two in the Norian of Idaho and two in the Lower Triassic. The two Lower Triassic species *W. klamathensis* Smith, 1927, and *W. windowblindensis*, new species, are clearly derived from conservative tabulate stock found in the Permian.

There are two conditions of the selenizone which may have an important taxonomic significance. In one type, the medial lira of the selenizone is the exact edge of the periphery or shoulder (the upper and lower lira are the upper and lower margins of the selenizone). On either side of this medial lira the selenizone surfaces are concave. A number of species possess this type of morphology, *W. schirjaevensis* Stuckenberg, 1905, *W. tuberculifera* Koken, 1900, and *W. conica* Assmann, 1937. In the other type the selenizone surface is uniformly convex and usually forms the periphery or shoulder and spiral ornament may develop along with reinforced lunulae. This can be observed on *W. tabulata* Conrad or *W. windowblindensis*, new species, and many others.

Yin and Yochelson (1983a, p. 164) have subdivided *Worthenia* into several subgenera partly based on these different selenizone conditions and partly on height of the spire. For example, *Humiliworthenia* Yin and Yochelson (1983) is high spired with a flat to concave bisected selenizone.

***Worthenia windowblindensis*, new species**

Figures 1–3

**DIAGNOSIS:** Tabulate shells with dominant spiral ornament and flat to concave outer whorl face.

**DESCRIPTION:** Upper whorl face is slightly concave with well-developed cord adjacent to the suture. Sutures are deeply incised. One or two spiral threads on upper whorl face equidistant from the sutural cord. Keel forms the periphery with selenizone bisecting the shoulder. Selenizone margins are weakly formed threads and no lunulae were observed because of lack of collabral ornament. Outer whorl face is flattened or somewhat concave with prominent medial spiral cord. Base is marked by spiral cord less well developed than medial cord. Spiral threads between each of these cords. Base is flatly rounded with 10 or so spiral cords and minutely phanerom-

phalus to cryptomphalus depending on degree of columellar lip reflection; see figure 3.

**DISCUSSION:** All species of *Worthenia* described to date have both spiral and collabral ornament developed to one degree or another. In the fullest development both spiral and collabral ornament are equally developed forming reticulation as seen in the type species, *W. tabulata*. In the weaker phases of development, only interference nodes may be present. *W. windowblindensis* is unique in lacking collabral ornament of any type.

Most Triassic species are tabulate and *W. beaumonti* (Klipstein) is closest in shape to *W. windowblindensis*. *Worthenia beaumonti* has four or more spiral cords on the upper whorl surface, four spiral cords on the outer whorl face, and an evenly developed collabral ornament forming distinct lunulae on the selenizone. It is moderately widely phaneromphalus, thus differing from *W. windowblindensis* which is the first described species from the Lower Triassic of North America.

**SPECIMENS:** Ninety-seven.

**MEASUREMENTS:** Holotype AMNH 42961, H 4.8 mm, W 4.8 mm, SPANG 67°. Paratype AMNH 42962, H 6.0 mm, W 5.3 mm, SPANG 67°. Paratype AMNH 42963, H 4.5 mm, W 3.1 mm, SPANG 63°.

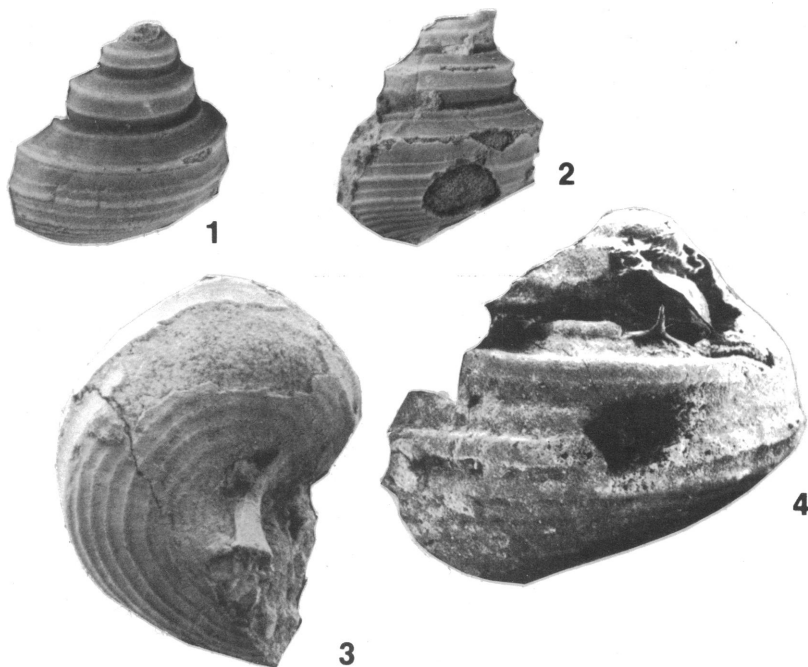
**ETYMOLOGY:** Named for Windowblind Butte, Utah.

*Worthenia* cf. *canalifera* Münster, 1843

Figure 4

*Worthenia canalifera* Münster, 1843.

**DESCRIPTION:** Low-spined shells with an alveozone just above the periphery. Sutures are sharply impressed and whorls embrace just beneath the selenizone. Upper whorl surface is concave with well-developed spiral cord adjacent to suture forming a narrow sutural trough. Selenizone forms a large shoulder cord and appears to have faint spiral threads. Outer whorl face is evenly to unevenly rounded. Alveozone is relatively narrow and concave with spiral cord just beneath the middle. Lower margin of the alveozone is marked by large spiral cord. Beneath this marginal cord is another equally developed spiral cord which also forms periphery of the whorl. Just beneath peripheral cord is another cord that marks the upper border of outer whorl face and the third of the larger spiral cords on the



Figs. 1–4. 1–3. *Worthenia windowblindensis*, new species. 1. Holotype, AMNH 42961, oblique side view,  $\times 6$ . 2. Paratype, AMNH 42962, side view; note stronger development of upper whorl face ornament,  $\times 6$ . 3. Paratype, AMNH 42963, oblique basal view, note hemiomphalus condition due to partial columellar lip reflection,  $\times 11$ . 4. *Worthenia* cf. *canalifera* Münster, AMNH 42964, oblique side view,  $\times 25$ .

outer whorl face marks margin of base. At least eight spiral threads are on rounded base; they decrease in intensity toward columellar lip.

**DISCUSSION:** The three fragments in hand are so well preserved that there can be no ambiguities in interpreting the morphology. They probably represent a new species but we are unwilling to describe a new species based on fragments. They resemble ?*Worthenia*, new species No. 2 of Haas (1953, pl. 1, figs. 8, 9) but that illustration shows a shell that has a rapid whorl expansion rate so that the last whorl is quite large in proportion to earlier whorls and the base is more tapered than in the two fragments from the Sinbad. Also, the whole shell is more turriculate in the Haas illustration. Most of the specimens of *Worthenia* from Guizhou, China, are higher spired. Zardini's illustration (1978, pl. 5, fig. 1a–d) of *W. canalifera* Münster is similar to these fragments in the concave upper whorl surface, the spiral cord adjacent to the

suture, with a cord marking the lower margin of the alveozone and a cord marking the border of the base. The Zardini illustration differs from our fragments in having a somewhat flatter base and a narrower outer whorl face which gives the shell a more tabulate appearance. Also the basal spiral threads are finer and more numerous.

**SPECIMENS:** Three.

**MEASUREMENTS:** Ill. Spec. AMNH 42964, H 2.1 mm, W 2.1 mm, SPANG  $108^\circ$ .

#### SUPERFAMILY TROCHACEA

#### FAMILY TURBINIDAE RAFINESQUE, 1815

#### SUBFAMILY HOMALOPOMATINAE COSSMANN, 1888

#### GENUS *BOUTILLIERIA* DESHAYES, 1863

**TYPE SPECIES:** *Turbo eugeni* Deshayes, 1863.

**DESCRIPTION:** Small shells with spiral sculpture. Well-developed, narrow umbili-

cus. Adult shell has a grossly expanded aperture. Whorl profile is inflated but upper whorl face has strong spiral ornament. Columellar lip is reflexed slightly and thickened. Hemiomphalus to cryptomphalus.

DISCUSSION: Cox (1949) placed this genus as a subgenus of *Homalopoma* Carpenter, 1864, and this was adapted by Haas (1953, p. 104). *Boutillieria* consistently displays unevenly developed spiral ornament particularly on the upper whorl surface which causes a tabulate shell shape. *Homalopoma*, on the other hand, has evenly developed spiral ornament over the entire globose shell, and lacks an umbilicus. We believe these features are sufficiently different to define separate genera. Most species are from the Cretaceous except for *B. subcinctum* (d'Orbigny) and *B. sp.*, identified by Haas (1953) in the Triassic of Peru. This is the first report of the genus in the Triassic of North America.

*Boutillieria sinbadensis*, new species

Figure 5

DIAGNOSIS: Trochiform shells with unevenly spaced spiral ornament on the upper whorl surface and with inflated whorls.

DESCRIPTION: Globose shells with deeply incised sutures. Horizontal (flat) sutural ramp is present when adjacent spiral cord is fully developed. In shells where sutural spiral element is a thread, the convex upper whorl surface terminates at suture with no ramp evident. One or two spiral cords just below the sutural cord. Upper whorl face terminates at a shoulder formed by spiral cord. The upper whorl face is concave between these cords. Periphery is rounded and marked by a spiral cord. Rounded base is bordered by basal spiral cord and has 8–11 spiral cords. Broad, weakly developed collabral elements on whorl surface. Growth lines (hence the outline of the aperture) form a broad sinus with its deepest portion at periphery. Whorls embrace on basal spiral cord. Minutely phanero-mphalus.

DISCUSSION: There is a moderate amount of variability between the five specimens available for study. The gap between the two closely spaced cords on the upper whorl surface and the shoulder is concave and may be shallow and wide or narrow and deep causing

a steplike upper whorl profile. The cord on the periphery may be weak so that the area between the shoulder and the basal spiral cord (the outer whorl face) may be flat or convex. The spiral ornament may be weak or sharply defined. In one specimen the whorls embrace lower on the whorl, below the basal spiral cord, causing a higher spired shell.

This species differs from *B. subcinctum* (d'Orbigny) Haas, 1953, in lacking the well-developed collabral elements that form interference nodes with spiral ornament in that species. It differs from *B. eugeni* Deshayes, 1863, in being more tabulate and having more unevenly formed spiral ornament, but is similar in having the shoulder and basal spiral cords more fully developed than other spiral elements.

SPECIMENS: Five.

MEASUREMENTS: Holotype AMNH 42965, H 7.3 mm, W 6.4 mm, SPANG 64°; paratype AMNH 42966, H 4.5 mm, W 4.3 mm, SPANG 66°; paratype AMNH 42967, H 5.5 mm, W 4.2 mm, SPANG 55°.

ETYMOLOGY: Named for Sinbad member of the Moenkopi Formation.

SUBFAMILY COLLONIINAE COSSMANN, 1916

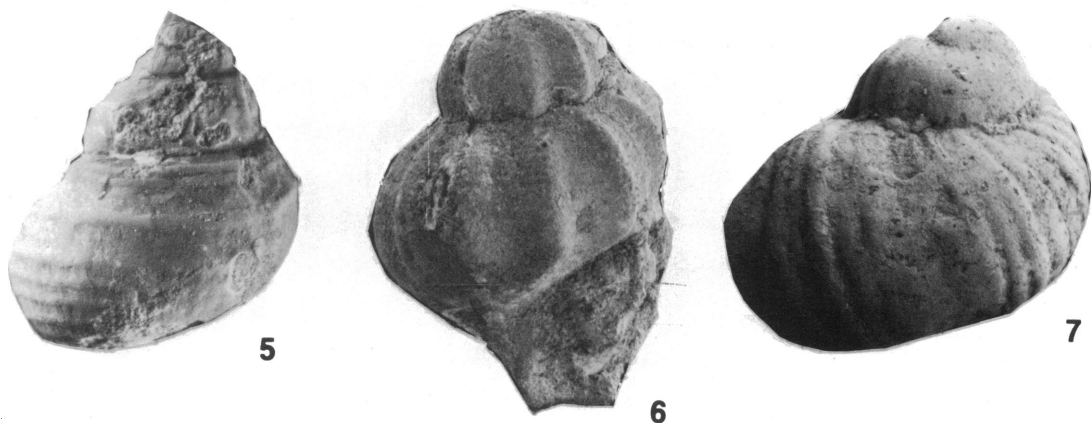
GENUS *NATIRIA* DEKONINCK, 1881

TYPE SPECIES: *Natica lirata* Phillips, 1836.

DISCUSSION: Yin and Yochelson (1983b, p. 530) were of the opinion that *Natiria*, placed by Knight et al. (1960) in the heterogeneous Craspedostomatidae, should be considered a turbinid along with *Eucycloscala* Cossmann, 1895, and *Liotina* Fischer, 1885. The latter two genera are in the subfamily Liotiinae which includes genera with strongly developed spiral and collabral ornament and with apertures that are grossly thickened. There is much variation in shell shape within this group, ranging from high-spired forms (*Microcheilus*) Kittl to sinistral planispiral forms (*Pseudoliotina*) Cossmann. We would suggest that *Natiria* is more closely associated with genera such as *Collonia* Gray, which is turbiniform with collabral ornament or with *Otomphalus* Cossmann, which is loosely coiled. We provisionally place *Natiria* in this group, the subfamily Colloniinae.

As noted by Yin and Yochelson (1983b, p. 515), the superfamily Trochacea previously





Figs. 5–7. 5. *Boutillieria sinbadensis*, new species, holotype, AMNH 42965, side view,  $\times 5.5$ . 6. *Natiria striatocostata* (Münster), AMNH 42968, side view,  $\times 25$ . 7. *Natiria aequicostata*, new species, holotype, AMNH 42969, oblique side view,  $\times 13$ .

had not been recognized in Paleozoic faunas. *Natiria* was previously considered a craspedostomatid (which does occur in the Paleozoic), but is now considered a trochacean. They identified *N. striatocostata* Münster, originally described as a species of *Naticella* from the Triassic of Europe, from the Triassic of China.

The presence of a shallow siphonal trough in *N. striatocostata* from the Sinbad seems anomalous because all trochids, along with most archeogastropods, are considered holostomous. However, recently Batten (1985) reported a siphonal notch in *Eucycloscala asiatica* Batten, 1985. *Eucycloscala* is believed by Yin and Yochelson (p. 523) to be related to *Natiria*.

The most important feature of the genus is the persistent development of collabral cords across the whorl and a reflexed columellar lip which may be thickened. It is phaneromphalus, hemiomphalus, or cryptomphalus depending on the relative development of the columellar lip.

#### *Natiria striatocostata* (Münster)

##### Figure 6

**DESCRIPTION:** Moderately high-spired, very small trochiform shells with large axial cords. Whorl profile is evenly rounded. Sutures sharply defined and wavy, reflecting development of cord and intercord areas adjacent

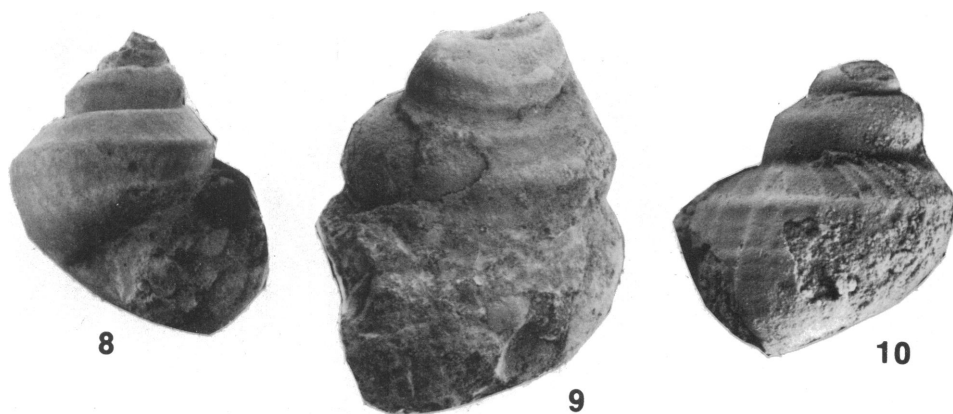
to suture. Axial cords are almost vertical and more fully developed on outer whorl surface and disappear on base. There are 14 cords on final whorl. Whorls embrace just below a medial, poorly defined periphery. Spiral threads are evenly distributed across whorls and base. Columellar lip is slightly thickened and inner lip is formed into a siphonal trough at the junction of columellar lip. Anomphalus.

**DISCUSSION:** This single, but well-preserved specimen is almost identical to that illustrated as *Naticella striatocostata* in Zardini (1978, pl. 20, fig. 7a, b). His illustration is that of a somewhat lower-spired shell, with whorls embracing on the periphery. In all other features the two are inseparable, including what appears to be a shallow siphonal trough on his specimen.

Yin and Yochelson (1983b) have identified a shell from Guizhou which is similar but has fewer, larger cords which extend onto the base of the whorls. Whorls embrace at the periphery so that the Chinese specimen is lower spired and somewhat more globose appearing compared to the Sinbad specimen. Also the authors do not report any spiral ornament. Perhaps these differences are large enough to constitute a separate species, but more specimens are needed.

**SPECIMENS:** One.

**MEASUREMENTS:** AMNH 42968, H 2.3 mm, W 1.4 mm, SPANG 63°.



Figs. 8–10. 8. *Chartronella unicostata*, new species, holotype, AMNH 42971, apertural view,  $\times 11$ . 9. *Chartronella* species, AMNH 42973, oblique side view,  $\times 11$ . 10. ?*Chartronella pagina*, new species, holotype, AMNH 42974, side view,  $\times 7$ .

*Natiria aequicostata*, new species

Figure 7

**DIAGNOSIS:** Naticiform shells with closely spaced, evenly developed collabral cords, whorls embrace on, or just below, the periphery.

**DESCRIPTION:** Small, globose shells with evenly formed whorl profiles with a broad periphery at mid-whorl. Sutures deeply incised and wavy, reflecting the collabral ornament which terminates at the suture. Whorls embrace at or just below periphery. Collabral cords evenly developed, numerous, and closely packed. Cords are opisthocline. Ornament developed only on the last two adult whorls; early whorls are smooth. Ornament fully developed on the outer portion of the base and abruptly disappears at umbilicus. Columellar lip reflexed and somewhat thickened, forming a depressed callus. Narrowly phaneromphalus or hemiomphalus.

**DISCUSSION:** The collabral cords of this species are very different from other species of the genus in being closely spaced and with no other ornament other than faint collabral threads between the cords which may, in fact, be growth lines. In various illustrations of *N. striatocostata* the cords are widely spaced with either spiral or collabral secondary ornament (or both) between the cords. Most species have opisthocline cords sweeping backward and

down, except for *N. striatocostata*, illustrated in this study, where the cords are nearly vertical. The cords of *N. aequicostata* are similar to those of *N. sublineata* Münster, 1841, which are finer, but the whorls are more rounded and embrace higher, above the periphery. The depression on the callus of the columellar lip suggests that there might have been an operculum.

**SPECIMENS:** Four.

**MEASUREMENTS:** Holotype AMNH 42969, H 3.3 mm, W 3.6 mm, SPANG 82°. Paratype AMNH 42970, H 2.2 mm, W 2.5 mm, SPANG 74°.

**ETYMOLOGY:** *Aequalis*, Latin for same; *costa*, Latin for rib.

FAMILY PARATURBINIDAE COSSMANN, 1916

GENUS *CHARTRONELLA* COSSMANN, 1916

**TYPE SPECIES:** *Chartronella digoniata* Cossmann, 1902.

**DISCUSSION:** Cossmann placed the genus in this family because of the thick shell, a feature also mentioned by Haas (1953, p. 80). However, the shells from the Sinbad are fairly thin and comparable to that illustrated by Haas (in spite of his statement that the shells are thick). In any event, *Chartronella* does not have a shell nearly as thick as other genera of the family, nor is it as gross. In other features, such as the turbiniform shell shape and

the dominant spiral ornament, the genus would better fit into the group which includes *Boutillieria* (the Homalopomatinae).

***Chartronella unicostata*, new species**

Figure 8

**DIAGNOSIS:** Tabulate shells with a spiral cord forming the periphery at mid-whorl and with a weak basal spiral cord.

**DESCRIPTION:** Sutures deeply impressed and narrow sutural ramp inclined downward to suture. Upper whorl face is convexoconcave with convex portion adjacent to well-developed spiral cord that forms keel or periphery at mid-whorl. Faint spiral thread in middle of outer whorl face, marking boundary between concave and convex portions. Lower whorl face is convex and merges with flatly rounded base. Faint, but wide, spiral cord in middle of rather narrow lower whorl face. Growth lines moderately opisthocline on the upper whorl face and prosocline on lower whorl face forming a V-shaped shallow sinus. Collabral ornament consists of evenly formed and spaced threads over whorl surface. Hemiomphalus. Columellar lip thickened into a callus with medial groove suggesting an operculum.

**DISCUSSION:** *C. unicostata* is quite similar to the St. Cassian species *C. subcarinatus* (Münster) which has a well-developed shoulder but the basal spiral cord is relatively weak compared to the Sinbad species. This is in contrast to most post-Triassic species which usually have both cords equally well developed. *C. unicostata* differs from *C. subcarinatus* by having a very weakly formed basal spiral thread and dominant collabral ornament, while that species has cancellate ornament. *C. subcarinatus* has a well-developed convex alveozone which is nearly vertical, while the Sinbad species has a poorly defined alveozone which slopes into the base because of the weakly developed basal thread. Whorls embrace on this basal thread. The columellar lip is strongly reflexed so that there is a cryptomphalus condition in *C. subcarinatus*. In *C. unicostata* the columellar lip is thickened into a callus which only partially obscures the umbilicus.

**SPECIMENS:** Three.

**MEASUREMENTS:** Holotype AMNH 42971,

H 3.6 mm, W 3.6 mm, SPANG 61°. Paratype AMNH 42972, 4.2 mm, W 3.5 mm.

**ETYMOLOGY:** *Unus*, Latin for one, *costa*, Latin for rib.

***Chartronella* sp.**

Figure 9

**DESCRIPTION:** Tabulate shell with a sutural cord, a keel, and a basal spiral cord. A narrow, concave sutural ramp is separated from upper whorl face by well-developed spiral cord. Upper whorl face relatively narrow and concave, terminating at keel with well-developed spiral cord. Lower whorl is concave and separated from flatly rounded base by basal spiral cord, somewhat less developed than peripheral cord. Whorls embrace just below this basal cord.

**DISCUSSION:** This species is quite distinct by virtue of the strong development of the peripheral cord. It differs from *C. unicostata* in the more pagodaform shell shape, the strong development of the peripheral cord, and the presence of a strong basal spiral cord. The whorls embrace lower on the whorl giving this species a higher spired shell. It differs from the type species *C. digoniata* in the differentially developed sutural and basal cords. Unfortunately, only a single fragmented specimen was found with only a small portion of each of two adjacent whorls intact.

**SPECIMENS:** One.

**MEASUREMENTS:** AMNH 42973 H 3.8 mm, W 3.0 mm, SPANG 48°.

**?*Chartronella pagina*, new species**

Figure 10

**DIAGNOSIS:** Trochiform shells with a periphery high on the whorl, with a well-developed spiral cord and a broad whorl face; the collabral ornament is lamellose.

**DESCRIPTION:** Sutures are sharply incised with a flat, ill-defined sutural ramp with collabral ornament. Upper whorl surface is convex, sloping toward periphery. A spiral cord is located in center of upper whorl face. Outer whorl face is nearly vertical, flattened, and somewhat wider than upper whorl face. Two well-developed and evenly spaced spiral cords present on outer whorl face. Basal spiral cord is more strongly formed than two outer whorl cords. Whorls embrace just below basal cord.

Rounded base has 10 or more spiral threads. Collabral ornament consists of evenly spaced and asymmetrical ribs with a raised concave leaflike flange with the gentle slope away from aperture. Collabral ornament is more strongly developed on upper whorl face and gradually becomes weaker toward base where it is only faintly visible as threads. Columellar lip is slightly reflexed. Aperture is holostomous. *Anomphalus*.

SPECIMENS: One.

MEASUREMENTS: Holotype AMNH 42974, H 6.0 mm, W 5.4 mm, SPANG 56°.

ETYMOLOGY: *Pagina*, Latin for page.

SUBORDER NERITOPSINAE  
COX AND KNIGHT, 1960

SUPERFAMILY NERITACEA  
RAFINESQUE, 1815

FAMILY NERITOPSIDAE GRAY, 1847

DISCUSSION: The most commonly encountered snails in both the Sinbad and the Virgin members of the Moenkopi Formation are two species of *Naticopsis* M'Coy, 1844, occurring in astronomical numbers. In addition to *Naticopsis*, two other genera belonging to this family are found, *Neritaria* Koken, 1892, and *Vernelia* Böhm, 1895. Yin and Yochelson, 1983b, also noted the prevalence and diversity of this family in the Middle Triassic of China.

In the Upper Paleozoic and Lower Mesozoic there are naticiform genera that have been described from the Alpine region of Europe during the latter part of the 19th century. These include *Naticopsis*, *Pachyomphalus* Böhm, 1895; *Fedaiella* Kittl, 1894; *Hologyra* Koken, 1892; *Vernelia* Böhm, 1895; *Planispirina* Kittl, 1899; *Damesia* Holzapfel, 1888; *Dicosmos* Canavari, 1890; and *Marmolatella* Kittl, 1894. Some of these are recognized on the basis of shell shape (involving multiple characters such as whorl expansion rate, axial translation rate, and whorl profile changes). For example, *Marmolatella* has a high whorl expansion rate and a low translation rate with a flattened upper whorl surface. However, the most important generic features are the inductural deposits (callus developments such as teeth, ornament, and funicles), type of columellar lip, presence of an umbilicus, and the

nature of the inner lip. A large number of species have been described from the Middle Triassic deposits of central and eastern Europe and, seemingly, have been haphazardly, almost senselessly, placed in these genera (Yin and Yochelson, 1983b, pp. 515–518).

The problem is that the character combinations in some of the species do not match those of any one genus. For example, in the new species *Vernelia fenestravella*, there is no parietal inductura (found in all other genera and species) but there is a circumbilical ridge characteristic of *Vernelia*, which Yin and Yochelson (1983, p. 517) believe to be the most diagnostic feature.

GENUS *NATICOPSIS* M'COY, 1844  
SUBGENUS *NATICOPSIS* (*NATICOPSIS*)  
M'COY, 1844

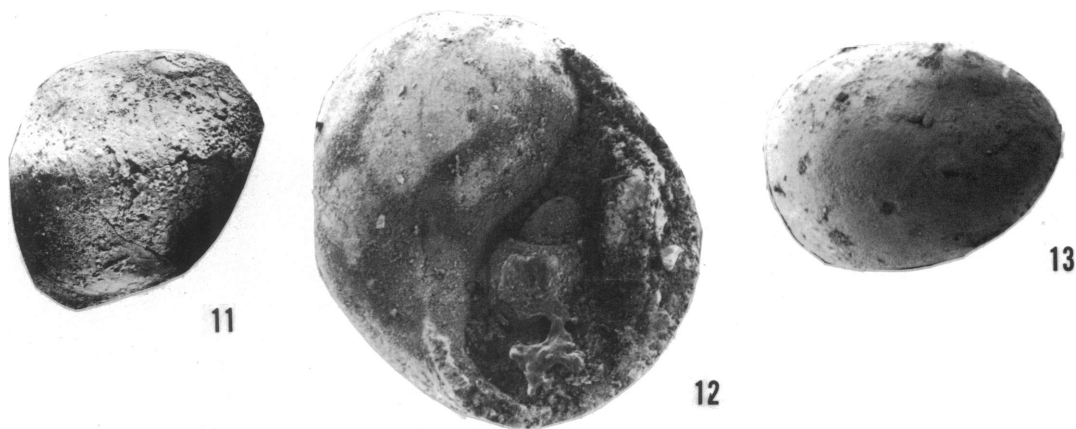
DISCUSSION: The two species newly described herein, *N. (N.) depressispirus* and *N. (N.) utahensis*, are the two most abundant species in the Sinbad and Virgin limestones. They occur in astronomical numbers and are found as small shells about 2 mm in width. The sample size listed under each of the species represents the specimens selected at random to represent the hypodigm.

Both of the species fall within the range of morphotypes found in the Upper Paleozoic (Batten, 1979, p. 12, for a discussion of naticopsid morphotypes); *N. (N.) utahensis*, for example, belongs to the *N. (N.) worthenia* Knight, 1933, morphotype. Each of the Sinbad species are clearly distinct as discussed below and their numerical distribution makes it unlikely that they represent a sexual dimorphism.

*N. (Naticopsis) depressispirus*,  
new species  
Figures 11–13

DIAGNOSIS: Naticiform shells with a flattened upper whorl surface, with whorls embracing above the periphery; only a small portion of the earlier whorls are exposed.

DESCRIPTION: Inflated whorls have a periphery high on whorl and a moderately high whorl expansion rate. Upper whorl surface is flattened. Sutures are sharply defined and impressed. Outer whorl face varies from slightly angulate to rounded. Base is rounded. An-



Figs. 11–13. *Naticopsis (Naticopsis) depressispirus*, new species. 11. Holotype, AMNH 42975, oblique top view,  $\times 2.5$ . 12. Paratype, AMNH 42976, apertural view,  $\times 3.8$ . 13. Paratype, AMNH 42977, side view,  $\times 30$ .

omphalus. Columellar lip is reflexed with a thickened, smooth callus limited to a narrow band.

**DISCUSSION:** There is much variation in the shape of the whorls from a flattened upper whorl face and an almost angulate periphery high on the whorl with a somewhat flattened angulate base to an almost evenly globose whorl profile with a periphery more nearly at mid-whorl and with a rapid whorl expansion rate. Whorls embrace very high on the whorl in the angulate specimens and somewhat lower on the more globose specimens. In globose specimens the callus is less well developed and more diffused over the parietal surface.

This species comes closest to *Neritaria dicosmoides* Haas, 1953, in the rate of whorl expansion and the sharply defined callus. That species is consistently more globose with the periphery consistently lower on the whorl and with the whorls embracing lower on the whorl. *N. (N.) depressispirus* is similar to *N. (N.) mandelslohi* (Klipstein) in whorl expansion rate but the whorls embrace much lower and the periphery is lower on the whorls. The columellar lip consists of an upper callus, a funicle plugging the umbilicus, and a lower reflexed grooved lip.

Most specimens in the Sinbad fauna are obviously immature (having two or three whorls) and all fall within the range of 1–2

mm in width. A single specimen from the Virgin Limestone at Blue Diamond Mine, Nevada, serves as the holotype since it is the only known adult.

**SPECIMENS:** Ninety-three.

**MEASUREMENTS:** Holotype AMNH 42975, H 6.0 mm, W 6.8 mm, SPANG  $87^\circ$ . Paratype AMNH 42976, H 1.4 mm, W 1.4 mm, SPANG  $120^\circ$ .

**ETYMOLOGY:** *Depressus*, Latin for low; *spiralis*, Latin for coil.

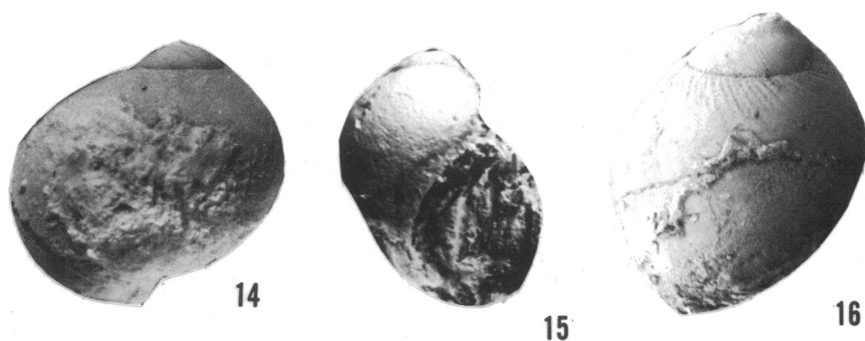
#### *N. (N.) utahensis*, new species

Figures 14–16

**DIAGNOSIS:** Globose shells with evenly rounded whorls, periphery at mid-whorl, whorls embrace just above the periphery.

**DESCRIPTION:** Sutures shallow and sharply defined. Whorls evenly inflated with a rounded, somewhat flattened upper whorl surface. Whorl expansion rate moderate for the genus. Outer whorl face rounded to slightly flattened and base rounded. Broad collabral cords with sharply defined intercord areas may be present. Whorl embracement just above periphery.

**DISCUSSION:** The main variation observed in this species involves the shape of the whorl profile which varies from a broad rectangular outline with a slightly flattened outer whorl



Figs. 14–16. *Naticopsis (Naticopsis) utahensis*, new species. 14. Holotype, AMNH 42978, side view,  $\times 6.5$ . 15. Paratype, AMNH 42979, apertural view,  $\times 8$ . 16. Paratype, AMNH 42980, oblique side view showing collabral ornament,  $\times 20$ .

face to an evenly rounded profile. A relatively low whorl embracement causes a higher spired shell than seen in *N. (N.) depressispirus*. It is similar to *N. (N.) praealta* Wanner, 1922, in the whorl profile, rate of whorl expansion, and height of spire, but the periphery is higher in that species. Unfortunately, the aperture is not preserved on any specimen, but from observing a portion of the base that is preserved on a single specimen, it is probable that the columellar lip does not have a heavy callus.

SPECIMENS: Fifty-six.

MEASUREMENTS: Holotype AMNH 42978, H 4.5 mm, W 5.0 mm, SPANG  $108^\circ$ . Paratype AMNH 42979, H 2.4 mm, W 2.7 mm, SPANG  $99^\circ$ . Paratype AMNH 42980, H 2.3 mm, W 1.8 mm, SPANG  $110^\circ$ .

ETYMOLOGY: Named for Utah, a western state.

#### GENUS *VERNELIA* BÖHM, 1895

TYPE SPECIES: *Natica fastigiata* Stoppani, 1858 (= *N. excelsa* Hauer, 1851); SD B. B. Woodward, 1896.

DISCUSSION: Yin and Yochelson (1983b, p. 530) have defined *Vernelia* as being naticiform with a narrow umbilical gap bordered by an umbilical keel with a flattened inner lip covered by a callus and without parietal tubercles. Several of the neritopsid genera found in the Middle Triassic are defined on the basis of the callus deposits—*Hologyra* Koken, 1892, has a tubercle on the inner lip and a circumbilical carina. *Fedaiella* Kittl,

1894, has two teeth on the inner lip plus the circumbilical ridge or carina. *Vernelia*, besides having the circumbilical ridge, has a narrow, but shallow, trough adjacent to the suture on the upper whorl face. This is the first report of the genus in the Western Hemisphere.

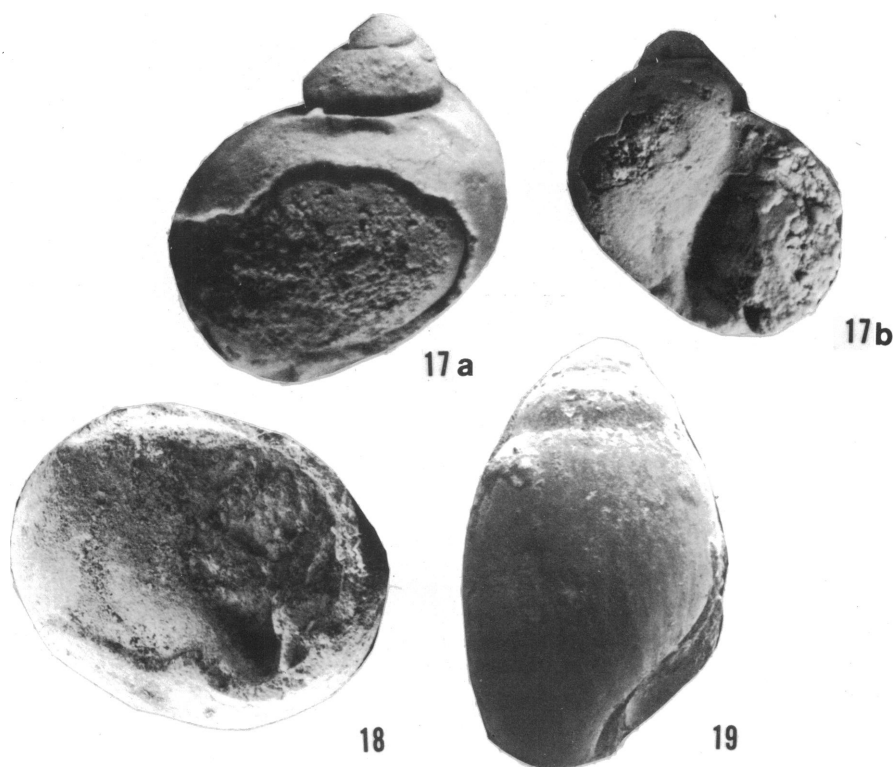
#### *Vernelia fenestravella*, new species

Figures 17, 18

DIAGNOSIS: Neritiform shells with a shallow umbilicus and a narrow sutural trough with a carina.

DESCRIPTION: Whorl profile varies from evenly rounded to a more flattened upper whorl face. If whorl profile is rounded, periphery is mid-whorl, if flattened, periphery is higher on the whorl. Sutures are sharply defined. Sutural cord on upper whorl surface separates a narrow shallow trough on upper whorl face from an even more narrow trough adjacent to suture. Whorls evenly rounded and outer lip is elliptical. Whorls embrace at or just below periphery, so that shell will appear relatively high-spired in specimens with evenly rounded whorl profiles, such as the holotype. Columellar lip apparently has no parietal inductura. Poorly developed circumbilical ridge fades away toward inner lip. Narrowly phaneromphalus to cryptomphalus.

DISCUSSION: This species differs from all other species, such as *V. subimpressa* Yin and Yochelson, 1983b, in lacking a parietal callus or inductura. It does have the characteristic circumbilical ridge. The Chinese species has



Figs. 17–19. 17a, b, 18. *Vernelia fenestravella*, new species. 17. Holotype, AMNH 42981; a. oblique side view,  $\times 9$ ; b. apertural view,  $\times 7.5$ . 18. Paratype, AMNH 42982, apertural view,  $\times 20$ . 19. *Pachyomphalus americanus*, new species, holotype, AMNH 42983, side view,  $\times 21$ .

delicate spiral and collabral ornament, missing in the Sinbad species, and a narrow sutural trough not set off by a cord like *V. fenestravella*. The type species, *V. fastigiata* Stoppani, 1858, is higher spired with a much lower whorl expansion rate.

SPECIMENS: Fourteen.

MEASUREMENTS: Holotype AMNH 42981, H 4.8 mm, W 4.8 mm, SPANG 70°. Paratype AMNH 42982, H 2.8 mm, W 3.0 mm, SPANG 84°. Paratype AMNH 42982a, H 3.2 mm, W 3.6 mm, SPANG 78°.

ETYMOLOGY: *Fenestra*, Latin for window; *velum*, Latin for curtain.

GENUS *PACHYOMPHALUS* BÖHM, 1895

TYPE SPECIES: *Pachyomphalus concinnus* Böhm, 1895.

DISCUSSION: This genus was recognized by the relatively high-spired shell with an elon-

gated whorl, which is extreme for the family. The shell is relatively thin and the type has a narrow inductura on a reflexed columellar lip. The other species placed by Böhm in this genus is *P. rectelabiata* Kittl, 1894, which has an even, less well developed inductura confined to the slightly reflexed columellar lip.

*Pachyomphalus americanus*, new species

Figure 19

DIAGNOSIS: Tiny, littoriniiform shells with a broad, flattened periphery.

DESCRIPTION: Sutures are shallow, but sharply set off. Whorls are evenly inflated with broad, flattened outer whorl face and ill-defined peripheral region with a mid-whorl center. Whorls embrace progressively lower on upper margin of outer whorl face. A flattening of upper whorl face adjacent to suture forms a narrow, ill-defined sutural ramp. Or-

nament is lacking. Growth lines very gently sinuous, opisthoclinal at the suture, becoming prosoclinal at mid-whorl, and sweeping backward on rounded base. Aperture is ovoid. Columellar lip is slightly reflexed and thickened.

DISCUSSION: There is some variation among the three specimens. The whorl expansion rate is lower in two of the paratypes giving the shells a more robust appearance, similar to *P. rectelabiata* Kittl, 1894. The sutural ramp is similar to that seen in the Kittl species and the whorls embrace at the same position, but the periphery is lower on that species and the base flattened. Other Triassic European species assigned to this genus are more globose with rounded bases and with the sutural ramp more obvious. The aperture of *P. americanus* is not completely preserved but a small section of the columellar lip shows that it is reflexed and there is no evidence of parietal deposits which would indicate a *Naticopsis* affinity.

SPECIMENS: Three.

MEASUREMENTS: Holotype AMNH 42983, H 2.2 mm, W 1.4 mm, SPANG 76°. Paratype AMNH 42984, H 2.0 mm, W 1.5 mm, SPANG 62°.

ETYMOLOGY: Named for the North American continent.

#### FAMILY NERITIDAE RAFINESQUE, 1815

##### SUBFAMILY NERITINAE RAFINESQUE, 1815

##### GENUS *NERITARIA* KOKEN, 1892

TYPE SPECIES: *Natica plicatilis* Klipstein, 1843 (= *Protonerita* Kittl, 1894).

##### *Neritaria costata*, new species

Figures 20, 21

DIAGNOSIS: Naticiform shells with sinuous costae fully developed from suture to base.

DESCRIPTION: Shells with an evenly globose whorl profile and a periphery high on the whorl. Sutures are sharply defined and depressed. Whorls embrace on periphery, and whorl expansion rate is high. Collabral ornament consists of sinuous costae somewhat more strongly developed on upper and outer whorl faces. Inner lip and columellar lip are thickened, with funicle in mid-columellar lip region, covering umbilicus.

DISCUSSION: This species most closely resembles *N. plicatilis* (Klipstein). However, the type species, from the St. Cassian beds of Italy, has a periphery low on the whorl, costae more fully developed and stronger on the upper whorl face, and the inner lip is not as thickened. This new species is quite similar to *N. hologyroides* Haas, 1953, but the columellar lip has a fully formed callus. All specimens of the new species appear to be juveniles.

SPECIMENS: Four.

MEASUREMENTS: Holotype AMNH 42985, H 1.0 mm, W 0.9 mm.

ETYMOLOGY: *Costa*, Latin for rib.

#### SUPERFAMILY LOXONEMATACEA

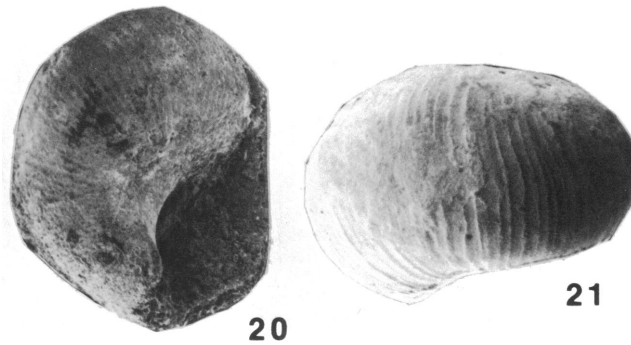
KOKEN, 1889

##### FAMILY ZYGOPLEURIDAE WENZ, 1938

DISCUSSION: The relation of the Pseudozygopleuridae and the Zygopleuridae has been much discussed (Knight et al., 1960, pp. 312–313; Batten, 1985, pp. 11–12). We believe that the species assigned to *Zygopleura* Koken, 1892, *Kittliconcha* Bonarelli, 1927, and others are related to those described in the Upper Paleozoic as pseudozygopleurids. There is a dual classification of Upper Paleozoic genera in which those having a smooth embryonic shell are recognized as separate genera from those having a pseudozygopleurid embryonic shell. For example, Hoare and Sturgeon, 1981, observed that the type species of *Hemizyga*, *H. elegans* Girty, 1915, has a smooth embryonic shell and hence cannot be a pseudozygopleurid. They segregated those species of *Hemizyga* which have pseudozygopleurid embryonic shells into a new genus, *Gamizyga* Hoare and Sturgeon, 1981, now considered as a subgenus of *Plocezyga* Hoare, 1980.

Fortunately, *Zygopleura* has priority over the Pseudozygopleuridae so that the Mesozoic taxa will not suffer nomenclatural changes but certainly the Paleozoic names should be changed since the Mesozoic names have priority. This is true for a number of genera which are found in both the Paleozoic and Mesozoic; for example, *Glabrocingulum* Thomas, 1940, has been used for a common group of species in the Upper Paleozoic and it clearly is the same as *Rhaphistomella* Kittl,





Figs. 20, 21. *Neritaria costata*, new species. 20. Holotype, AMNH 42985, apertural view,  $\times 38$ . 21. Paratype, AMNH 42986, side view,  $\times 10$ .

1891, described from the Middle Triassic of Europe. Such dual classifications have obscured the interpretation of the Permo-Triassic extinction event.

In any event, all post-Paleozoic zygopleurids and the Recent abyssochrysid have smooth embryonic whorls. Only *Anoptychia* Koken, 1892, has a complex early shell similar to the pseudozygopleurids but, even so, the first several whorls are smooth. The main evolutionary pattern in the Mesozoic is away from the *Zygopleura*-*Pseudozygopleura* bauplan of dominant collabral cords on inflated whorls. Thus, recognizing the Zygopleuridae as separate from most of the pseudozygopleurids has some merit and we will conditionally adopt this separation since it will not affect Triassic nomenclature.

#### GENUS *ZYGOPLEURA* KOKEN, 1892

TYPE SPECIES: *Turritella hybrida* Münster, 1841, SD Cossmann, 1909.

DISCUSSION: Most of the species currently assigned to this genus have smooth, non-pseudozygopleurid embryonic whorls which gradually develop ornament, usually collabral, which continues into the adult whorls. Many specimens and illustrations do not show the early whorls preserved so that they cannot be evaluated, but none that are present in the Sinbad fauna show anything but smooth embryonic whorls. In all other respects, the morphotypes seen in the Triassic species duplicate those of the Upper Paleozoic. Since the species are distinct, and the species names

have priority over the Paleozoic species of *Pseudozygopleura*, we will continue to use the valid Triassic species designations.

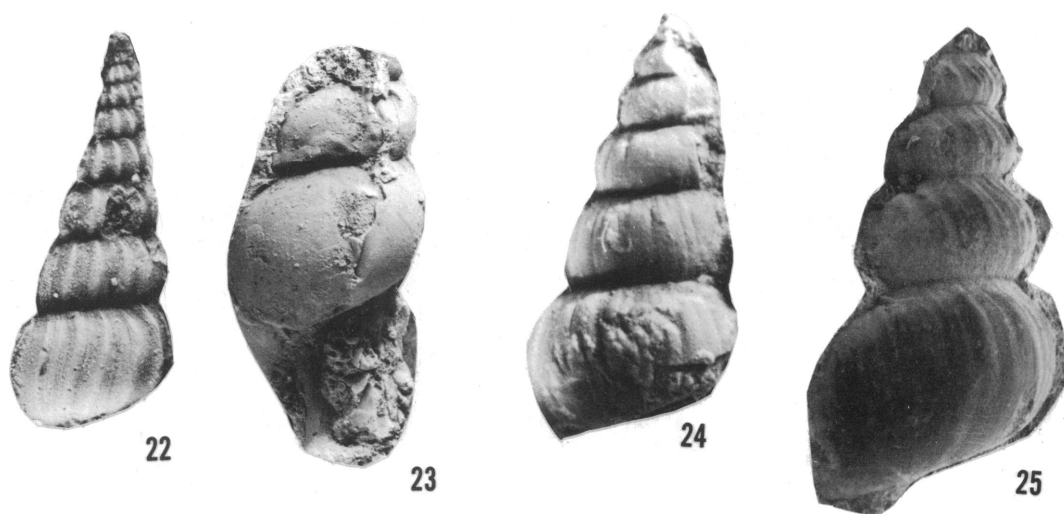
#### *Zygopleura haasi*, new species

Figures 22, 23

DIAGNOSIS: High-spined shells with whorls embracing on the base; whorl profile evenly inflated with orthocline collabral cords strongest on outer whorl face.

DESCRIPTION: Orthoconoid shells with a relatively rapid axial translation rate and whorls embracing on the base. Whorls vary from evenly inflated with a broad, centrally located periphery to somewhat more flattened upper and lower whorl faces and slightly angular periphery which may be somewhat below mid-whorl. Sutures are sharply defined but wavy, reflecting collabral ornament which terminates at suture. Some shells have sutural depression of upper whorl surface which lacks ornament. Collabral cords evenly developed over the surface of the whorl, tapering to threads adjacent to suture. Cords mostly orthocline and vertical. Whorl surface between cords shows reinforced growth lines. Collabral cords become threads on base. Columellar lip is straight; insipient siphonal notch at junction of lower lip, see figure 23. Aperture holostomous. Anomphalus.

DISCUSSION: The shape of the whorl is somewhat variable as is the degree of collabral cord development ranging from sharp and steep-sided with relatively broad intercord areas to gentle-sided and occupying most



Figs. 22–25. 22, 23. *Zygopleura haasi*, new species. 22. Holotype, AMNH 42987, side view,  $\times 6.5$ . 23. Paratype, AMNH 42988, apertural view, note loss of ornament on adult whorl and insipient siphonal notch,  $\times 3.5$ . 24, 25. *Zygopleura rugosa*, new species. 24. Holotype, AMNH 42991, side view,  $\times 9$ . 25. Paratype, AMNH 42993, side view,  $\times 19$ .

of the whorl surface. Most specimens show orthocline cords, but some show slightly arcuate cords forming a broad sinus. A few specimens have smooth adult whorls or the adult whorls have greatly reduced ornament, a very common condition in this superfamily.

This species resembles *P. (Pseudozygopleura) croneisi* Knight, 1930, in the development of the collabral cords, the shape of the whorls, and centrally located periphery. It differs in the whorl embracement which is much lower on the whorl than in the Knight species and has less intercord area exposed. It is quite similar to *Z. obliquecostata* (Münster) in the position of whorl embracement, development of the collabral cords, height of shell, and reduced ornament on the adult whorls. It differs in having a slower whorl expansion rate causing a higher appearing shell and having the periphery slightly higher on the whorl with finer, more numerous collabral cords.

**SPECIMENS:** Sixty-six.

**MEASUREMENTS:** Holotype AMNH 42987, H 7.0 mm, W 3.0 mm, SPANG 21°. Paratype AMNH 42988, H 9.1 mm, W 3.8 mm,

SPANG 16°. Paratype AMNH 42989, H 18.8 mm, W 8.6 mm, SPANG 15°.

**ETYMOLOGY:** Named for Otto Haas.

*Zygopleura rugosa*, new species

Figures 24, 25

**DIAGNOSIS:** Turritelliform shells with irregular, sinuous collabral ornament which becomes progressively weaker during ontogeny.

**DESCRIPTION:** Whorl profile changes from pendant-shaped concavoconvex with a periphery low on the whorl to evenly convex profile with a broad, centrally located periphery. Whorls embrace well below periphery giving shell a high-spired appearance. Whorl expansion rate is rather low. Collabral cords in early whorls are large, flattened, and sinuous. Growth lines are opisthocline from suture to periphery and prosocline from periphery to base forming a sinus. Collabral cords are separated by narrow intercord area which is a groove. Later whorls have more widely spaced intercord areas since collabral cords are less well developed and formed into threads separated by slightly more developed

cords. Final two whorls have numerous collabral threads of varying intensity, covering the base as well.

**DISCUSSION:** The most striking feature of this species is the very irregular development of the collabral ornament in mid to late ontogeny. There are only a few loxonematids that show this; *P. (Pseudozygopleura) nigra*, Knight, 1930, and *P. (P.) williamsi* Knight, 1930, have reduced ornament but show smooth adult whorls; neither has irregular development of the ornament. *Zygopleura walmstedti* (Klipstein), 1843, as illustrated by Zardini (1978, pl. 24, fig. 12), has reduced, irregular ornament in later stages of ontogeny but early growth lines are prosocline, becoming vertical in adult whorls. The whorl profile is flattened with the whorl embracement at the juncture of the outer whorl face and the base. *Z. rugosa* is a distinctive species at the far end of a narrow spectrum of collabral ornament variant patterns.

**SPECIMENS:** Ten.

**MEASUREMENTS:** Holotype AMNH 42991, H 5.2 mm, W 2.8 mm, SPANG 23°. Paratype AMNH 42992, H 2.5 mm, W 1.3 mm, SPANG 27°.

**ETYMOLOGY:** *Ruga*, Latin for wrinkle.

GENUS *KITTLICONCHA* BONARELLI, 1927

**TYPE SPECIES:** *Loxonema walmstedti* Kittl, 1894 (non Klipstein, 1843).

**DISCUSSION:** Haas (1953, pp. 116–117) has fully discussed the relationship of *Kittliconcha* Bonarelli, 1927, *Katosira* Koken, 1892, and *Anoptychia* Koken, 1892. Basically the differences involve ornament variation. *Anoptychia* has secondary ornament only on the early whorls; *Katosira* has primary collabral cords with secondary spiral and collabral ornament which forms a cancellate network between the primary collabral cords. *Kittliconcha* has primary collabral cords with secondary spiral threads between them which become reduced to absent on the adult whorl and with an unornamented base.

There are other differences. *Katosira* is high-spined with flattened, elongated whorl profiles giving a more turritellid shell shape and the base has very heavy spiral ornament. *Kittliconcha* has a higher whorl expansion rate and a lower-appearing spire with globose or inflated whorls.

The Sinbad species, *K. sciaphostera*, new species, comes closest to the type species in ornament, whorl profile, and apertural features. It would be placed in the subgenus *Hemizyga* (or using the Hoare and Sturgeon concept, in (*Plocezyga*) (*Gamizyga*) Knight, 1930) if it were found in the Paleozoic. One specimen of our Sinbad species has a smooth embryonic whorl; thus their definition would make it a member of the genus *Hemizyga*. To invoke the "rules," all *Plocezyga* species of the Paleozoic belong to the genus *Kittliconcha*.

***Kittliconcha sciaphostera*, new species**

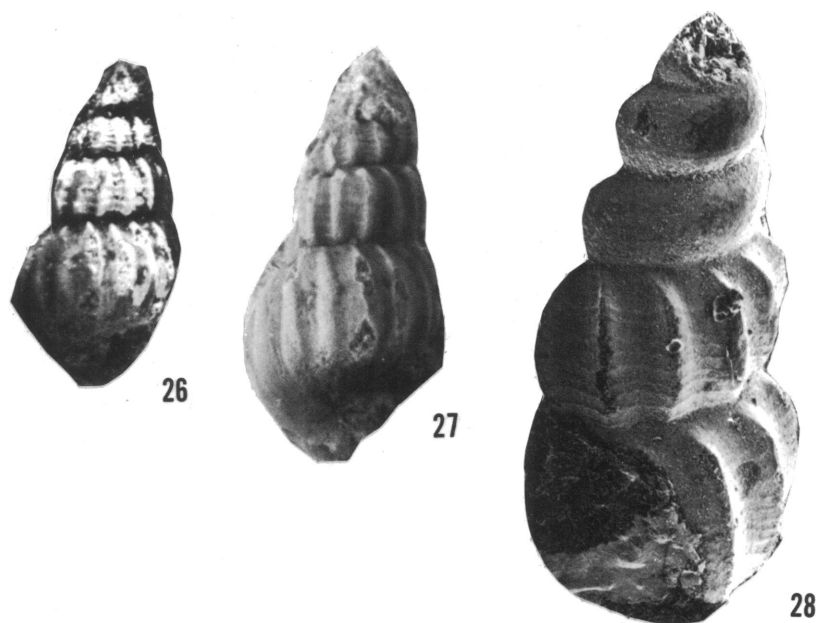
Figures 26–28

**DIAGNOSIS:** Moderately high-spined shells with smooth embryonic whorls and inflated later whorls with collabral cords which become weaker in adult stages. Intercord areas with spiral threads.

**DESCRIPTION:** First three embryonic whorls slightly swollen, evenly inflated, and smooth. Next four to six whorls with strongly developed spiral threads mostly evenly spaced across whorl face. Collabral cords strongly opisthocline near suture, becoming vertical over the flatly rounded whorl profile and terminating at lower margin of outer whorl face. Base is flatly rounded with spiral threads gradually becoming weaker toward columella. Faint collabral threads on outer whorl face may form a cancellate pattern with spiral threads on intercord areas. Final three whorls with primary and secondary collabral ornament only. Holostomous. Anomphalus.

**DISCUSSION:** There is some variation in the rate of whorl expansion affecting the relative height of spire. There is considerable variation in the development of the spiral threads which may bunch closely together near the suture and then spread unevenly across the whorl surface, or be restricted to the upper and lower portion of the whorl face particularly in the last whorl. The spiral ornament ends abruptly at the 11th whorl.

This species resembles the type species *K. walmstedti* in the development of the ornament, but differs in having a more inflated whorl profile and vertical collabral cords. It differs from *K. obliquecostata* (Bronn) (in Zardini, 1978), in having a broad periphery



Figs. 26–28. *Kittliconcha sciaphostera*, new species. 26. Holotype, AMNH 42994, side view,  $\times 8$ . 27. Paratype, AMNH 42995, side view,  $\times 6$ . 28. Paratype, AMNH 42996, oblique side view showing smooth nuclear whorls,  $\times 60$ .

in mid-whorl and with the spiral ornament terminating in the adult, rather than throughout the shell. It resembles *K. doelloi* Bonarelli, 1927, but that species has finer and more numerous collabral cords that are prosocline.

SPECIMENS: Twenty-five.

MEASUREMENTS: Holotype AMNH 42994, H 5.5 mm, W 2.9 mm, SPANG  $28^\circ$ . Paratype AMNH 42995, H 7.6 mm, W 4.6 mm, SPANG  $22^\circ$ . Paratype AMNH 42996, H 4.0 mm, W 2.7 mm, SPANG  $37^\circ$ .

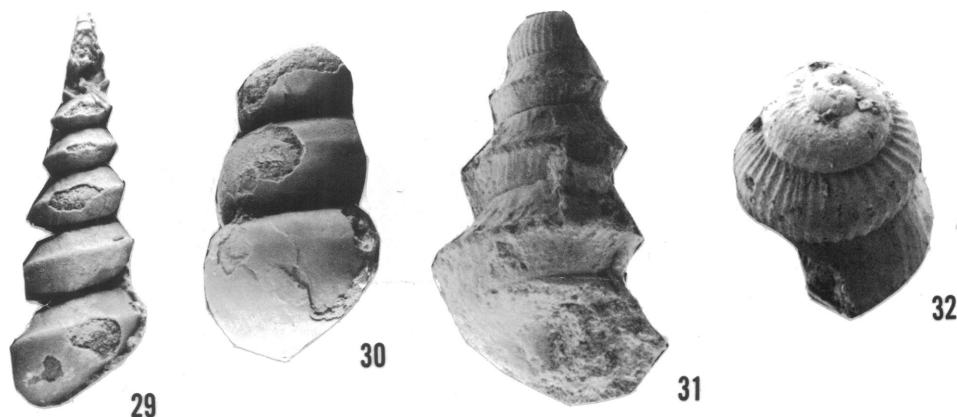
ETYMOLOGY: *Scia*, Greek for shade or blind; *phoster*, Greek for window.

GENUS *ANOPTYCHIA* KOKEN, 1892

TYPE SPECIES: *Melania supraplecta* Münster, 1841, SD Kittl, 1894, non Cossmann, 1909.

DISCUSSION: There was some early confusion over whether the type species was *Melania superplecta* Münster or *Turritella superplecta* Münster; see Haas (1953, pp. 122–123) for detailed discussion. In any event, the genus is a well-established zygopleurid characterized by having well-developed spiral and

collabral ornament confined to the early whorls of the shell and with smooth, inflated whorls in the adult forms. The base, in some species, may have spiral ornament in the adult. The broad sinus is usually located on the upper whorl surface, but many species (such as *A. canalifera* Münster or *A. multi-torquata* Münster) have shallow mid-whorl sinuses. The early embryonic whorls may have one or two spiral ribs or a sharp mid-whorl periphery with strong collabral cords on the outer whorl face, or collabral cords only. There is much variation in this ornament which may be confined to just a few of the early whorls or extend down to the penultimate whorl as in *A. eotriassica*, new species. The presence of a mid-whorl angular periphery and collabral cords in the later shell is similar to that of the adult shell of the type species *Goniospira armata* Münster, 1841. The base of most species is phaneromphalus with a reflexed columellar lip and the aperture is holostomous. It is widely reported in the European Triassic and by Haas from the Peruvian Triassic and is found in the Middle Triassic of Idaho.



Figs. 29–32. *Anoptychia eotriassica*, new species. 29. Holotype, AMNH 42997, side view,  $\times 5$ . 30. Paratype, AMNH 42999, side view showing rounded adult whorls,  $\times 2.5$ . 31. Paratype, AMNH 43000, side view showing angulate early whorls and rounded ornamented embryonic whorl,  $\times 25$ . 32. Paratype, AMNH 43001, oblique top view showing heterostrophic nucleus,  $\times 60$ .

*Anoptychia eotriassica*, new species

Figures 29–32

**DIAGNOSIS:** High-spired, turritelliform shells with a smooth protoconch, collabral ornament on next three whorls, a mid-whorl periphery, and collabral ornament on the next nine whorls; the final adult whorl is evenly globose without ornament.

**DESCRIPTION:** Single whorl of planktotropic larval shell is smooth and unornamented; the next  $1\frac{1}{2}$  whorls are evenly inflated with nearly vertical evenly developed and spaced collabral cords. Third whorl has angular periphery, fourth whorl has spiral cord on periphery forming a keel and collabral cords are reduced to numerous threads. Slightly concave upper whorl surface with broad sinus and concave alveozone under keel. Whorls embrace on lower margin of alveozone; base is flatly rounded. On final whorls (12–14), keel becomes broader and less prominent, migrating to just above periphery. Whorl becomes more globose and sinus migrates downward to a mid-whorl position and collabral threads disappear leaving growth line alone to indicate the position of sinus. Whorls in final phase embrace well below periphery and final whorl is evenly globose with no ornament. Narrowly phanerocephalus.

**DISCUSSION:** The above description is generalized and based on observations of the ho-

lotype and a number of paratypes. No specimen is complete but there are sufficient overlaps of the various stages to reconstruct the ontogenetic sequence.

Most of the species from central Europe tend to be lower spired with flatter whorls and base. The early whorls have collabral costae which are zygopleurid-like. *Anoptychia janus* Kittl, 1894, has two spiral ribs which dominate the early whorls. *A. janus* and *Anoptychia multitorquata* Münster are high spired with inflated whorls but lack the highly developed keel of the Sinbad species. *A. multitorquata* has parietal inductura that covers the umbilicus. Haas' species, such as *A. ninacacana*, are lower spired with less inflated whorls and with whorls embracing low on the outer whorl face.

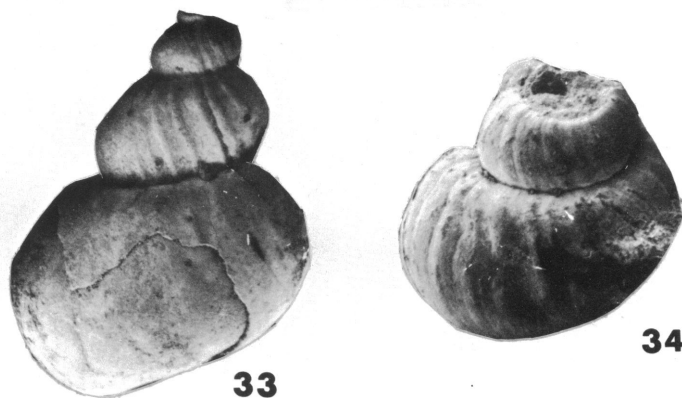
**SPECIMENS:** Two hundred seventy-three.

**MEASUREMENTS:** Holotype AMNH 42997, H 10.0 mm, W 3.0 mm, SPANG  $13^\circ$ . Paratype AMNH 42998, H 15.3 mm, W 3.5 mm, SPANG  $13^\circ$ . Paratype AMNH 42999, W 12.5 mm.

**ETYMOLOGY:** *Eos*, Greek for early, and Triassic, a geological system.

FAMILY COELOSTYLINIDAE  
COSSMANN, 1909

**DISCUSSION:** Wenz (1938, pp. 390–397) has placed a number of genera in this family; all are high spired, some without ornament, but



Figs. 33, 34. *Coelostylina costata*, new species. 33. Holotype, AMNH 43002, side view,  $\times 20$ . 34. Paratype, AMNH 43003, oblique side view,  $\times 10$ .

most have collabral ornament patterns. Nine genera are siphonate and 11 are holostomous. There are certain problems with this arrangement, particularly with *Omphaloptychia* von Ammon, 1893, and *Coelostylina* Kittl, 1894, because species have been placed in these genera which are far removed from the type characteristics; this has caused a great deal of confusion regarding what each genus represents.

Cossmann (1909) was the first to erect the superfamily Loxonematacea for families that have turruculate genera with holostomous apertures and with a sinuous outer lip. This definition, even from the beginning, was incorrect because of the large number of genera which clearly are siphonate, and were recognized as such in Cossmann's own work. Nonetheless, the Coelostylinidae, as constructed by Wenz, should remain in this superfamily.

#### GENUS *COELOSTYLINA* KITTL, 1894

TYPE SPECIES: *C. conica* Münster, 1841.

DISCUSSION: To our knowledge, this is the earliest report of the genus. The previous report of an early occurrence is from the Anisian of China (Yin and Yochelson, 1983b). The only other report of the genus in the Western Hemisphere is by Haas (1953) and Bonarelli (1927) from the Late Triassic of Peru and Argentina.

Morphological relationships to *Ompa-*

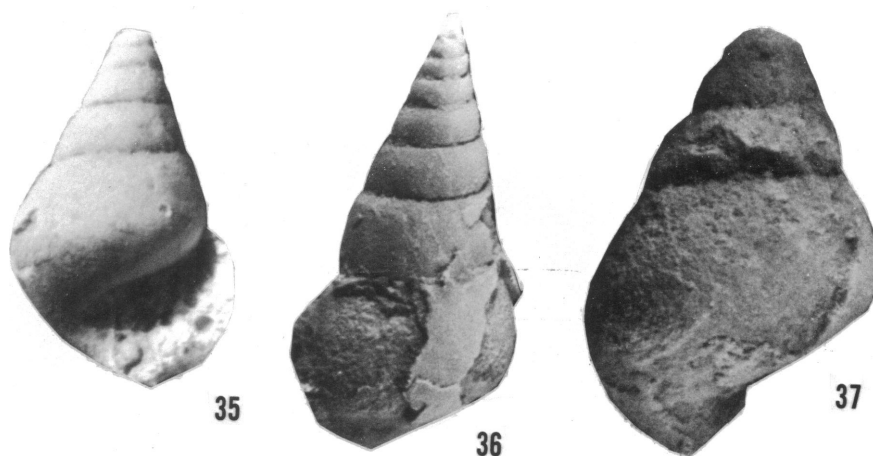
*loptychia* are discussed under that genus. In brief, we are assigning species to this genus that tend to be high spired (with whorl embracing well under the periphery) with a low rate of whorl expansion, resulting in a smaller body whorl and with a sutural ramp. There usually is some collabral ornament, particularly on the early whorls in some species such as *C. crassa* Münster or *C. speciosa* (Haas), 1953. On the whole, ornament is typically faint to absent in both genera.

#### *Coelostylina costata*, new species

Figures 33, 34

DIAGNOSIS: Trochiform shells with a wide, ornamented sutural ramp and inflated, ornamented whorls.

DESCRIPTION: Embryonic whorls are smooth and relatively high-spined. Sutures are deeply incised and sharply defined. Flat, relatively wide sutural ramp has irregularly developed collabral cords becoming less intense toward suture. Whorl profile is evenly inflated with a broad ill-defined mid-whorl periphery. Outer whorl face has irregularly developed collabral cords separated by fine collabral threads. Ornament becomes quite irregular on final whorl and cords may broaden, occupying most of whorl surface and separated by very narrow grooves. Whorls embrace below periphery on lower whorl face. Base is rounded with collabral cords or threads



Figs. 35–37. *Coelostylina virginensis*, new species. 35. Holotype, AMNH 43004, apertural view,  $\times 10$ . 36. Paratype, AMNH 43005, side view of high-spired variant,  $\times 9$ . 37. Paratype, AMNH 43006, side view of low-spired variant,  $\times 10$ .

becoming weak near columella. Base is hemi-omphalus. Columellar lip is reflexed and has a callus. Aperture is holostomous.

**DISCUSSION:** Well-developed but irregular collabral ornament makes this a highly unusual species. Only one other species, *C. crassa* (Münster), has ornament which is also somewhat irregular, but finer, and the shell is more gradate because the sutural ramp is narrower and sharply declined toward the suture. The whorl profile is concavoconvex and flattened. It is phaneromphalus. The Sinbad species is similar in shape to *C. cochlea* (Münster) but that species is without ornament and is widely phaneromphalus and somewhat lower spired.

There is some variation in whorl embracement; some specimens embrace on the base, others near or on the periphery. Some specimens have a more rapid whorl expansion rate so that they appear lower spired (see fig. 34). Some specimens have more evenly developed and spaced collabral cords in the ornament.

**SPECIMENS:** Four.

**MEASUREMENTS:** Holotype AMNH 43002, H 4.4 mm, W 3.8 mm, SPANG 47°. Paratype AMNH 43003, H 3.8 mm, W 4.1 mm, SPANG 59°.

**ETYMOLOGY:** *Costa*, Latin for rib.

### *Coelostylina virginensis*, new species

Figures 35–37

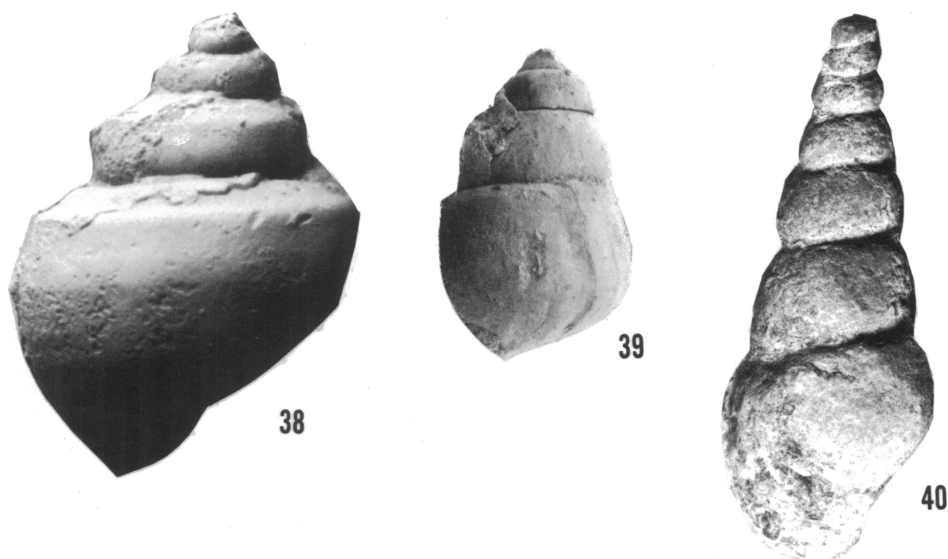
**DIAGNOSIS:** Moderately high-spired conical shells with flattened whorl profiles and a flat base.

**DESCRIPTION:** Adult shells have about 10 whorls. Conical shells with a broad, sloping outer whorl face that culminates at angular to subangular periphery low on whorl. Sutures are sharp with narrow sutural ramp. Whorls embrace below periphery on base. Base is flatly rounded. Narrowly phaneromphalus. Columellar lip is reflexed.

**DISCUSSION:** These distinctive shells are restricted to the Virgin Limestone. They differ from all other species in having flattened whorls giving a smoothly conical shape. Most variation is seen in the whorl expansion rate so that some specimens seem lower spired than others. They resemble *C. conica* (Kittl) as illustrated by Zardini, 1978 (pl. 29, fig. 1a, b) but those illustrated are much more rounded and whorl expansion rate makes the shells appear lower spired. They are similar to *C. waageni* (Kittl) but that species is more fusiform with more rounded whorls and with whorl embracement at the periphery.

**SPECIMENS:** Thirteen.

**MEASUREMENTS:** Holotype AMNH 43004,



Figs. 38–40. 38. *Coelostyline* cf. *angulifera* (White), illustrated specimen, AMNH 43007, side view,  $\times 4.5$ . 39. *Coelostyline* species a. Illustrated specimen, AMNH 43008, oblique basal view,  $\times 19$ . 40. *Coelostyline* species b. Illustrated specimen, AMNH 43009, side view,  $\times 2$ .

H 5.4 mm, W 3.5 mm, SPANG  $50^\circ$ . Paratype AMNH 43005, H 6.1 mm, W 3.4 mm, SPANG  $32^\circ$ . Paratype AMNH 43006, H 5.7 mm, W 3.7 mm, SPANG  $52^\circ$ .

ETYMOLOGY: Named for the Virgin Limestone member of the Moenkopi Formation.

*Coelostyline* cf. *angulifera* (White), 1874

Figure 38

*Macrocheilus anguliferous* White, 1874.

DISCUSSION: A single specimen, a steinkern with a small section of the shell preserved, belongs to this species. This species was first reported from the Virgin Limestone member of the Moenkopi Formation by Larson (1966, p. 143, pl. 8, figs. 1–5) as *Omphaloptychia anguliferous*. On the basis of our definition of the two genera we believe that this species should be placed in *Coelostyline*.

The Sinbad specimen has a rapid whorl expansion rate and hence is relatively low spired. The sutures are deeply incised and the upper whorl face is narrow, nearly horizontal, and convexoconcave with a sutural ramp that slopes downward to the suture. It is congruent with the convex portion of the whorl

face. The shoulder has a keel formed by a spiral cord and serves also as the periphery. The narrow outer whorl face is flat to slightly convex and is equivalent to an alveozone in the archeogastropods. The lower whorl face is evenly inflated and grades into the rounded base. Apertural details are unknown but the parietal surface is devoid of any parietal thickening.

This specimen differs from those illustrated by Larson in having a wide and flatter upper whorl face, a shoulder with a spiral cord, and a more gradate whorl profile. Larson's figure 5 shows a somewhat wider upper whorl face than his other illustrations, but still not as wide as the Sinbad specimen.

SPECIMENS: One.

MEASUREMENTS: AMNH 43007, H 13.9 mm, W 10.3 mm, SPANG  $64^\circ$ .

*Coelostyline* species a

Figure 39

DESCRIPTION: Small turbiniform shells with narrow sutural ramp sloping sharply to suture. Whorls are flatly rounded. Angular periphery is low on the whorl. Whorls embrace



on or slightly below periphery. Base is flatly rounded. No details of aperture are known.

**DISCUSSION:** Several tiny immature specimens are sharply different from other species of the genus. The flattened whorl profiles and narrow sutural ramp cause a smooth almost *Melania*-like shell shape unlike *C. angulifera* (White) with its stepped outline. It differs from *C. costata* in lacking ornament and by having a much narrower sutural ramp. Many individuals were observed in the fauna that probably belong to this group but they are not sufficiently preserved to be sure. The specimens in the sample are those that were highly distinctive and well preserved.

**SPECIMENS:** Seven.

**MEASUREMENTS:** Ill. Spec. AMNH 43008, H 2.0 mm, W 1.5 mm, SPANG 52°.

#### *Coelostylina* species b

Figure 40

**DESCRIPTION:** High-spired turriculate shells with moderate whorl expansion rates; whorls rounded. Early whorls have periphery low on whorl and somewhat flattened upper whorl faces. Later whorls are evenly inflated with centrally located peripheries. Whorls embrace just below periphery on outer margin of base; base is evenly rounded.

**DISCUSSION:** These specimens are, unfortunately, steinkerns but the shapes are distinctive enough to warrant placement in this genus. They are similar to *C. solida* Böhm, as illustrated by Zardini (1978, p. 31, fig. 14a, b).

**SPECIMENS:** Four.

**MEASUREMENT:** Ill. Spec. AMNH 43009, H 8.5 mm, W 4.2 mm, SPANG 30°.

#### GENUS *OMPHALOPTYCHIA*

VON AMMON, 1893

**TYPE SPECIES:** *O. nota* von Ammon, 1893.

**DISCUSSION:** Haas (1953) has exhaustively discussed the relationship and recognition problems of *Coelostylina* Kittl, 1894, and *Omphaloptychia*. Both genera are overlapping and contain a large number of species. The basic problem is that they are relatively featureless, hence recognition of valid species is difficult, much as for *Naticopsis*. End member species appear to have shared derived

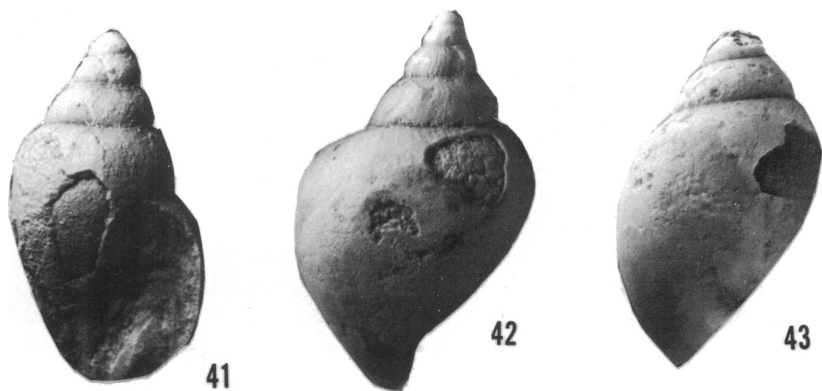
characters and these validate the genera. We will retain Haas' *modus operandi* in relegating high-spired species to *Coelostylina* and lower-spired species to *Omphaloptychia*.

The type species of *Coelostylina* is *C. conica* (Münster), 1841, which has whorls embracing just below an ill-defined medial periphery giving the shell a slightly turriculate shape. There is a flat sutural ramp and the lower apertural lip is extended, possibly forming a shallow siphonal trough; the type specimen is broken at a critical point so that this cannot be substantiated. However, Zardini (1978) illustrated five specimens attributed to this species from the type locality, two of which show a shallow siphonal trough at the juncture of the lower and columellar lips (pl. 29, figs. 1 and 3). But the other specimens (pl. 28, fig. 14; pl. 29, fig. 2) clearly show a holostomous aperture with the lower lip and columellar lip forming a continuum.

The illustrations (in von Ammon) of the type species *O. nota* is of an evenly inflated shell with a holostomous aperture. It was described from the uppermost Triassic. Haas (1953, pl. 8) illustrates four species of the genus. Most specimens show a holostomous aperture, but several identified as *O. jaworskii* Haas, 1953, clearly show a shallow, but well-defined siphonal trough, so that the definition of the genus should include siphonate species.

Kittl (1899, pp. 108–140) reported over 35 species and subspecies of this genus, many of them very large. For example, *O. aldrovandii* (Stoppani), 1858 (on pl. 17, fig. 1) is 160 mm high. In current taxonomic practice many of these would be placed in other genera and even different families. *Omphaloptychia aldrovandii* is the type species of *Gigantogonia* Cossmann, 1909. As with *Coelostylina*, species assigned to this genus are variable. Some have siphonal troughs; others are holostomous. In the present study, no species having sutural ramps are recognized as belonging to this genus.

We recognized species belonging to *Coelostylina* that are relatively high spired, with sutural ramps, with or without collabral ornament and sutural troughs. Species assigned to *Omphaloptychia* are lower spired, without sutural ramps, with or without collabral ornament and sutural troughs.



Figs. 41–43. *Omphaloptychia homolirata*, new species. 41. Holotype, AMNH 43010, apertural view,  $\times 4$ . 42. Paratype, AMNH 43011, side view, note collabral ornament on the early whorls,  $\times 4$ . 43. Paratype, AMNH 43012, side view,  $\times 6$ .

***Omphaloptychia hormolira*, new species**

Figures 41–43

**DIAGNOSIS:** Subulitiform shells with collabral cords on early whorls and an angular periphery in mid-whorl.

**DESCRIPTION:** Moderately high-spired shell with shallow, but well-defined sutures. Upper whorl face somewhat flattened to concave; outer whorl face strongly convex with broad but angular periphery at mid-whorl. Whorl expansion rate is moderate so that body whorl is larger in proportion to earlier whorls. Well-developed collabral cords confined to first four to five whorls. Adult whorls without ornament. Base is elongate, rounded, and aperture is holostomous. Columellar lip is thickened but not reflexed.

**DISCUSSION:** Well-developed collabral ornament is uncommon within this genus and family. When it is developed, as in *Coelostylina crassa* (Münster), it is ill-defined and uneven. An angular periphery is equally uncommon. *C. waageni* (Kittl) is one example that has an angular periphery, but it is low on the whorl with whorls embracing on or just below it, giving a more turriculate appearing shell. No other species seems related.

**SPECIMENS:** Fifty-five.

**MEASUREMENTS:** Holotype 43010, H 8.3 mm, W 5.0 mm, SPANG 55°. Paratype AMNH 43011, H 9.03 mm, W 5.0 mm, SPANG 56°.

**ETYMOLOGY:** *Hormos*, Greek for chain, *lira*, Greek for bold.

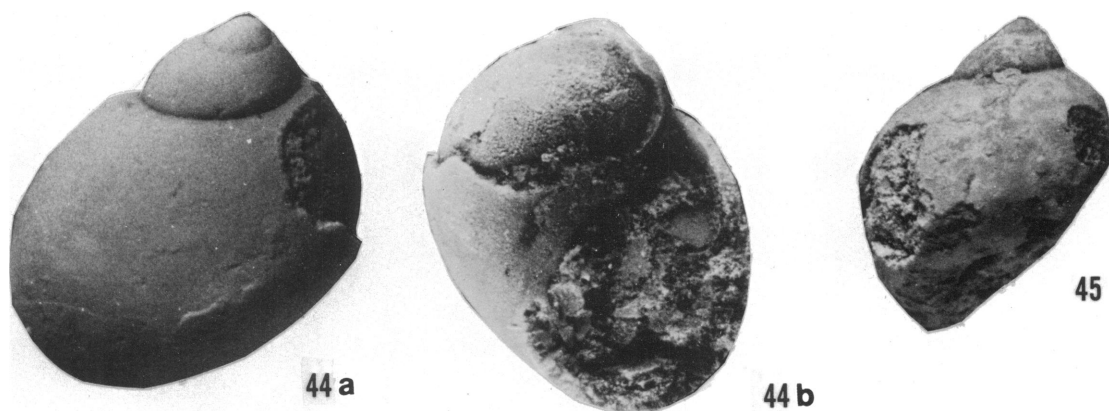
***Omphaloptychia laevisphaera*, new species**

Figures 44, 45

**DIAGNOSIS:** Globose, relatively low-spired shells with a smooth whorl surface and rapid whorl expansion.

**DESCRIPTION:** Very evenly inflated and rounded whorls with broad ill-defined periphery at mid-whorl. Sutures sharply defined, but shallow. Whorls embrace just above periphery or higher, giving a low, naticiform appearance. Growth lines are nearly vertical so that aperture is a flat plane. Base is evenly rounded, phaneromphalus to cryptomphalus. No parietal thickening. Circumbilical ridge is low and rounded, columellar lip is a shovel-like depression. Inner lip and columellar lip are continuous, forming an arc.

**DISCUSSION:** There is subtle variation noted in the shape of the whorl which may be somewhat elongated and the profile less globose with whorls embracing lower on the periphery in some specimens causing a slightly higher-spired shell. Without having the columellar lip preserved, this species could easily be confused with *Naticopsis utahensis*, new species, which has almost the same shape. That species has the typical naticopsid apertural features including a thickened, flat parietal inductura on the columellar surface, with a callus extending the length of the lip and with prosocline growth lines. There are countless thousands of immature or small specimens with the same whorl shape and shell appearance as these two species (*O. lae-*



Figs. 44, 45. *Omphaloptychia laevisphaera*, new species. 44. Holotype, AMNH 43013; a. oblique side view,  $\times 10$ ; b. apertural view,  $\times 10$ . 45. Paratype, AMNH 43014, side view showing a variant with a more globose whorl profile,  $\times 18$ .

*visphaera* and *N. (N.) utahensis*) in the Sinbad Limestone. To identify these requires careful preparation with needles of each apertural region; therefore, the proportion of each species in the fauna remains unknown.

All of the species of *Coelostylinia* and *Omphaloptychia* are higher spired than *O. laevisphaera*; *Omphaloptychia jaworskii* Haas, 1953 has evenly rounded whorls but they embrace at or well below the periphery, and it has a sutural ramp and lacks a circumbilical ridge.

**SPECIMENS:** Twenty-five with known apertural features.

**MEASUREMENTS:** Holotype AMNH 43013, H 4.9 mm, W 4.3 mm, SPANG  $85^\circ$ . Paratype AMNH 43014, H 6.2 mm, W 7.2 mm, SPANG  $78^\circ$ . Paratype AMNH 43015, H 3.7 mm, W 3.6 mm, SPANG  $71^\circ$ .

**ETYMOLOGY:** *Laevis*, Latin for smooth, *sphaerus*, Latin for round.

SUPERFAMILY CERITHIACEA  
FLEMING, 1822

FAMILY MATHILDIDAE WENZ, 1938

*PROMATHILDA* ANDREAE, 1887

**TYPE SPECIES:** *Cerithium biserta* Münster, 1846.

**DISCUSSION:** This genus includes a large number of small-size Triassic and Jurassic species widely distributed primarily in the Tethyan faunal realm. Most species are rel-

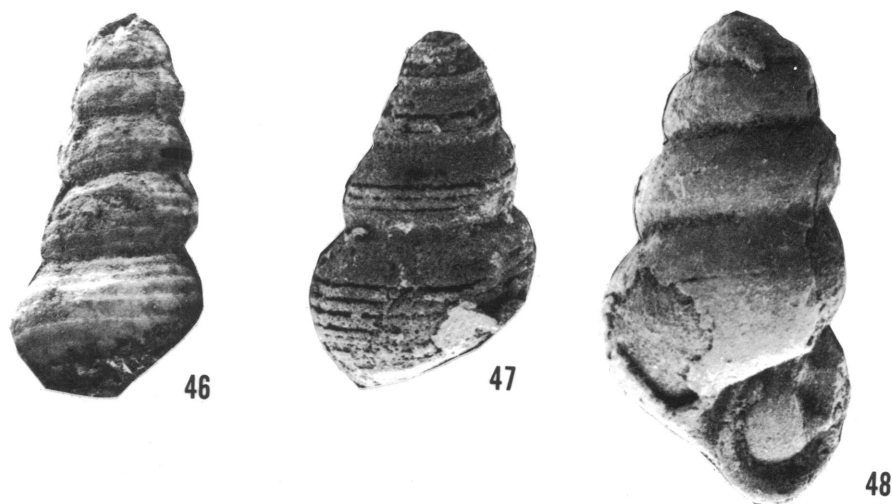
atively high-spired and turriculate shells with a dominance of spiral ornament. One of the distinctive features is the presence of heterostrophic nuclear whorls in most, but not all, species. Heterostrophic nuclear whorls are found in several unrelated gastropod groups such as the pyramidellids which are also high spired with spiral ornament, but living representatives clearly show that they are opisthobranchs. Within the Cerithiacea the architectorids have hyperstrophic nuclear whorls.

Another feature mentioned by Haas (1953, p. 185) that is peculiar to *Promathilda* is the curved growth lines that form a sinus, usually at mid-whorl. However, many species also show nearly vertical growth lines without forming a sinus, such as *P. margaritifera* (Münster) and *P. subcrenata* (Münster). *Promathilda* is the only genus of this family that is high spired in the Triassic.

*Promathilda spirocostata*, new species  
Figures 46–48

**DIAGNOSIS:** Loxonematiform shells with spiral cords and threads unevenly developed and spaced over the whorls.

**DESCRIPTION:** Nuclear whorls unknown. Whorl profile evenly inflated and globose. Sutures shallow and not well defined. Broad periphery at mid-whorl has spiral rib which marks keel. Whorls embrace on base well below periphery. Upper whorl surface has a spi-



Figs. 46–48. *Promathilda spirocostata*, new species. 46. Holotype, AMNH 43015, side view,  $\times 19$ . 47. Paratype, AMNH 43016, side view,  $\times 17.5$ . 48. Paratype, AMNH 43017, apertural view showing reflexed columellar lip,  $\times 17$ .

ral thread or cord adjacent to suture and another midway between suture and periphery. Two prominent spiral ribs bracket periphery. Spiral cords and threads on base become weaker near umbilical region. Phaneromphalus or hemiomphalus. Columellar lip is slightly reflexed and thickened with slight depression near lower lip. Aperture is holostomous.

DISCUSSION: Several specimens differ from the holotype in preservation; the whorl surfaces have been modified so that the three larger spiral cords are represented by narrow, deep grooves (see fig. 47). The most obvious variation is the development of the two spiral threads on the upper whorl surface. The upper thread may be more or less formed than the medial cord. The lower cord also varies in development. In the less well preserved specimens there is no evidence of an upper sutural thread or cord.

Most species tend to have a low periphery and a concave outer whorl surface forming a turritelliform shell. *Promathilda spirocostata* comes closest to *P. intermittens* (Kittl) which has a much faster whorl expansion rate, with strong cords on the base; but it lacks a sutural thread or cord. *P. stuoresensis* (Kittl) has a

very low periphery with the strongest cord forming a keel. The spiral ornament is less well developed than in this new species.

SPECIMENS: Six.

MEASUREMENTS: Holotype AMNH 43016, H 2.5 mm, W 1.4 mm, SPANG  $21^\circ$ . Paratype AMNH 43017, H 2.2 mm, W 1.1 mm, SPANG  $19^\circ$ .

ETYMOLOGY: *Spiralis*, Latin for coil, *costa*, Latin for rib.

#### SUPERFAMILY SUBULITACEA

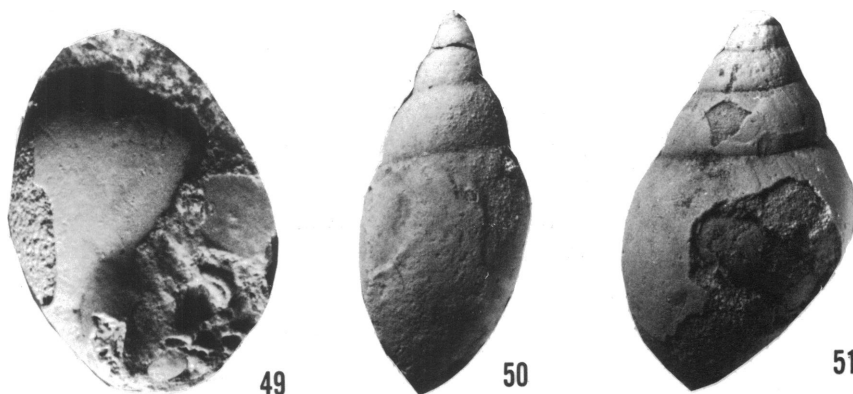
#### FAMILY SUBULITIDAE

#### SUBFAMILY SOLENESCINAE

#### *STROBEUS* DEKONINCK, 1881

TYPE SPECIES: *Strobeus ventricosus* DeKoninck, 1881, SD Cossmann, 1909.

DISCUSSION: This is a rather conservative genus known from some 12 or 13 species in the Carboniferous and 4 in the Permian. The presence of a columellar fold is the most critical feature. In all other respects the new species described below would be placed as a member of *Omphaloptychia*. This is the first report of *Strobeus* in the Triassic and *S. cf. paludinaeformis* is one of the few species



Figs. 49–51. *Strobeus* cf. *paludinaeformis* (Hall). 49. Illustrated specimen, AMNH 43018, apertural view showing the columellar fold,  $\times 4$ . 50. Illustrated specimen, AMNH 43019, side view,  $\times 3$ . 51. Illustrated specimen, AMNH 43020, side view,  $\times 4$ .

that crosses the era boundary. It is possible that this group of specimens is not *S. paludinaeformis* (Hall), 1858, but we cannot find any morphological feature suggesting that they belong to any other species. This is one of the more common species in the Sinbad and the large sample indicates variation identical to that in the Paleozoic. Still, this genus and species lacks ornament and other features to aid in securing a taxonomic assignment.

*Strobeus* cf. *paludinaeformis* (Hall)

Figures 49–51

*Macrocheilus paludinaeformis* Hall, 1858.

**DIAGNOSIS:** Moderately high-spined fusiform shells with flatly rounded whorls that embrace at or just below the mid-whorl periphery.

**DESCRIPTION:** Shells variable in whorl profile and whorl embracement. A coeloconoid, moderately high-spined shell. Sutures sharply impressed but shallow. No shoulder or ramp. Whorl profile is evenly inflated and the very broad periphery is mid-whorl. Whorl expansion rate is variable, tending to be rapid so that final whorl is greater in proportion to earlier whorls. In shells having a more rapid expansion rate, whorls embrace at periphery. Whorls embrace slightly lower on whorl, shell is more fusiform, and whorls are less inflated

in shells having a slower expansion rate. Aperture is oblique and extends over half shell height. Inner lip is arcuate and joins columellar lip without a siphonal reentrant. Columellar fold is low on columellar lip and slightly thickened by parietal inductura.

**DISCUSSION:** All of the morphology within this sample of 187 specimens falls well within the concept of *S. paludinaeformis*. However, we must add the disclaimer that there are relatively few characters that the species is based on and there is a distinct possibility that these features in the Sinbad population may reflect homeomorphy.

There is considerable variation in the morphology of this species—a statement remarkable in that there are so few characters to describe and deal with. The principal variation is in the whorl profile which, while evenly inflated, may be almost globose to a flattened profile giving the shell a more elongate and high-spined appearance. The whorl embracement is quite variable and seems to be related to the shape of the whorl. When the whorl is more globose, the whorls tend to embrace at the periphery; if the whorl is more elongate the whorls embrace below the periphery. The shell is fairly thick and most shells do not have the outer shell layer preserved. We are unsure if this is due to the nature of the wall itself (perhaps a coarse prismatic layer) or to

the type of preservation involving feathering of the calcitic matrix. In any event, most specimens do not display the outer surface. Those specimens that are well preserved show nearly vertical growth lines.

*S. paludinaeformis* is one of the more common gastropods in the Pennsylvanian, reviewed by Harper (1981, p. 181), where the problem of the name of the genus was discussed. Judging from published illustrations, and from examining relatively large samples of the species in the AMNH collections, there appears to be less variation in the Pennsylvanian populations which are of the more globose, slightly lower-spined, fusiform type. Looking over the Permian collections at the U.S. National Museum, the AMNH, and the Timor collections at the University of Amsterdam and Delft, we believe that *S. paludinaeformis* is present in the Permian; for example, it has been described as *S. girtyina* Erwin, 1986, from the Permian of Texas.

**SPECIMENS:** One hundred eighty-seven.

**MEASUREMENTS:** AMNH 43019, H 9.7 mm, W 5.8 mm, SPANG 59°; AMNH 43020, H 9.8 mm, W 4.7 mm, SPANG 40°.

GENUS *CYLINDROBULLINA*  
VON AMMON, 1878

**TYPE SPECIES:** *Acteonina fragilis* Dunker, 1848, SD Cossmann, 1895.

**DISCUSSION:** There are two groups of species that have different names applied to them in the Upper Paleozoic and Mesozoic, *Acteonina* and *Cylindrobullina*; again, as in *Omphaloptychia* and *Coelostylina*, they have been applied in a seemingly haphazard fashion. Unfortunately, the subsequently designated type species of both genera appear to be of the same group of species. Basically, the two groups can be separated on several features; the most obvious is the heterostrophic nucleus in one group versus an orthostrophic nucleus in the other. All species are very small in absolute size so that, unlike the pseudozygopleurids, the nuclear whorls are usually preserved. Thus *Acteonina carbonaria* deKoninck, 1843, has an orthostrophic nucleus as does *Cylindrobullina fragilis*. Other overlapping features include the teardrop-shaped aperture, an anal notch, columellar folds, a parietal inductura, and spiral ornament. (See

Haas, 1953, pp. 256–278; Cossmann, 1895, p. 62; Knight, 1932, for extensive discussions.) Perhaps the problem can be resolved by precedence of past usage. Batten (1966) assigned specimens from the Carboniferous of Great Britain to *Acteonina carbonaria* that possessed orthostrophic nuclear whorls. Haas (1953) described over ten species to *Cylindrobullina*, all having heterostrophic nuclei. However, Yochelson and Saunders (1967) transferred all orthostrophic nuclear species to *Girtyspira*, except those also having spiral ornament. The Sinbad species differs from all others assigned to *Cylindrobullina* in having a thick shell, as is the case of *Acteonina*.

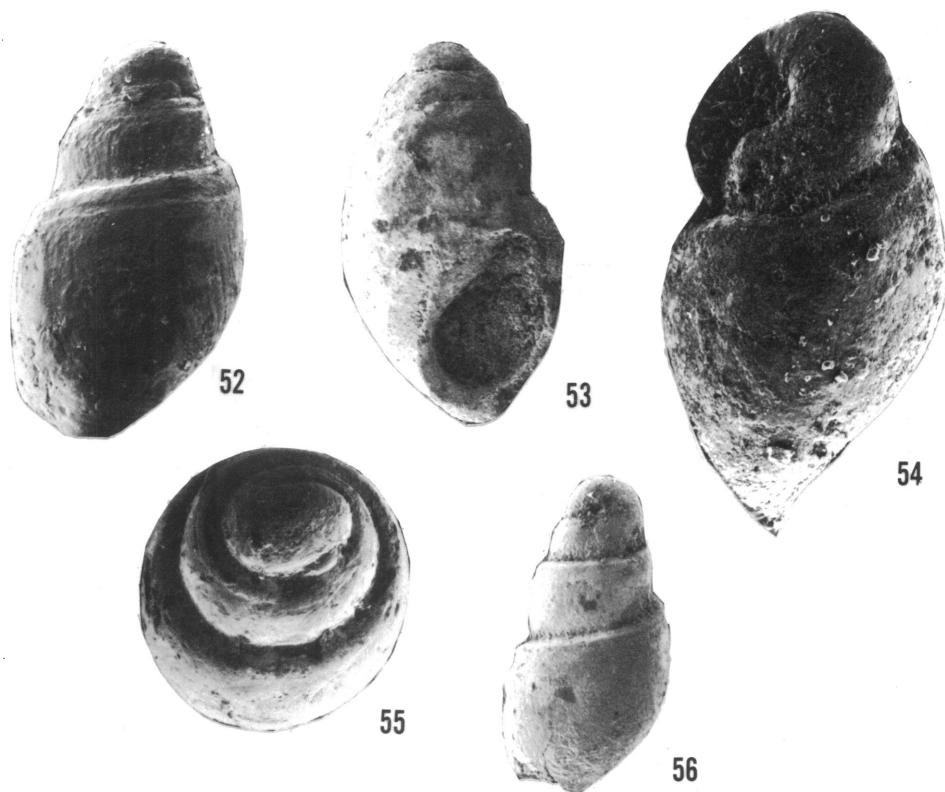
*Cylindrobullina convexa*, new species

Figures 52–56

**DIAGNOSIS:** Small, fusiform, thick-walled shells with a wide sutural ramp and evenly inflated whorls.

**DESCRIPTION:** Axis of first two whorls and protoconch varies between 90 and 120° to adult whorl. First two whorls are globose with nearly vertical growth lines. Sutural ramp (upper whorl face) is concave or flat and either horizontal or slightly inclined toward suture. Sutures are sharply defined. Keel at edge of ramp has raised and flattened collar, separated from outer whorl face by sharply defined groove. Whorl profile is evenly inflated, slightly convex, with broad periphery at mid-whorl. Whorls embrace at or just below periphery. Base is rounded, phaneromphalus. Growth lines form anal notch on the keel; become broadly sinuous across outer whorl face. Aperture is holostomous. Columellar lip and lower lip are thickened by callus; parietal inductura extends beyond plane of aperture. No columellar folds.

**DISCUSSION:** This species occurs in astronomical numbers in the Sinbad; only the immature shells of the naticopsids are more numerous. It is quite a variable species. The axis of the nuclear whorls varies between 90 and 120° with most specimens closer to 90°. The sutural ramp is relatively narrow and concave in most specimens with a sharp keel marking its outer boundary. In some specimens the sutural ramp is wide and flat and may slope outward and downward (see fig.



Figs. 52–56. *Cylindrobullina convexa*, new species. 52. Holotype, AMNH 43021, side view, note groove just beneath the keel,  $\times 63$ . 53. Paratype, AMNH 43002, apertural view,  $\times 57$ . 54. Paratype, AMNH 43023, oblique side view, note that the nuclear whorl is “overtured”  $120^\circ$ ,  $\times 100$ . 55. Paratype AMNH 43024, top view showing nuclear whorls  $90^\circ$  to the adult axis,  $\times 80$ . 56. Paratype, AMNH 43025, side view of high-spired variant,  $\times 45$ .

55). The whorl profile is usually evenly inflated, but again, in the specimens with a wide ramp, the outer whorl face is much more flattened and the whorls embrace low on the whorl near or on the basal margin, giving the shell a steplike outline. The collar around the keel can be quite wide and elevated or flat and depressed. The steinkern of one specimen shows that some specimens may be hemiomphalus or cryptomphalus. The columellar lip may be either reflexed or just thickened with a callus.

*Cylindrobullina convexa* is similar to *C. scalaris* (Münster) in general shell shape, the presence of a collar, whorl profile, and details of the aperture (a columellar lip with a thickened callus). It differs in lacking spiral ornament, in having a flat or concave sutural

ramp rather than a convex one, and having a flat collar as opposed to a rounded one. None of Haas' Peruvian species are similar; most have the whorl embracement high on the whorl and spiral ornament. *C. convexa* comes closest to *C. peruviana* Haas, 1953, in whorl profile, with a flat sutural ramp with a terminal collar on the keel, but the nuclear whorls are at less than a  $90^\circ$  axis to adult whorls; whorls embrace high on the whorl, and it has basal spiral ornament.

SPECIMENS: One hundred thirty-two.

MEASUREMENTS: Holotype AMNH 43021, H 0.9 mm, W 0.6 mm, SPANG  $42^\circ$ . Paratype AMNH 43022, H 1.0 mm, W 0.6 mm, SPANG  $35^\circ$ . Paratype AMNH 43024, H 1.0 mm, W 0.5 mm, SPANG  $45^\circ$ .

ETYMOLOGY: *Convexa*, Latin for curved.

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