PERMIAN GASTROPODA OF THE SOUTHWESTERN UNITED STATES

1. EUOMPHALACEA, TROCHONEMATACEA, PSEUDOPHORACEA, ANOMPHALACEA, CRASPEDOSTOMATACEA, AND PLATYCERATACEA

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ELLIS L. YOCHELSON
United States Geological Survey

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE FACULTY OF PURE SCIENCE COLUMBIA UNIVERSITY

WITH A SECTION ON THE EFFECT OF THE CRINOID HOST ON THE VARIABILITY OF PERMIAN PLATYCERATIDS BY
ARTHUR L. BOWSHER
United States Geological Survey

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INTRODUCTION

ABSTRACT

THE PRESENT PAPER contributes to the systematic summation of the Permian gastropods of the United States by describing members of six superfamilies from this largely unknown assemblage.

The finest Permian section in the United States is in western Texas. Many of the limestones there yield quantities of silicified fossils upon solution in hydrochloric acid. Collecting and acidizing programs of the United States National Museum and the American Museum of Natural History have resulted in the accumulation of large gastropod collections, which form the basis for this work. In addition, smaller collections of both silicified and non-silicified specimens from other areas have been treated.

Following a brief review of the technical terms and methods employed in description, some comments on the paleoecology are given. Gastropods occur chiefly in four kinds of assemblages. A characteristic example of each of these assemblages is described, and from the evidence presented it is concluded that two of these four are transported and mixed and two are approximately *in situ*. It is concluded that most gastropods were from shallow water, where algae were most abundant. Attention is called to possible differences between "limestone" and "shale" gastropod faunas, but collections available do not permit one to draw any conclusions at this time.

The main part of the paper is given to systematic descriptions of species, genera, and higher categories. All diagnoses and descriptions are original. Superfamilies diagnosed are the following: Euomphalacea, Trochonematacea, Pseudophoracea, Anomphalacea, Craspedostomatacea, and Platyceratacea. Families diagnosed are the following: Euomphalidae, Omphalotrochidae, Trochonematidae, Pseudophoridae, Anomphalidae, Craspedostomatidae, and Platyceratidae. The Craspedostomatidae are divided into three subfamilies: Craspedostomatinae, Brochidinae, and Dichostasinae. The last two are new categories.

Genera or subgenera heretofore known and rediagnosed are *Straparollus* (*Euomphalus*), *Amphiscapha* (*Amphiscapha*), *Omphalotrochus*, *Cyclites*, *Anomphalus*, *Brochidium*, and *Platyceras* (*Orthonychia*). *Brochidium* has not previously been reported in the Permian of North America. New genera or subgenera recognized are *Amphiscapha* (*Cylicioscapha*), *Straparollus* (*Leptomphalus*), *Planotectus*, *Babylonites*, *Discotropis*, *Diploconula*, *Sallya*, and *Dichostasia*.

The remainder of the paper consists of descriptions of species of the genera listed above. These include two Pennsylvanian species, deemed pertinent to the Permian studies and not described or illustrated since the original diagnosis, and 45 Permian species given in approximate stratigraphic order. Thirty-nine of the Permian species are considered to be new, and 30 species are well enough known to warrant being formally named. Variation in one species of *Platyceras* (*Orthonychia*) is considered to be caused by the specimens' being modified to conform to the calyx of several different crinoids. Occurrence data given in connection with all the Permian species are summarized on a single table.

The most complete section of fossiliferous marine Permian rocks in the United States is developed in west Texas. Indeed, the Permian sequence of this area has been considered a standard section for this country (Tomlinson and others, 1940, pp. 339–340). Thus knowledge of the fauna of these rocks can add immeasurably to our understanding of Permian environments and life and has important bearing on correlations, both within the United States and between this and other countries. The Permian period, which was characterized by widespread changes in the formerly prevailing epicontinental sea, was a critical time for marine animals. Taxonomic information about these faunas has bearing on general problems of phylogeny, patterns of evolution, and other related disciplines. This paper is concerned with description of some of the Permian species of one class of Mollusca and therefore provides basic information bearing on some of the problems noted above.

With the exception of a few species described in a single large paper by Girty (1909) and several short papers (Girty, 1937; Shumard, 1859), the Permian gastropods of the southwestern United States are virtually unstudied. Large collections of well-preserved gastropods are available, however, for studies such as that undertaken here.

Study of west Texas Permian gastropods was begun by J. B. Knight in 1941 while a member of the teaching staff of Princeton

University. Since 1945, Knight has been associated with the United States National Museum. The press of other duties and the continual accumulation of new specimens made it clear that he would not be able to complete his studies. In 1950, he suggested that part of the gastropods be studied by Roger Batten and the present author. This is the first paper of a series planned by Knight, Batten, and myself to cover the gastropods of the Permian system in the southwestern United States.

In many places, fossils of the Permian limestones in the west Texas area have been replaced by silica (Newell and others, 1953, pp. 171–174). The limestone matrix may be leached away by treatment with hydrochloric acid, leaving abundant free specimens as an insoluble residue. The acid-etching program of the United States National Museum (Cooper and Knight, 1946) has resulted in the accumulation of many undescribed fossils, including many gastropods, from the Permian formations exposed in the Glass Mountains, west Texas. A similar program has been developed by Newell at the American Museum of Natural History with Permian limestone blocks from the Sierra Diablo Mountains and Guadalupe Mountains. This technique of mass collecting has provided a great variety of well-preserved fossil invertebrates, including many kinds not visible at the outcrop. The bulk of the gastropods described in this report have been taken from the siliceous residue of 45 to 50 tons of limestone.

Permian shales of north central Texas and limestones of Cochise County, Arizona, also contain many gastropods, and these have been included in the present study. Specimens from eastern New Mexico and a few other areas have also been included.

ACKNOWLEDGMENTS

The writer is grateful to Dr. Norman D. Newell, the American Museum of Natural History and Columbia University, for enabling him to participate during one field season in the Permian reef-study project in west Texas sponsored by the two institutions named, and financed by the Humble Oil and Refining Company. Dr. Newell further arranged for the writer to study collections of gastropods of the American Museum as a thesis problem in connection with studies for the doctorate at Columbia University. As thesis advisor, he has critically reviewed the manuscript.

Collections of Permian gastropods in the custody of the United States National Museum were made available for study by Dr. G. A. Cooper, Curator of Invertebrate Paleontology and Paleobotany. Dr. Cooper also arranged for use of the facilities of the museum and supplied unpublished information on the stratigraphy of the Glass Mountains.

Other collections of west Texas Permian gastropods were lent for this study by Drs. Carl Dunbar, Yale University, B. F. Howell, Princeton University, and R. C. Moore, University of Kansas. Dr. Otto Haas, the American Museum of Natural History, guided the writer to important references on Triassic gastropods.

The writer is indebted to Dr. J. B. Knight, United States National Museum, for his continued guidance. Not only did he relinquish his plans for study of part of the fauna, but he generously gave advice from his wide experience with Paleozoic gastropods. His help with the systematics has been invaluable, and such scientific value as the present paper has is largely due to his guidance and example.

Individuals at several institutions have generously arranged for the loan to the author of type specimens. For such courtesies, it is appropriate to acknowledge the aid of Dr. C. W. Collinson, Illinois Geological Survey; Dr. A. Myra Keen, Stanford University; Mr. L. F. Brady, Museum of Northern Arizona; Dr. J. H. Peck, Jr., University of California; and Dr. Karl Waage, Yale University.

Colleagues of the United States Geological Survey have offered numerous helpful suggestions. Geological Survey collections from west Texas and Arizona were available to the writer for this study, and he was also granted time for the purpose from official duties. Mr. A. L. Bowsher aided in formula-

tion of ideas regarding the platycerataceans and has contributed a separate section on them.

The publication of the present paper and that of the section by Arthur L. Bowsher contained herein have been authorized by the Director of the United States Geological Survey.

Finally, the writer wishes to acknowledge the assistance of his friend and fellow student, Dr. Roger Batten, University of Wisconsin, and considerable assistance in the typing of the manuscript and the preparation of the plates from Mrs. M. J. Zuckerman and Mrs. Sally Yochelson.

METHODS AND PROCEDURES

The present paper is the first of a contemplated series of papers which it is hoped will eventually survey much of the gastropod fauna of the Permian system in southwestern United States. Except in the placement of one or two genera, the classification followed is that which is to be published in the "Treatise on invertebrate paleontology" (Knight, Batten, and Yochelson, MS). All diagnoses given, however, are original and do not invariably coincide with views to be presented in the forthcoming treatise.

With the exception of gastropods from the Phosphoria formation, all species of the groups under consideration previously described from the Permian of the United States have been revised. Gastropods of the Permian Phosphoria formation have been intentionally excluded from this study, as they represent a distinctly different geographic and ecologic division of the Permian. Extensive collections of the United States Geological Survey from these beds will provide the material for a separate study.

Because specific differences of gastropods are in many cases obscure and usually difficult to illustrate, no attempt has been made here to compare the American forms with each of the foreign species. Rather, study of foreign Permian species has been limited to placement of the several species in what is considered here to be the proper genus. This is a procedure followed by Newell (1942, pp. 77–78) in his study of upper Paleozoic mytilacean pelecypods. Generic assignments of the foreign species necessarily are provisional, because, with a few exceptions, virtually no foreign specimens were available for study.

The "Bibliographic index of Permian invertebrates" (Branson, 1948) fills a need for the assembling of records of earlier named species and genera. It is widely available, so, to avoid unnecessary repetition, complete bibliographic references have not been given to the species listed there. Full references are given to those species not indexed by Branson (1948). Foreign publications have been systematically investigated to January, 1954.

An attempt has been made to compare the Permian gastropods with related forms of Triassic age. All conclusions as to the placement of species have been based on publications, especially by Kittl (1891–1894, 1895, and 1899) and Koken (1896, 1897) on the Alpine upper Triassic, and Haas (1953) on the Peruvian Triassic.

The ranges listed for the genera take into account both Paleozoic and Triassic species. Most of this information is derived from studies undertaken in connection with the "Treatise on invertebrate paleontology." Gastropods of Jurassic or younger age have not been investigated; it is doubted that many of the genera considered herein range into beds above the Triassic.

American Permian species of the genera considered herein have been differentiated from one another. In addition, American Pennsylvanian species known to the writer have been discriminated from the Permian species. Most of the former are considered and illustrated by Knight (1933, 1934). Two Pennsylvanian species have not been previously restudied, *Straparollus* (*Euomphalus*) *pernodosus* Meek and Worthen and *Anomphalus verrucliferus* (White). For the sake of completeness, they have been revised and newly illustrated. It is hoped that this continuity study of Pennsylvanian and Permian species will be extended by other workers downward into the Mississippian, so that eventually it will be possible to construct an accurate picture of the phylogeny of American upper Paleozoic gastropods.

Descriptions are patterned after those by Knight (1941, pp. 15–16). Following a brief diagnosis, the characteristics are given in the following general order: (1) apex, (2) adult whorl shape from the suture to the base, (3) umbilicus, (4) aperture, and (5) ornamentation.

For the most part, the terms employed in the species descriptions are those used by Knight (1941, pp. 23–28). The term "angulation" has been employed for the salient juncture of two surfaces, and "carina" has been used to designate a raised, keel-like ridge. Frequently a carina or keel is located on an angulation.

A new term, "umbilical angle," has been introduced here for euomphalids to characterize a widely phaneromphalous umbilicus. The umbilical walls are commonly curved, and the angle of flare must be considered as tangent to the walls. As it is exceedingly difficult to make measurements within the umbilicus, the result gives order of magnitude rather than a precise figure.

At the suggestion of Dr. L. R. Cox, British Museum (Natural History), three terms have been introduced to describe the course of growth lines on the whorl face of the shell: "prosocline," growth lines inclined forward, at upper or inner end; "orthocline," growth lines inclined nearly vertically; and "opisthocline," growth lines inclined backward at upper or inner end. The angles given in connection with the slope of growth lines and other features of the shell have been estimated with the aid of a contact goniometer.

In the tables of measurements, height and width refer to the entire specimen; H.A. refers to the height of the aperture, and W.A. to the width of the aperture. V. has been used to designate the vector angle of the logarithmic spiral, or spiral angle, calculated for the body whorl. For the statistical parameters calculated for certain populations, the following abbreviations have been used: *N*, number of observations; *M*,[1] mean of measurements; *S*, standard deviation from this mean; *r*, correlation coefficient; and *OR*, observed range in size.

Data on specimens from several localities are included in most of the descriptions of species. As several populations may be involved, locality data have been given with each set of measurements. Some localities, particularly those in the Glass Mountains, have been visited several times. The specimens obtained by different persons in successive years have not been treated separately. The specimens from each locality are used as a sample of a single population in both statistical and biological senses.

Most linear measurements have been made with vernier calipers. When fragile specimens were involved, a micrometer ocular and microscope were used. The same device has been used for all the specimens of a species measured. Linear measurements have been estimated on fragmentary specimens. Specimens that were so damaged that dimensions could not be estimated with reasonable accuracy are not included with measured specimens, even though they have been placed in the hypodigm.

Because of the relative simplicity of the shells, the non-pleurotomarians described herein are not so adaptable to measurements and statistical treatment as are some other groups. Shells of many of the species discussed are so low that the conventional measurements of total height and height of aperture are nearly identical.

Trials have shown that measurements of the vector angle of the logarithmic spiral are certainly not significant unless calculated from linear measurements taken with great precision. As a statistical tool this measurement does not seem to warrant the effort, time, or special apparatus (Sloan, 1951) required to obtain it precisely.

The chief reason for not establishing and comparing statistical parameters of many of the species described is that in most cases the specimens are too incomplete or imperfect to permit accurate measurements. Furthermore, careful study has shown that many seemingly excellent specimens have been crushed [see discussion of *Straparollus* (*Euomphalus*) *cornudanus*, p. 214]. If this crushing has not been at random, it has undoubtedly biased some of the statistical work.

The concept of the hypodigm as proposed by Simpson (1940) is followed by the writer. The number of specimens studied is tabulated so that the reader will have some idea

[1] Imbrie has recently published (1956) a paper in which the derivation of these statistics is discussed in detail. He uses $\bar{x}$ and $\bar{y}$ for the mean of x and y, respectively.

of the material basis for each species diagnosis.

Most of the specimens studied are silicified, and they vary considerably in the quality of preservation. In order that the reader may know the condition of the material of each hypodigm, the state of preservation is indicated. In general, excellent to good preservation refers to those entire specimens that show growth lines and can be measured accurately. Fair preservation refers to specimens that are broken but in which restored linear measurements can be estimated with some degree of certainty. Poor specimens can be identified specifically, but usually the original dimensions cannot be estimated.

A few species also are based in part on specimens that have weathered out of the matrix. Most of these are from collections of Princeton University, Yale University, and the United States Geological Survey. Commonly the ornamentation and shapes of these specimens are more poorly preserved than those of silicified forms, but occasionally they add significant information to the concept of a species.

All specimens referred to the hypodigm have been carefully documented as to horizon and locality. The following institutional abbreviations are used throughout:

A.M.N.H., the American Museum of Natural History

B.E.G., Bureau of Economic Geology, University of Texas, Austin, Texas

I.G.S., Illinois Geological Survey, Urbana, Illinois

K.U., Geology Department, University of Kansas, Lawrence, Kansas

M.P.U.C., Museum of Paleontology, University of California, Berkeley, California

P.C., Frederick B. Plummer collection, University of Texas, Austin, Texas

P.U., Geology Department, Princeton University, Princeton, New Jersey

S.U., Stanford University, Stanford, California

U.S.G.S., United States Geological Survey, Washington, D. C.

U.S.N.M., United States National Museum, Washington, D. C.

Y.P.M., Peabody Museum, Yale University, New Haven, Connecticut

Following these abbreviations, localities are referred to by number. Complete locality data are given in the Register of Localities. The few specimens that are not from numbered localities are documented in the paragraphs on occurrence.

In some cases, several institutions have collected from the same locality, each institution designating it with a separate locality number. In every case, the number of the institution that owns the collections has been used. For example, A.M.N.H. 512 and U.S.N.M. 728 both refer to the same locality.

In order to indicate conveniently the distribution of the various species, a summary range chart is included (table 1). Localities have been listed in presumed stratigraphic order.

The relative abundance of individuals of the various species cannot be given. Almost invariably the number of specimens of a species is a function of the amount of collecting done. Some localities, particularly those in the Glass Mountains, have been collected extensively; others have been sampled only once.

In one interpretation all specimens in the original hypodigm are paratypes. Modern museum procedure requires special handling and storage of "types," and this treatment does not appear warranted for the bulk of specimens studied. To avoid any further confusion, the specimens that are illustrated and a few significant collections of unfigured specimens have been given catalogue numbers and have been designated holotypes, paratypes, or hypotypes. All these specimens have been listed under the noncommittal heading of "numbered specimens." The letter abbreviations of the catalogue number, as given above, show the repository of each numbered specimen. The abbreviation "No." with the institutional abbreviation will distinguish specimen numbers from the locality numbers.

Standard lighting, with the high-light coming from the upper left corner, has been used for most of the illustrations. Before being photographed, specimens were whitened with ammonium chloride, a process that emphasizes details such as growth lines. In a very few instances masses of silica adhering to the specimens were painted out on the negative with photographic opaque; otherwise, none of the photographs has been retouched.

STRATIGRAPHIC SETTING

MOST OF THE GASTROPODS described in this paper are from five areas: (1) the Hueco Mountains in eastern El Paso and western Hudspeth counties, Texas; (2) the Sierra Diablo-Guadalupe Mountains regions in eastern Hudspeth and western Culberson counties, Texas; (3) the Glass Mountains in Brewster County, Texas; (4) the Colorado River Valley of north central Texas in portions of Coleman, Concho, McCulloch, and Runnels counties, Texas; and (5) central Cochise County, Arizona. Most of the specimens examined are from the second and third areas. (See fig. 1.)

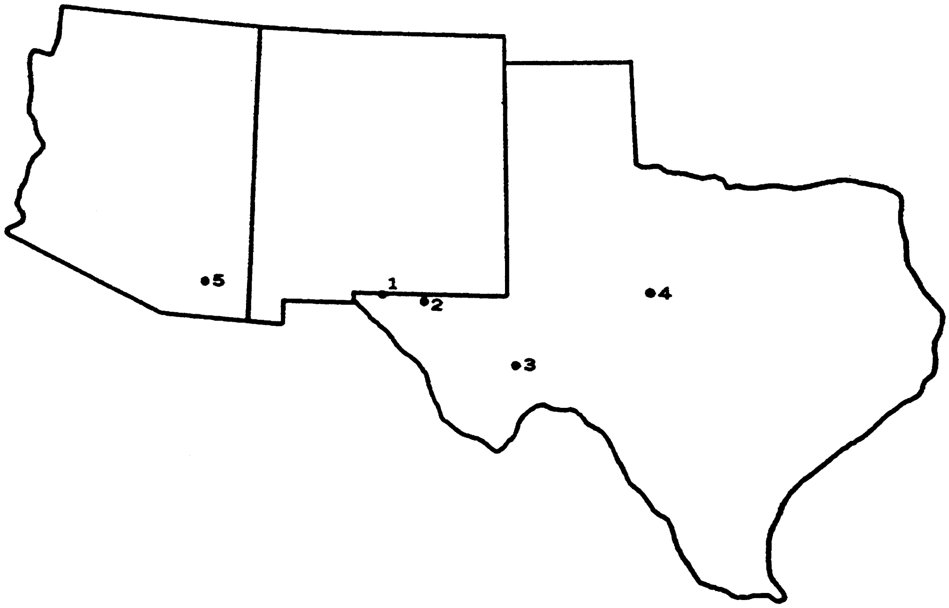

FIG. 1. Outline map of Texas, New Mexico, and Arizona showing five collecting areas: (1) Hueco Mountains; (2) Sierra Diablo-Guadalupe Mountains; (3) Glass Mountains; (4) part of the Colorado River Valley; and (5) central Cochise County, Arizona.

The west Texas Permian province includes the first three named areas of outcrop. The province as a whole is characterized by pronounced facies contrasts within short distances. In general, the stratigraphy becomes increasingly complex in the younger Permian deposits.

The Permian system is used here in the American rather than the conventional European sense, that is, the system includes as its basal division beds of Wolfcamp age, considered to be approximately equivalent to the "*Schwagerina* zone" of the Russian section (Dunbar, 1940, pp. 273–280). Formations of Wolfcamp age (Wolfcamp, Hueco, Clyde, and Colina [in part] formations) are classified by the United States Geological Survey as Permian.

Deposits of Wolfcamp age include the type Wolfcamp formation and the Hueco limestone. The Wolfcamp formation consists of interbedded limestones and shales, although small patch reefs occur in the Wolfcamp horizons in several places. Lateral changes of this formation are not well known, and the formation cannot be recognized with certainty except in the vicinity of the Wolfcamp Hills in the Glass Mountains. The Hueco, on the other hand, is a limestone unit that is relatively uniform and persistent over wide areas in the Sierra Diablo and the Hueco Mountains.

Leonard time was characterized by the first development of large reefs. In the Sierra Diablo Plateau, the Bone Spring limestone is clearly differentiated into a reef complex

TABLE 1
Faunal Distribution by Localities

Species	Wolf Mt. Formation (of Cheney, 1940)	Chaffin Formation (of Cheney, 1940)	Obregon Formation (of Cheney, 1940)	9880, Pueblo Formation	Putnam Formation	42-T-18	42-T-18-111.1	9802	Military Crossing	10973, Elm Creek Limestone Member?	4100	9854	9842	9848	9884	9861	9860	10769	8505	10874	4075	9847	9859	9844	9863
	NORTH-CENTRAL TEXAS					Admiral Formation, Wildcat Creek, Shale Member			Belle Plains Formation		Clyde Formation, Talpa Limestone Member									Grape Creek Limestone Member					
EUOMPHALACEA																									
raparollus (Euomphalus) cornudanus (Shumard)								x	x			x	x	x	x	x	x					x		x	x
raparollus (Euomphalus) glabribasis Yochelson, new species																									
raparollus (Euomphalus) kaibabensis (H. P. Chronic)																									
raparollus (Euomphalus) levicarinatus Yochelson, new species																									
Straparollus (Euomphalus) species																									
raparollus (Leptomphalus) micidus Yochelson, new species																									
mphiscapha (Amphiscapha) muricata (Knight)		x	x	x																					
mphiscapha (Amphiscapha) gigantea Yochelson, new species						x	x	x						x											x
mphiscapha (Amphiscapha) proxima Yochelson, new species																									
mphiscapha (Amphiscapha) dextrata Yochelson, new species																									
mphiscapha (Cylicioscapha) texana Yochelson, new species	x								x																
mphiscapha (Cylicioscapha) williamsi, Yochelson, new species																									
anotectus cymbellatus Yochelson, new species																									
mphalotrochus cochisensis Yochelson, new species											x							x							
mphalotrochus obtusispira (Shumard)					x					x								x	x						
mphalotrochus alleni Yochelson, new species																									
mphalotrochus wolfcampensis Yochelson, new species																									
mphalotrochus hessensis Yochelson, new species																									
mphalotrochus spinosus Yochelson, new species																									
mphalotrochus species																									
abylonites turritus Yochelson, new species																									
abylonites carinatus Yochelson, new species																									
abylonites acutus Yochelson, new species																									
abylonites conicus Yochelson, new species																									
iscotropis girtyi Yochelson, new species																									
iscotropis sulcifer (Girty)																									
iscotropis publicus Yochelson, new species																									
iscotropis species 1																									
iscotropis species 2																									
Discotropis species 3																									
iploconula biconvexa Yochelson, new species																									
TROCHONEMATACEA																									
yclites costatus Yochelson, new species																									
PSEUDOPHORACEA																									
ullya bicincta Yochelson, new species																									
ullya linsa Yochelson, new species																									
ullya striata Yochelson, new species																									
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nomphalus studiosus Yochelson, new species																									
nomphalus species																									
CRASPEDOSTOMATACEA																									
ochidium morrisi Yochelson, new species																									
ichostasia simplex Yochelson, new species																									
ichostasia complex Yochelson, new species																									
PLATYCERATACEA																									
atyceras (Orthonychia) bowsheri Yochelson, new species																									
atyceras (Orthonychia) species 1																									
atyceras (Orthonychia) species 2																									

Species	7011	708r	708s	708t	701g	93	701d	701h	701c = 91	706x	7419	3360	702x	707d	707o	3358	707b	707c	7	707a	707q	702f	6690	702d	702b	174	702 = 500 = 128 = 2	702un	702ent	703b	702a	702c	703a = 504
	WEST TEXAS AREA, Glass Mountains, Wolfcamp Formation															Leonard Formation																	
EUOMPHALACEA																																	
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mphalotrochus obtusispira (Shumard)																																	
mphalotrochus alleni Yochelson, new species															x																		
mphalotrochus wolfcampensis Yochelson, new species		x	x	x		x	x	x	x	x	x	x	x																				
mphalotrochus hessensis Yochelson, new species																						x	x	x									
mphalotrochus spinosus Yochelson, new species																																	
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abylonites turritus Yochelson, new species																	x		x		x					x	x	x		x			x
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nomphalus studiosus Yochelson, new species																	x													x		x	x
nomphalus species					x																												
CRASPEDOSTOMATACEA																																	
ochidium morrisi Yochelson, new species																								x			x			x		x	x
ichostasia simplex Yochelson, new species																								x						x			
ichostasia complex Yochelson, new species																											x					x	x
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atyceras (Orthonychia) bowsheri Yochelson, new species																																	
atyceras (Orthonychia) species 1																													x				
atyceras (Orthonychia) species 2																																	

Species	703d	703c = 503	703 = 501	707e	706c = 505 = 27	706	22-T-11	706e = 11 = 4	242	706b = 18	142	252	14425	14424	7003a	14432	14431	7028	37r	37	14426	14438	14430 = 719	6937 = 14437	47	57a	700	7050 = 720	7004	7007 = ?24	53
	Glass Mountains, Word Formation												Sierra Diablo Plateau, Hueco Limestone																		
EUOMPHALACEA																															
raparollus (Euomphalus) cornudanus (Shumard)															x	x		x	x	x		x	x	x	x	x					
raparollus (Euomphalus) glabribasis Yochelson, new species																															
raparollus (Euomphalus) kaibabensis (H. P. Chronic)		x	x																												
raparollus (Euomphalus) levicarinatus Yochelson, new species			x																												
Straparollus (Euomphalus) species																															
raparollus (Leptomphalus) micidus Yochelson, new species																															
mphiscapha (Amphiscapha) muricata (Knight)																															
mphiscapha (Amphiscapha) gigantea Yochelson, new species																															
mphiscapha (Amphiscapha) proxima Yochelson, new species																													x		
mphiscapha (Amphiscapha) dextrata Yochelson, new species																															
mphiscapha (Cylicioscapha) texana Yochelson, new species																															
mphiscapha (Cylicioscapha) williamsi, Yochelson, new species																															
anotectus cymbellatus Yochelson, new species																															
mphalotrochus cochisensis Yochelson, new species																															
mphalotrochus obtusispira (Shumard)													x				x				x		x	x	x			x	x		
mphalotrochus alleni Yochelson, new species																															
mphalotrochus wolfcampensis Yochelson, new species																															
mphalotrochus hessensis Yochelson, new species																											x				
mphalotrochus spinosus Yochelson, new species																															
mphalotrochus species																															
abylonites turritus Yochelson, new species			x																												
abylonites carinatus Yochelson, new species					x	x		x	x	x	x	x																			
abylonites acutus Yochelson, new species				x	x	x																									
abylonites conicus Yochelson, new species					x			x		x																					
iscotropis girtyi Yochelson, new species																															
iscotropis sulcifer (Girty)			x	x																											
iscotropis publicus Yochelson, new species					x			x		x																					
iscotropis species 1						x																									x
iscotropis species 2	x																														
Discotropis species 3																															
iploconula biconvexa Yochelson, new species	x	x	x			x	x																								
TROCHONEMATACEA																															
yclites costatus Yochelson, new species																															
PSEUDOPHORACEA																															
ullya bicincta Yochelson, new species																															
ullya linsa Yochelson, new species		x	x																												
ullya striata Yochelson, new species			x																												
ANOMPHALACEA																															
nomphalus vanescens Yochelson, new species																															
nomphalus studiosus Yochelson, new species		x	x																												
nomphalus species																															
CRASPEDOSTOMATACEA																															
ochidium morrisi Yochelson, new species		x	x		x																										
ichostasia simplex Yochelson, new species																															
ichostasia complex Yochelson, new species			x			x																									
PLATYCERATACEA																															
atyceras (Orthonychia) bowsheri Yochelson, new species					x	x		x		x																					
atyceras (Orthonychia) species 1																															
atyceras (Orthonychia) species 2			x																												

Species	20g	629	628	625	655	3	5	433	592	716	7055	8539	369	678	2930	600	519	512 = 728	31	537	397	410
	Sierra Diablo Plateau, Bone Spring Limestone												Bone Spring Limestone		Cherry Canyon Formation Getaway Limestone Member					Bell Canyon Formation, Pinery Limestone Member	Rader Limestone Member	
EUOMPHALACEA																						
raparollus (Euomphalus) cornudanus (Shumard)																						
raparollus (Euomphalus) glabribasis Yochelson, new species					x		x			x		x										
raparollus (Euomphalus) kaibabensis (H. P. Chronic)																						
raparollus (Euomphalus) levicarinatus Yochelson, new species																	x	x				
Straparollus (Euomphalus) species																						
raparollus (Leptomphalus) micidus Yochelson, new species													x									
mphiscapha (Amphiscapha) muricata (Knight)																						
mphiscapha (Amphiscapha) gigantea Yochelson, new species																						
mphiscapha (Amphiscapha) proxima Yochelson, new species																						
mphiscapha (Amphiscapha) dextrata Yochelson, new species																						
mphiscapha (Cylicioscapha) texana Yochelson, new species																						
mphiscapha (Cylicioscapha) williamsi, Yochelson, new species				x																		
anotectus cymbellatus Yochelson, new species																		x				
mphalotrochus cochisensis Yochelson, new species																						
mphalotrochus obtusispira (Shumard)																						
mphalotrochus alleni Yochelson, new species																						
mphalotrochus wolfcampensis Yochelson, new species																						
mphalotrochus hessensis Yochelson, new species																						
mphalotrochus spinosus Yochelson, new species			x																			
mphalotrochus species		x		x						x												
abylonites turritus Yochelson, new species	x						x		x		x											
abylonites carinatus Yochelson, new species																x		x	x	x		
abylonites acutus Yochelson, new species																		x				
abylonites conicus Yochelson, new species																		x				
iscotropis girtyi Yochelson, new species						x		x	x													
iscotropis sulcifer (Girty)															x							
iscotropis publicus Yochelson, new species																x	x	x		x	x	
iscotropis species 1																						
iscotropis species 2																						
Discotropis species 3																						x
iploconula biconvexa Yochelson, new species																						
TROCHONEMATACEA																						
yclites costatus Yochelson, new species																	x	x				
PSEUDOPHORACEA																						
ullya bicincta Yochelson, new species																						
ullya linsa Yochelson, new species						x		x		x							x					
ullya striata Yochelson, new species													x	x		x						
ANOMPHALACEA																						
nomphalus vanescens Yochelson, new species																						
nomphalus studiosus Yochelson, new species																						
nomphalus species																						
CRASPEDOSTOMATACEA																						
ochidium morrisi Yochelson, new species																		x				
ichostasia simplex Yochelson, new species																						
ichostasia complex Yochelson, new species																						
PLATYCERATACEA																						
atyceras (Orthonychia) bowsheri Yochelson, new species																		x				
atyceras (Orthonychia) species 1																						
atyceras (Orthonychia) species 2																						

Species	2915	2925	6721	61a	7129 = 55	712	712a	712b	712h	712i	712j	712c	712d = 51	712f = 53	391	722	723	724	726	San Andres Formation	8529	5314	5315	8188	8527	8488	8501	8502	8503	8513	8971	8532	8522
	NEW MEXICO, Hueco Mts., N. Otero County, Hueco Limestone															Florida Mts. Gym Limestone				San Andres Mts.	ARIZONA, Cochise County, Earp Formation	Probably Colina Limestone			Colina Limestone								
EUOMPHALACEA																																	
raparollus (Euomphalus) cornudanus (Shumard)				x	x	x	x	x				x	x	x	x		x	x															
raparollus (Euomphalus) glabribasis Yochelson, new species																																	
raparollus (Euomphalus) kaibabensis (H. P. Chronic)																				x													x
raparollus (Euomphalus) levicarinatus Yochelson, new species																																	
Straparollus (Euomphalus) species																																	
raparollus (Leptomphalus) micidus Yochelson, new species																																	
mphiscapha (Amphiscapha) muricata (Knight)																																	
mphiscapha (Amphiscapha) gigantea Yochelson, new species																																	
mphiscapha (Amphiscapha) proxima Yochelson, new species									x	x	x	x									x												
mphiscapha (Amphiscapha) dextrata Yochelson, new species													x					x															
mphiscapha (Cylicioscapha) texana Yochelson, new species																																	
mphiscapha (Cylicioscapha) williamsi, Yochelson, new species																																	
anotectus cymbellatus Yochelson, new species																																	
mphalotrochus cochisensis Yochelson, new species						x																x	x	x	x	x	x	x	x	x			
mphalotrochus obtusispira (Shumard)	x	x	x	x	x		x	x					x	x	x	x		x	x														
mphalotrochus alleni Yochelson, new species																																	
mphalotrochus wolfcampensis Yochelson, new species																																	
mphalotrochus hessensis Yochelson, new species																						x											
mphalotrochus spinosus Yochelson, new species																																	
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abylonites turritus Yochelson, new species																																	
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TROCHONEMATACEA																																	
yclites costatus Yochelson, new species																																	
PSEUDOPHORACEA																																	
ullya bicincta Yochelson, new species							x						x	x																			
ullya linsa Yochelson, new species																																	
ullya striata Yochelson, new species																																	
ANOMPHALACEA																																	
nomphalus vanescens Yochelson, new species						x		x																									
nomphalus studiosus Yochelson, new species																																	
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CRASPEDOSTOMATACEA																																	
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atyceras (Orthonychia) species 2																																	

and thin-bedded black limestone of the basin (Stehli, 1954, pp. 271–274). A United States Geological Survey Professional Paper is currently being prepared on this area (P. B. King, personal communication), which will fully document these relationships.

Smaller reefs of the patch-reef type were developed in the Glass Mountains. Exposures are poorer and structural relationships are more complicated here than in the Sierra Diablo.

The greatest reef development occurred during Guadalupe time. The lower Guadalupe is characterized by the development of patch reefs, but the upper Guadalupe contains the famous Capitan reef. This reef has been detected in the subsurface from its outcrop in the Guadalupe Mountains to the Glass Mountains and may have been nearly 400 miles in length. The reef complex separated the deposits of the stagnant basin, which it surrounded from the hypersaline seas of the back-reef shelf area (Newell and others, 1953, pp. 203–205).

The relations of the various named stratigraphic units of the Permian in the west Texas province and the inferred correlations between the isolated areas of outcrop listed above are shown in figure 2. An excellent discussion of this province has been given by King (1942). Newell and others (1953) have discussed the relationships of the Guadalupe Mountains in great detail, particularly in regard to the paleoecology.

The upper Paleozoic stratigraphy of Cochise County, Arizona, has been summarized by Gilluly, Cooper, and Williams (1954). These authors raised the Naco formation to group rank and subdivided it. The formations of the Naco group in ascending order are as follows: Horquilla limestone, Earp formation, Colina limestone, Epitaph dolomite, Scherrer formation, and Concha limestone. Almost all of the gastropods available from this area are from the Colina limestone, although a few have been collected from the Earp formation. Little has been written about the Permian environments of deposition in this area, but lithic descriptions of the sequence of rocks, given in measured sections, suggest that it is more or less a shelf type of deposit similar to the Hueco limestone.

In discussing the gastropods of the Colina limestone, Knight (*in* Gilluly, Cooper, and Williams, 1954) has noted similarities with collections from the Hueco limestone and the Clyde formation. Many of the gastropod species on which Knight based this conclusion are covered in the present paper. Similar conclusions on the time equivalence of these formations had been reached independently by the present writer. The evidence for these correlations is shown in table 1. This correlation between the north central and west Texas sections differs somewhat from that of Moore (1949) and of Cheney (1940, p. 66; 1947, p. 207) noted in the next paragraph.

Most gastropods from the Colorado River Valley area in north central Texas included in this study were collected by Moore (1949) while mapping the area. The greatest number of specimens are from the Clyde formation, a sequence of shaly limestones and calcareous shales. A preponderant number of these are from the Talpa limestone member near the top of the Clyde formation. The columnar sections given by Moore (1949) suggest lithic similarity to beds of Wolfcamp age in Kansas and Nebraska. Moore tentatively considers the Clyde formation to be equivalent in part to the Leonard formation of west Texas.

Gastropods from the *Uddenites* zone below the type Wolfcamp formation in the Glass Mountains area have been excluded as an undesirable extension of the scope of the present paper. The controversial question of Pennsylvanian versus Permian age of the *Uddenites* zone has been reopened by Cooper (1953, p. 75). Generally, the gastropods from the *Uddenites* zone are not well preserved, and they add little morphologic data to our knowledge of undoubted Permian species. On the other hand, the specimens are stratigraphically important, and it is hoped to make them the subject of another paper. Occurrence of the supposed Permian guide, the gastropod *Omphalotrochus*, high in the *Uddenites* zone has been noted (Yochelson, 1954, p. 233).

Knight, Cooper, and Newell (personal communications) consider the fauna of the first limestone member of the Word formation of the Glass Mountains to be virtually the same as that of the underlying Leonard

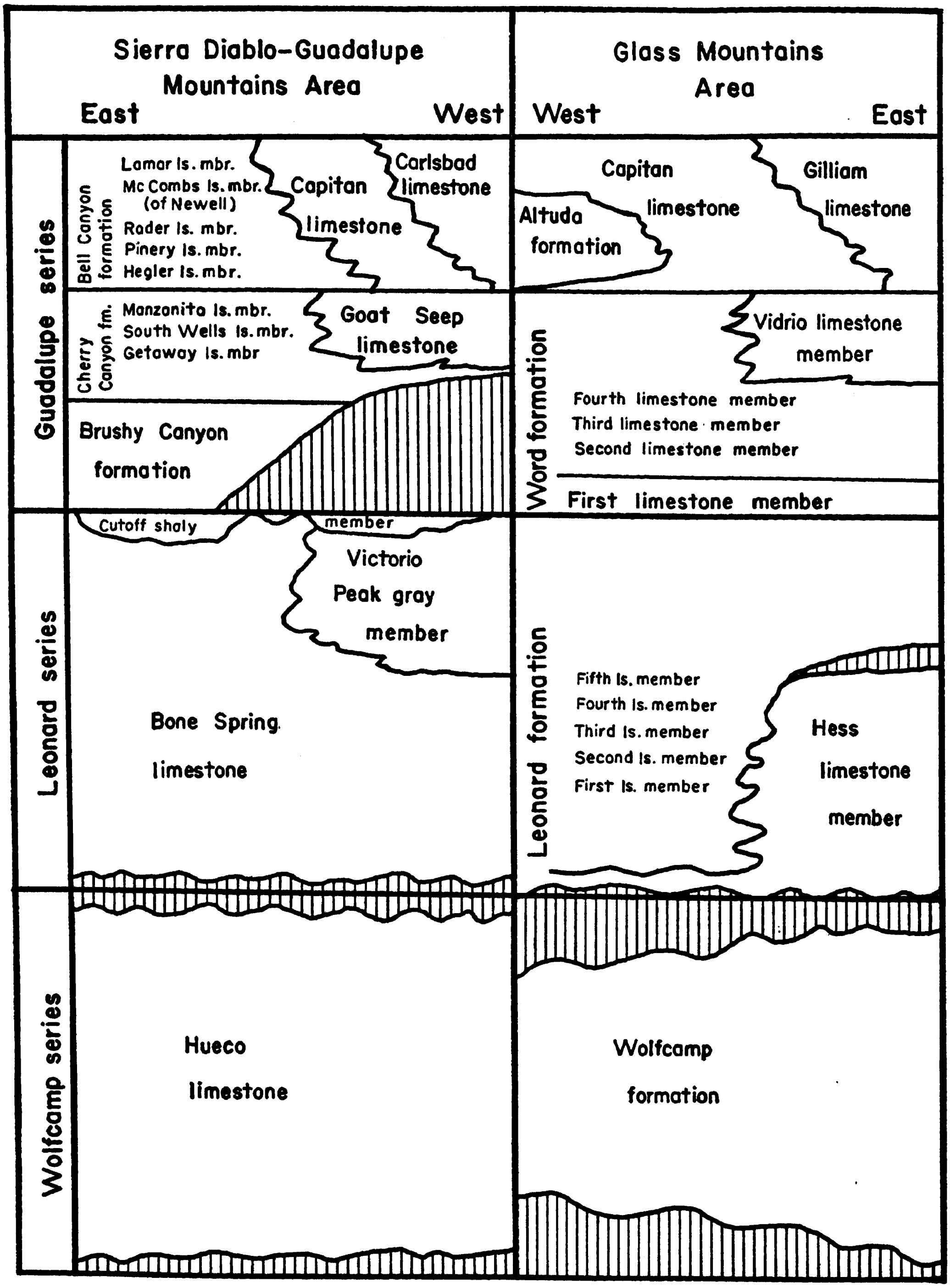

FIG. 2. Correlation of fossiliferous Permian units in the west Texas region. McCombs limestone member of Newell and others (1953) used for flaggy limestone bed of King (1951). Modified from King (1942).

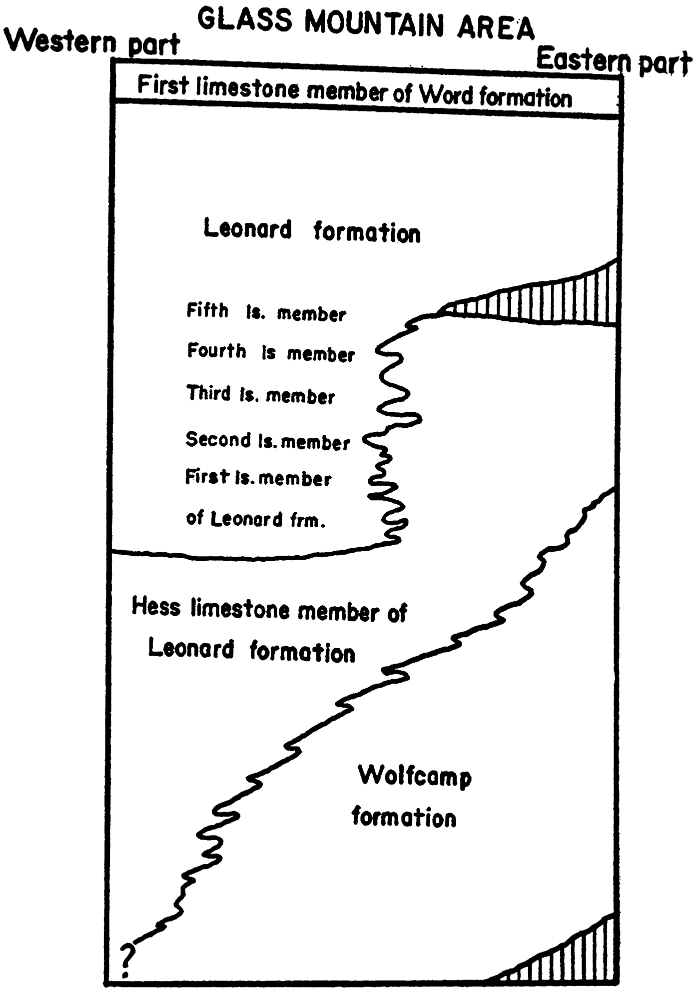

Fig. 3. Possible age relationships of certain stratigraphic units, which in the author's opinion differ from the traditional interpretation. Compare with figure 2.

formation. The gastropods studied for the present paper add some evidence to confirm this opinion. Study of other gastropods and extensive field work by G. A. Cooper suggest that the age relationships of other rock units in the Glass Mountains be modified also. Suggested age relationships are shown in figure 3.

These alternative age interpretations of the established rock units are shown here only to suggest that modifications of traditionally accepted ages are considered by certain workers in the Permian. The present work is primarily a faunal study, and because it is based on study of only part of the animals of one class out of the many phyla represented in the west Texas Permian, the writer is reluctant to propose changes in the stratigraphy or correlations of the strata of that area. Precise locality data on the studied material have been given, so that, in the event of any changes in formation limits by later workers, the stated ranges of the species discussed may be modified with a minimum of uncertainty.

INFERRED PALEOECOLOGICAL SETTING

EXAMINATION OF silicified and etched material from the west Texas area impresses upon one the fact that in most localities gastropods are rare. The proportion of brachiopods to gastropods in post-Wolfcamp strata is overwhelming. On a numerical basis the gastropods are estimated to comprise not more than a fraction of 1 per cent of the total number of Permian fossils collected, whereas the brachiopods constitute probably 75 per cent or more of the total. Thus one may infer that, except in those few horizons that bear abundant gastropods, such as parts of the Hueco formation, gastropods comprised but a small part of the ecological community.

In spite of their small numbers, the gastropods exhibit a relatively high degree of taxonomic differentiation, which is by no means remarkable as many faunules of Paleozoic gastropods characteristically include large numbers of genera and species represented by but few specimens. Little has been published on the ecological interpretation of such faunules. The Permian collections provide some information, but not enough is yet known about the ecological requirements of the various taxonomic groups to permit more than a few inferences on their habitats.

It is well known that fossil collections are not accurately representative of former life associations. Rather, one is dealing with segments of a continuous spectrum ranging from the dead and broken skeletons of a former biocoenosis, in which the parts of animals capable of fossilization in the former community of life are associated in about the same proportions as they were in life, to the situation in which remains of animals with many diverse hibitats have been mixed. It is essential that one attempt to discriminate the effects of transportation and mixing on the fossils present before undertaking paleoecological interpretations at a fossil locality.

Most of the gastropods collected in the west Texas province are from four general kinds of associations. Two of these are almost certainly a mixture of contrasting biofacies, and the other two may be only very slightly disturbed. A representative locality of each of these four associations is discussed below.

A United States National Museum locality (706c) from the second limestone of the Word formation, in the Glass Mountains, is characteristic of many of the post-Wolfcamp localities in the area. The composition of a typical assemblage given is based on examination of 15 museum cabinet drawers, approximately 22 by 28 inches and 1 to 2 inches deep, containing thousands of silicified and etched specimens.

About 90 per cent of all identifiable animal remains larger than 5 mm. from this locality are brachiopods. They are estimated below:

Productids	65%
Chonetids	7
Leptodids	5
Richthofenids	4
Enteletids	4
Spiriferids	3
Meekellids and derbyids	3
Rhynchonellids	2
Rostrospiriferids	4
Dielasmatids	1
Other brachiopods	2

Next in abundance at this locality, comprising possibly half of the remaining 10 per cent of the fauna, are the bryozoans. Five or six main types are present, with no relative preponderance of any one form. Both massive and branching colonies are included.

Corals seem to be the third commonest group of organisms. Several genera of solitary corals and one genus of branching colonial coral are found. The two types occur in almost equal numbers.

Fourth in abundance are the echinoderms. Very large echinoid spines and plates are found. Fragmentary crinoid stems occur abundantly, but they present unique problems in the estimating of percentages of a fauna and have not been included in the estimated percentages of animal abundance. The stems are commonly present as single columnals or very short sections of column. Calices are rare.

Mollusks also occur but are estimated to comprise much less than 1 per cent of the specimens examined. Of these, virtually all are gastropods. Among the gastropods platyceratids comprise almost 50 per cent of the forms; *Babylonites*, new genus, and *Straparollus* (*Euomphalus*) Sowerby comprise most of the other half. Pleurotomarians are quite rare and are represented almost exclusively by the genus *Peruvispira* B. J. Chronic. Pelecypods are rare and exhibit little taxonomic diversity. Both ammonoids and nautiloids are present but also rare. Chitons and scaphopods are represented by only one or two specimens each.

A few relatively large sponges and occasional trilobites are found. Fusulines are abundant, but, because all tests are not silicified, percentages cannot be accurately estimated. Therefore they have not been included in the estimates given.

Many of the productids are worn fragments. Spines on the shells are generally broken. The alate extremities of most spiriferoids and most of the leptodoids are broken; even the larger shells commonly are incomplete at the beak, as though they had been torn loose. Almost without exception, the anchoring spines of richthofenoids are broken away. All sponges are incomplete; none retains any vestige of the base. Although many of the bryozoans do not appear to be fragments, the maximum size of the colonies observed is approximately 2 inches in width, and most colonies are considerably smaller than this.

Both cemented brachiopods and free-living types are represented at this locality. Sponges, bryozoans, and corals may have been attached, but they show clear evidence of being torn loose from their substratum, and most of these specimens show some evidence of wear. The insoluble residue left after acid etching contains a high percentage of fine sand and very little clay-size residue. Fragments intermediate in size between sand and small pebbles are mostly shell fragments.

All these facts seem to indicate that most of the fossils at this locality are transported shell debris. Storms may have torn many of the animals loose from areas of firm attachment in other habitats, perhaps organic reefs, and currents then scattered them across the bottom. These animals accumulated with others that normally lived on a softer bottom of sand. Many of the specimens from this locality were obviously dead shells to which small brachiopods attached themselves.

Still another type of mixed associations are the "molluscan ledges" in the Bone Spring limestone of Leonard age. United States Geological Survey upper Paleozoic locality 6938, near Black John Canyon, in the northern part of the Sierra Diablo, is an example. Only a few localities of this kind are known, and no large collections have been etched from them, but these particular localities have yielded a high percentage of gastropods. The discussion given below is based on examination of one drawer containing several hundreds of silicified fossils and several incompletely etched blocks.

All types of fossils, other than mollusks, are very rare at this locality. Two specimens of sponge, five corals, several small bryozoan colonies, and three brachiopods, including one leptodoid, are present. There are only two or three specimens each of echinoid spines, crinoid stems, and trilobites. Fusulinids occur, but owing to the differential silicification of their tests, as noted above, their original abundance is not known.

Pelecypods are abundant, comprising well over half of the fossils recovered from the locality. Of these, *Nucula*, *Nuculana*, and *Astartella* are the commonest types, and parallelodontids are fourth in abundance. Most of the other pelecypod genera are represented by only a few specimens.

Gastropods are varied, being represented by nearly 20 genera. High-spired forms of several unrelated genera are somewhat more common than gastropods of other shapes; however, there is no striking difference in numbers of individuals among the several genera. No large gastropods occur, and few of medium size are present.

Orthoconic nautiloids are moderately rare. Well-preserved larger nautiloids are exceedingly rare, and ammonoids are absent. Scaphopods and chitons are common, the latter group being the more abundant.

An examination of specimens etched from limestone blocks shows that most specimens are fragmentary. The rock is a true coquina, with many of the larger fragments of shells being those of large cephalopods. All these fragments are silicified and cemented together so firmly that only the material in the outer few inches of the block can be separated by dissolution of the matrix.

These "molluscan ledges" are local accumulations of fossils seldom extending more than a few ten's of feet laterally. The surrounding matrix is thin-bedded, black limestone characteristic of the Bone Spring limestone, having a high silt content and containing virtually no fossils.

The locality under discussion was at least 800 feet below the surface of the sea, if King's (1942, p. 626) cross section may be interpreted as a reconstruction of the paleogeography. Knight (personal communication) suggests that animals were swept down into deeper parts of the sea from shallower areas and accumulated as windrows on the bottom. Turbidity currents, such as occurred during Guadalupe time (Newell and others, 1953, pp. 69-77), may have been the transporting mechanism. Some of the pelecypods, however, may have lived at this depth.

An example of an entirely different type of locality from the two discussed above is A.M.N.H. 512, from the Getaway limestone member of the Cherry Canyon formation of Guadalupe age in the Guadalupe Mountains. The discussion given below is based on examination of 30 museum drawers of etched fossils from that locality.

Brachiopods comprise possibly 50 per cent of the fauna by number. One is not struck by their abundance, however, as most of the brachiopods are small, unspectacular forms. When the phylum is broken down to a lower taxonomic level, percentages by number are approximately as follows:

Rhynchonellids	35%
Meekellids	20
Productids	20
Spiriferids	10
Richthofenids	5
Rostrospiriferids	5
Other brachiopods	5

Of next importance in volume, and even more so in number, are crinoid stems and fusulinids. Somewhat less abundant than these, but still important numerically, are several different types of bryozoans and small colonial corals. Occasional solitary corals are also present.

The mollusks rank fourth in importance, with pelecypods and gastropods in almost equal numbers. Many genera of pleurotomarians and other gastropods have been found at this locality. Scaphopods are relatively rare, as are cephalopods and chitons.

Sponges of moderate to fairly large size also appear. Though of little importance numerically, they constitute an appreciable volume of the total fauna.

One is impressed by the difference in appearance between etched material from this locality and that from U.S.N.M. 706c, second limestone of the Word formation. For the most part, only fragments are present at the latter locality, with unbroken fossils constituting not more than one-third of the total volume of the material. Fragments from A.M.N.H. 512 vary in size, but most are small, as the size of the greater number of complete animals is smaller than of those at U.S.N.M. 706c. The unworn condition of many of the fossils suggests that there has been little sorting by currents at this locality.

The field relationships at this locality indicate that the fossiliferous beds were formed of waste from a near-by patch reef similar to A.M.N.H. 511, described by Newell and others (1953, pp. 102–104). The fossils at A.M.N.H. 512 have not been extensively mixed, if at all, with those from other environments.

This kind of gastropod habitat, somewhat modified, is represented in U.S.N.M. 703c, from the upper part of the Leonard formation, Glass Mountains, Brewster County, Texas. Among the fossils present are extremely large slender sponges and an abundant mixed fauna with many gastropods. The American Museum of Natural History locality 369, from near the middle of the Bone Spring limestone, Guadalupe Mountains, also contains many gastropods, and in addition has crinoid stems and abundant sponge spicules. These two localities and A.M.N.H. 512 probably contain representatives of 50 per cent or more of all the gastropod species known from the west Texas area.

An example of a fourth kind of locality is found in the Hueco Mountains. Gastropods are rare throughout much of the Hueco limestone. However, there are several horizons, particularly in the middle and upper part of the formation, where this class of mollusks is very abundant (King and

Knight, 1945). The present writer has not examined the area of outcrop, and most limestone blocks collected from it were etched before this study was begun. The description of a typical locality, A.M.N.H. 51, middle Hueco limestone, is necessarily less detailed than the others given, being based on only one-half of a drawer of etched, unsorted, insoluble residue.

The quantity of fine material in the residue is so large that the rock could with some justification be called a calcareous claystone. Fine sand and coarser fragments are virtually absent.

The fauna contains many species of gastropods distributed in more than two dozen genera, with most genera represented by numerous specimens. Although large forms occur, most are smaller than 2 cm. in diameter. Echinoid spines are rare. Brachiopods are rare, and most specimens are small representatives of *Composita*. Pelecypods are exceedingly rare.

Algal remains are abundant. These are wavy lamellar growth forms resembling "potato chips." These structures have been found at almost all the localities from which Hueco limestone blocks have been etched. Similar growths occur with Pennsylvanian gastropods in the St. Louis outlier area.

Knight (personal communication) offers the following interpretation for this locality. The marginal seas of Hueco time were shallow and at times became hypersaline by evaporation. The gastropods thrived in this hypersaline water. Abundant algae were present, and most of the gastropods crawled over the plants. *Composita* may have lived with the pedicle attached to the algae. When the animals died they fell into the soft mud where their shells were essentially undisturbed.

None of the localities with which the writer is acquainted gives any suggestion as to the extent of wave or current action. The presence of extremely long, slender sponges in U.S.N.M. 703c, Leonard formation, Glass Mountains area, suggests indirectly that the waters were relatively quiet. It would be hazardous to extend this suggestion to the rest of the localities. The residue of fine-size particles in some localities also suggests quiet water.

Although some living gastropods have a considerable depth range, most live in shallow waters (Durham, 1947, p. 1260). The abundant occurrence of what may be gastropod trails interrupted locally, possibly by surging action of waves, has been taken as one indication of shallow-water deposition in the lower Ordovician (Cloud and Barnes, 1948, pp. 59–60). The inference that most gastropods are found in what were shallow-water deposits can be reënforced from both local and regional observations in the west Texas Permian province.

Deposits of the deeper part of the Permian Delaware basin which are thought to have been laid down in depths up to several thousand feet (Newell and others, 1953, p. 190) have not yet yielded gastropods *in situ*. Conversely, the Hueco strata, which contain abundant gastropods, are miles away from this basin. The widespread shelf sea of Hueco time was presumably shallow and probably was not much more than 100 feet deep at the maximum (Newell and others, 1953, p. 191).

Rigby (personal communication), who has studied the Permian strata of the Guadalupe Mountains in detail, suggests that the beds at A.M.N.H. 512, noted above, were formed within 25 feet of the surface. The marginal deposits of A.M.N.H. 512 may have been deposited in deeper waters. Stehli (1954, pp. 280–282) suggests that localities in the Sierra Diablo that have yielded gastropods were within a few dozen feet of the sea surface.

From Rubey's (1951) study of the geologic history of sea water and from the regional stratigraphic relationships (King, 1942), it seems reasonable to assume that the salinity and oxygen content of the open Permian sea were essentially the same as in the modern oceans. Some of these considerations as applied to the more restricted west Texas Permian basin are discussed by Newell and others (1953, pp. 183–209).

Knight (personal communication) attributes the abundance of gastropods in certain beds of the Hueco to hypersalinity of the Permian sea water. Parts of the Kaibab limestone in Arizona, which contain abundant gastropods and pelecypods, have been interpreted as being deposited under hypersaline conditions (Nicol, 1944, p. 553; H. P. Chronic, 1952, p. 110). Newell and others (1953, pp. 203–205) give evidence strongly supporting this opinion for the shelf facies of Capitan time, a facies quite similar to the Hueco.

Geochemical studies on temperatures of the lower and middle Permian seas have not been made. However, the great abundance and more particularly the variety of fossils found in the west Texas Permian province suggest that the seas were warmer than those found in the same latitude today, conditions being subtropical, if not tropical. The regional physical setting supports this opinion (Newell and others, 1953, pp. 183–185).

Gastropods in the Guadalupe back-reef Carlsbad limestone undoubtedly lived under conditions of abnormal salinity (Newell and others, 1953, pp. 204–205). However, the most abundant gastropods there, primarily bellerophontaceans and neritaceans, are superfamilies not treated in this paper.

One of the major unsolved problems in the study of the Permian is the evaluation of the differences between faunas collected from shale sequences and those from limestone sequences; workers agree that there are strong biofacies differences. The gastropods examined in connection with this paper provide several examples of how the biofacies of shales and limestones differ.

Collections from basal marls of the Hueco limestone on Threemile Mountain near Van Horn, Texas (e.g., U.S.G.S. 6937) bear an impoverished fauna, with few genera, quite different from that of the gastropod beds of the middle and upper Hueco. The brachiopod *Dictyoclostus* is abundant; the brachiopod *Composita* is common, as is the gastropod *Straparollus* (*Euomphalus*). Some specimens of *Omphalotrochus*, a scaphopod (?*Plagioglypta*), and scattered bryozoan colonies occur. Most of the few remaining species are represented by only one or two specimens each.

Many of the specimens of *Omphalotrochus* available for study were collected from shale beds of the Wolfcamp formation in the Glass Mountains. Farther east, the north central Texas collections contain abundant *Straparollus* (*Euomphalus*), many loxonemataceans, a few *Omphalotrochus*, and neritaceans, and very few gastropods of other types. As are the Wolfcamp gastropods, most of these are from shales.

These localities suggest that larger gastropods are generally more abundant in shale beds than in limestone. Before undue weight is given to this circumstance, it is important to note two points: (1) the euomphalaceans are characterized by a thick calcitic outer shell layer and are much more resistant to weathering and wear than many gastropods of other families, and (2) the Permian *Straparollus* (*Euomphalus*) and *Omphalotrochus*, being fossils of large size, are more easily seen at the outcrop than are the smaller forms. The gastropods from the Talpa member of the Clyde formation bear an obscuring coat of adhering shale, and even these large specimens are difficult to identify in the field.

The writer has not seen the area in Cochise County, Arizona, from which available collections were obtained. Most of the specimens are *Omphalotrochus* etched from limestone. Examination of weathered surfaces on some of the incompletely etched limestone blocks suggests that hand samples bearing large gastropods were selected in the field.

By way of summary, we may divide the gastropods of the west Texas area into three groups which, to some extent, probably reflect differences in ecological requirements. Group 1 includes the euomphalaceans; group 2, the platyceratids; and group 3, most other gastropods.

The euomphalaceans occur in limestones and shales and are among the most abundant forms in many shale beds of the west Texas province. It may be that this group could thrive in areas of shale deposition, where other gastropods also lived, but did not flourish. On the other hand, it may be that abundance of euomphalaceans in collections from shale beds is a result of differential collection, because of their large size in relation to many other Permian gastropods. Differential preservation, as the euomphalaceans are more resistant to weathering, may also be a factor. Only additional collecting and more detailed study of localities will reveal the importance of this apparent difference between the shale and limestone fauna.

Platyceratids (group 2) were quite specialized in their living habits. Their occurrence on the calyx of Paleozoic crinoids is known. Evidence suggestive of coprophagous habit has recently been summarized (Bowsher, 1955, p. 6). Permian representatives of this family were so specialized that they spent all their post-larval life attached. The platyceratids, then, must have lived, by necessity, only in those areas where crinoids lived. Platyceratids frequently occur in the beds that contain brachiopods and crinoid stems. Euomphaloids do not occur in all these beds.

It should be noted that many of the platyceratid shells are encrusted, or bear holes, such as have been attributed to bryozoans (Condra and Elias, 1944, pp. 524–525). Some of the holes must have been bored through dead shells, because they begin from the inside of the shell.

The third group, including the majority of forms studied, occurs at relatively few localities, where individuals are abundant and taxonomically varied. At these localities there is little evidence of transportation and mixing of the fossils. The gastropods are believed to have lived either in algal patches growing in shallow water or on reefs. Many of these reefs may have been composed predominantly of algae (Newell and others, 1953, p. 202).

It is estimated that more than 90 per cent of the species of west Texas Permian gastropods are referable to the Archaeogastropoda. Many of the living Archaeogastropoda are herbivorous, and it is reasonable to suppose that their ancestors had similar dietary habits. There may be some correlation between the abundance and distribution of fossil gastropods and the occurrence of algae, but further field studies are needed.

LARGER EVOLUTIONARY TRENDS

THE EUOMPHALACEA, as presently constituted, consist of three families, the Euomphalidae, the Helicotomatidae, and the Omphalotrochidae (Knight, Batten, and Yochelson, MS). The earliest representatives of the first two families occur in the lower Ordovician. Moreover, the Helicotomatidae are the dominant group in the Ordovician, whether one judges by number of specimens or by taxonomic variety. During much of the remainder of the Paleozoic, the Euomphalidae are the dominant stock.

Interestingly enough, the youngest helicotomatid and the oldest omphalotrochid are both known from the Devonian. Representatives of the Omphalotrochidae are not reported again until the latest Pennsylvanian or earliest Permian (Yochelson, 1954). Within the Permian this family undergoes a rapid expansion. The Omphalotrochidae are seemingly the only members of the superfamily to continue into the Triassic, although earlier publications incorrectly refer species to *Euomphalus.*

The geologic distribution of the families outlined above suggests that there may have been a replacement of the Helicotomatidae by the Euomphalidae, this group in turn being replaced by the Omphalotrochidae. This distribution, if correctly interpreted, may suggest that all three families occupied essentially the same general ecological niche. Much further work is needed to test both of these admittedly speculative hypotheses.

Within the family Euomphalidae, two subgenera show parallel trends in the development of a rugose to a nodose upper keel. These are in the new subgenus *Amphiscapha* (*Cylicioscapha*) and in certain large species of *Straparollus* (*Euomphalus*). The presence of this trend suggests that the larger species of *Euomphalus* form a phyletic line different from that of many species of smaller dimensions commonly referred to the subgenus.

Starting with the rugose Pennsylvanian *Straparollus* (*Euomphalus*) *pernodosus* Meek and Worthen, a line may be traced through *S.* (*E.*) *cornudanus* (Shumard) of the Wolfcamp to the nodose *S.* (*E.*) *kaibabensis* (H. P. Chronic) of the Leonard and Word formations and equivalents. Similarly, the middle Pennsylvanian *Amphiscapha* (*Cylicioscapha*) *subquadratus* (Meek and Worthen) is rugose; the upper Pennsylvanian-lower Permian *A.* (*C.*) *texana*, new species, has elongate nodes and the Bone Spring *A.* (*C.*) *williamsi*, new species, has more well-rounded nodes. Other species of these and related subgenera of the Permian Euomphalidae do not appear to follow any definite lines of phyletic development.

Among the species of the Omphalotrochidae, there are again no clear-cut patterns. However, *Omphalotrochus* itself is noteworthy for the development of at least six species in North America, in beds of Wolfcamp age. Five of these species are discussed or described herein. Two other species of the genus are known from beds of probably earliest Leonard age. *Omphalotrochus* seemingly died out without leaving descendants, and the derivation of other genera in the family is unknown.

Babylonites and *Discotropis*, two new omphalotrochid genera, appear to have developed from a common stock. The former is much higher than the other, but the protoconch of each is similar and quite different from that of *Omphalotrochus*. *Diploconula*, a fourth Permian omphalotrochid, seemingly represents another stock.

Phyletic relations within the Craspedostomatacea are most uncertain. *Brochidium* Koken seems to have much in common with certain middle Paleozoic genera, but *Dichostasia*, new genus, apparently does not have any close relatives within the superfamily. It appears to have even less in common with other Paleozoic genera. The two known species of *Dichostasia* seem to follow a trend from simpler to more complex ornamentation.

No evident trends are developed in the other superfamilies studied. In the Pseudophoracea, one is faced with a distinct gap in the geologic record. The superfamily is known from the Mississippian and Permian, but not from the Pennsylvanian.

SYSTEMATIC PALEONTOLOGY

SUPRASPECIFIC DESCRIPTIONS

ALL GASTROPODS described in the present paper are referred to the Subclass Anisopleura Lankester, 1878, the Superorder Prosobranchia Milne-Edwards, 1848, and the Order Archaeogastropoda Thiele, 1925. The origin and early Paleozoic evolution of the subclasses of the Gastropoda have been discussed recently by Knight (1952). A tentative phylogeny of living and fossil orders and superfamilies of gastropods has been published by Knight, Batten, and Yochelson (1954) and is not discussed here. The major categories mentioned above will be diagnosed with some revisions in Knight, Batten, and Yochelson (MS).

SUPERFAMILY **EUOMPHALACEA** KONINCK, 1881

DIAGNOSIS: Depressed discoidal to trochiform gastropods with a sinus on upper whorl surface or at juncture of upper whorl surface and outer whorl face; protoconch commonly discoidal; sinus of outer lip shallow, rarely culminating in a slit; phaneromphalous in all growth stages; shell of at least two distinct layers, the outer one thick and calcitic, the inner layer thinner and probably aragonitic; commonly without ornamentation.

DISCUSSION: Of the various possibilities for origin of the Euomphalacea that have been suggested, derivation from the Macluritacea seems to be the most plausible. Certain lower Ordovician representatives of both superfamilies are similar in being discoidal and hyperstrophic. In these respects, they have more in common than other known early Paleozoic gastropods.

Knight (1952, p. 40) has remarked that if the notch keel surrounding the umbilicus of *Maclurites* Le Sueur is considered as the locus of the anus, there is little room in the shell for a right ctenidium. Because of this lack of space, he assumed that this ctenidium and associated organs had been lost. However, in the living dibranchiate *Haliotis* the right ctenidium occupies remarkably little space within the shell, certainly no more than was available for a second ctenidium within the shell of *Maclurites*. The hypothesis that Macluritacea were a dibranchiate group is now favored and is the basis for the present treatment.

If the Euomphalacea are descended from the Macluritacea, they could have had either paired ctenidia or a single ctenidium. The characteristic keel on the upper whorl surface probably was the locus of an anus as in the Macluritacea, and the distance of this keel from the suture would have allowed ample space in the mantle cavity for paired ctenidia. For this reason, they are considered dibranchiate.

The Paleozoic Euomphalacea are divided into three families (Knight, Batten, and Yochelson, MS). These are the Euomphalidae Koninck, 1881; the Helicotomidae Wenz, 1938; and the Omphalotrochidae Knight, 1945. The Euomphalidae are considered to be the parent stock from which the Helicotomidae and the Omphalotrochidae were derived. The Helicotomidae range from lower Ordovician to Devonian and are not discussed here.

FAMILY **EUOMPHALIDAE** KONINCK, 1881

DIAGNOSIS: Trochiform to discoidal gastropods, with most of the included genera developing a keel on outer edge of upper whorl surface; protoconch simple; outer lip bearing a sinus at position of keel or near juncture of upper and outer whorl faces of those genera not developing an upper keel; narrowly to widely phaneromphalous in all growth stages, some genera, perhaps all, developing septae that partition off abandoned whorls; growth lines commonly impressed, rarely rugose, other ornamentation lacking.

DISCUSSION: The relatively sharp keel at the junction of upper and outer whorl surfaces contains a channel that in some species is so pronounced as to form a true slit and selenizone. This is the strongest evidence within the family, and the superfamily, that this keel was the locus of an anus as in the Pleurotomariacea. In those few genera included in the family that do not develop a keel, the distinct sinus in the outer lip is approximately at the same position as the keel of other genera.

A phylogeny of the genera and subgenera of this family within the Paleozoic cannot be presented, because relatively little is known of the interrelationships of many lower Paleozoic gastropods referred to this family. It seems quite probable, however, that the Permian subgenera of *Straparollus* discussed in this paper are descended from *Straparollus* (*Euomphalus*).

Genus STRAPAROLLUS Montfort, 1810

Type Species: *Straparollus dionyaii* Montfort, 1810.

Diagnosis: Trochiform to depressed discoidal gastropods, always widely phanerophalous; protoconch discoidal, with rounded whorls; mature whorl cross section rounded to subquadrilateral, mature whorls not in contact in some species; aperture without slit, but developing a shallow sinus.

Discussion: This broad diagnosis covers at least five groups of somewhat different gastropods. These groups constitute nodal aggregates along a line of continuous complete intergradation. It has been the practice of recent workers to treat these aggregates as subgenera of *Straparollus*. The subgenera recognized here are as follows:

Straparollus (*Straparollus*): Conical, whorls rounded, shell smooth
Straparollus (*Philoxene*): Conical, whorls rounded, foreign matter cemented to shell
Straparollus (*Serpulospira*): Conical, whorls rounded, out of contact except in juvenile stages
Straparollus (*Euomphalus*): Low-spired to discoidal, upper shoulder developed, giving a subelliptical whorl section
Straparollus (*Leptomphalus*): Discoidal, upper shoulder poorly developed, giving a subcircular whorl section

The first three subgenera are discussed briefly below in so far as they bear on the study of Permian gastropods.

Subgenus *Straparollus:* As presently restricted, this subgenus ranges through the Mississippian and into the lower middle Pennsylvanian in America. So far as is known, it has never been reported in the Permian of North America.

Examination of all the references to foreign Permian species listed under *Straparollus* in Branson (1948) indicates that all species are probably incorrectly referred to the subgenus. Most specimens figured apparently are either inner shell layers only or completely denuded steinkerns (see p. 218). Either of these possibilities would give a rounded whorl profile mimicking *Straparollus, sensu stricto*. Whorls close but out of contact in published illustrations has been taken to indicate loss of one or both shell layers.

Straparollus? discoides Wanner, *Straparollus? exornatus* Gortani, *Straparollus minimus* Stuckenberg, *Straparollus minutus* Koninck as figured by Gortani, and *Straparollus? oyensi* Wanner very probably should be excluded from the subgenus. They may belong within the superfamily Anomphalacea. Kittl's Triassic species *Straparollus ultimus*, 1891 (Kittl, 1891–1894, vol. 6, p. 63), is clearly referable to another superfamily, probably the Anomphalacea also.

Subgenus *Philoxene:* This subgenus seems to be restricted to the Devonian.

Subgenus *Serpulospira:* So far as is known, this subgenus ranges from Devonian to Pennsylvanian. However, *Phymatifer sumatrensis* Roemer from the Permian of Sumatra appears to be distinctly uncoiled. Another later figure of the species by Fliegel is that of a steinkern. It may be that Roemer exaggerated the amount of supposed uncoiling of his specimen. Better specimens are needed to prove this point.

Range of the Genus: As presently known, this genus ranges from the Silurian through the Permian.

Subgenus STRAPAROLLUS (EUOMPHALUS) Sowerby, 1814

Schizostoma Bronn, 1834, p. 95.
Phymatifer Koninck, 1881, p. 149.
Paromphalus Grabau, 1936, p. 301.

Type Species: *Euomphalus pentangulatus* Sowerby, 1814.

Diagnosis: Discoidal to low-spired gastropods with a distinct angulation on outer edge of upper whorl surface; spire depressed in juvenile stage, with one or more whorls rising above discoidal protoconch; outer edge of upper whorl surface marked by a more or less distinct angulation, thus giving a subelliptical whorl section; base slightly flattened; upper and basal angulations sometimes bearing sharp keels; some species with nodes on upper angulation, basal angulation, or both.

DISCUSSION: Knight (1934, p. 143) discussed the subgenus at some length and concluded that *Schizostoma* Bronn and *Phymatifer* Koninck are junior synonyms of *Euomphalus*. Study of the Permian species described herein gives no reason for the resurrecting of either of these synonymous generic names. Most foreign species of *Schizostoma* and *Phymatifer* listed in Branson (1948) are referable to *Euomphalus*. The lack of ornamentation readily separates *Euomphalus* from genera of similar shape such as *Poleumita* Clarke and Ruedemann.

The following foreign species of Permian age as listed in Branson (1948) probably should be included in the subgenus *Euomphalus:*

Euomphalus catillus cora as figured by Gortani
Euomphalus infratuberculatus Yakowlew
Euomphalus khmerianus Mansuy
Euomphalus mongolicus Grabau
Euomphalus nodocarinatus Wanner
Euomphalus nora Grabau
Euomphalus parvus Waagen, not Portlock
Euomphalus pernodosus as figured by White
Euomphalus (Phymatifer) pernodosus as figured by Fliegel
Euomphalus perversus (Orbigny)
Euomphalus planorbites Geinitz, not Münster
Euomphalus poshanensis Ozaki
Euomphalus variabilis Krotow
Phymatifer pernodosus as figured by Reed
Straparollus ammonitiformis Etheridge
Straparollus lachiensis Oakley
Straparollus laevigatus as figured by Gortani
Straparollus lutugini Yakowlew

The five species listed below are not referable to the Euomphalacea. They are all poorly illustrated and the biologic position is uncertain, although they may be placed tentatively in the Pleurotomariacea.

Euomphalus crotalostomiformis Wanner
Euomphalus? pavlovi Netschejew
Euomphalus permianus rossicus Netschejew
Euomphalus simuloides Grabau
Phymatifer coroniferus as figured by Gortani

AMERICAN PERMIAN SPECIES: Prior to this paper, four species of Permian *Euomphalus* had been recognized and named. *Straparollus cornudanus* Shumard is redescribed herein, as is *Euomphalaus kaibabensis* H. P. Chronic. *Euomphalus sulcifer* Girty and *Euomphalus sulcifer* variety *angulatus* Girty are considered to be representatives of the Omphalotrochidae and are redescribed in connection with other species in that family.

The few published references to Permian specimens referred to previously named Pennsylvanian species are noted in the synonymy of the appropriate Permian species. *Euomphalus* species *a* and *Euomphalus* species *b* described by Girty (1909b, pp. 104–105) from the Manzano group of New Mexico have been investigated. All of Girty's specimens examined are considered to be unrecognizable as to species.

RANGE OF THE SUBGENUS: As used here, *Euomphalus* is considered to range from Silurian to Permian. Kittl (1891–1894, vol. 6, pp. 59–63) has referred numerous species to *Euomphalus* from the upper Triassic gastropod fauna of the Saint Cassian beds in Austria. All his species seem to be representatives of the Euomphalacea, but they do not appear to be referable to *Straparollus* (*Euomphalus*). Haas (1953, pp. 31–32) has referred upper Triassic specimens from Peru to *Euomphalus* and *Phymatifer*, which again may be euomphaloids, but not *Euomphalus*. Jurassic species referred to the genus (Cossmann, 1915, 1918, no. 11, p. 328) have not been investigated.

STRAPAROLLUS (LEPTOMPHALUS)
YOCHELSON, NEW SUBGENUS

TYPE SPECIES: *Straparollus* (*Leptomphalus*) *micidus* Yochelson, new species.

DIAGNOSIS: Widely phaneromphalous, discoidal shells with angulation on upper whorl surface weakly developed or absent; spire depressed to the extent that shell is nearly bilaterally symmetrical in cross section; whorls smoothly rounded or with a weakly developed angulation on outer edge of upper whorl surface; basal angulation not developed, but some species with a slight flattening near base.

DISCUSSION: There are relatively few species of *Straparollus* that have the spire so depressed as to approach bilateral symmetry. As a group, they seem to be distinctive enough to be recognized as a separate subgenus. *Paromphalus* Grabau may have the characteristics noted above, but the genotype, the only species described, is not well known and is represented only by poorly preserved specimens (Grabau, 1936, p. 32). Until such time as *Paromphalus* is reinvestigated, it seems best to refer no additional species to the subgenus.

Because there is complete intergradation between *Leptomphalus* and *Euomphalus*, it has sometimes been difficult to assign those species not truly discoidal. In general, *Leptomphalus* has been used in the restricted sense diagnosed above, and only species nearly subcircular in whorl cross section have been referred to it.

FOREIGN PERMIAN SPECIES: The following species listed by Branson (1948) are referred to this subgenus:

Euomphalus discomphalus Dietz
Euomphalus kweitingensis Grabau
Euomphalus pusilliformis Wanner
Euomphalus pusilliformis weinensis Wanner
Euomphalus pusillus Waagen
Euomphalus rennstiengensis Dietz
Euomphalus subcircularis Mansuy
Euomphalus sundaicus Wanner

AMERICAN PERMIAN SPECIES: No previously described American species are known that are referable to this subgenus.

RANGE OF THE SUBGENUS: As nearly as can be determined, this subgenus is restricted to beds of middle Permian age.

GENUS AMPHISCAPHA KNIGHT, 1942

TYPE SPECIES: *Straparollus* (*Euomphalus*) *reedsi* Knight, 1934.

DIAGNOSIS: Discoidal gastropods with depressed spire and wide, very shallow umbilicus; outer margin of upper whorl surface bearing an erect keel; outer and basal whorl surfaces meeting to form a distinct angulation, with angle near 90 degrees, the angulation sometimes bearing a horizontal flange; umbilicus very widely phaneromphalous, the umbilical angle approaching 180 degrees in some species.

DISCUSSION: In discussion following the original diagnosis of *Amphiscapha*, Knight (1942, p. 488) suggested that it might best be regarded as a subgenus of *Straparollus*. Subsequently, he carried out this suggestion as to taxonomic placement (Knight, 1944, p. 465). The general shape of species referred to this genus is quite distinctive, however, and, according to the interpretation preferred here, *Amphiscapha* does not grade into *Straparollus* (*Euomphalus*). Interpretation of the concept of intergradation varies among workers in the field, and it is quite probable that others would reduce *Amphiscapha* to subgeneric rank. Such questions can be argued indefinitely, but more evidence on phylogenetic relations and ancestral forms is needed before any conclusions should be drawn.

The known species of *Amphiscapha* may be readily divided into two groups. The differences between these groups appear to be constant but are slight and are considered to be of minor importance. Consequently, the two groups are treated as subgenera, which are distinguished as follows:

Amphiscapha (*Amphiscapha*): Profile of outer whorl face gentle curved
Amphiscapha (*Cylicioscapha*): Profile of outer whorl face with a "stair step"

RANGE OF THE GENUS: In North America *Amphiscapha* has been described from beds as old as Desmoinsian. An undescribed species may occur in beds of late Mississippian, Chester age (Knight, oral communication). In the west Texas area, the genus has not been found above the lowest beds of the Bone Spring limestone. When the large bulk of etched rocks of Guadalupe age is considered, the absence of specimens suggests that *Amphiscapha* did not live beyond Leonard time.

SUBGENUS AMPHISCAPHA (AMPHISCAPHA) KNIGHT, 1942

TYPE SPECIES: *Straparollus* (*Euomphalus*) *reedsi* Knight, 1934.

DIAGNOSIS: Discoidal gastropods with outer whorl face regularly and smoothly arched; angulation of upper whorl surface commonly bearing a narrow sharp keel; profile of outer whorl face below keel gently arched, although the development of a thickening or flange on basal angulation may make the profile appear concave; base and side meeting in a sharp angulation with angle near 90 degrees, so that a whorl section is distinctly four sided; very widely phaneromphalous, umbilical angle approaching 180 degrees in some species, the umbilical walls slightly curved, if at all.

DISCUSSION: The regularly convex profile of the outer whorl face between the two angulations readily separates species of this subgenus from *Amphiscapha* (*Cylicioscapha*). None of the described species referred to the typical subgenus bears distinct nodes on the upper or lower keels, although in some species either or both of these keels may be rugose or even serrated. Spiral ornamentation is absent from all known species.

Most described species of this subgenus are known from only few strata, several named species being from beds of approximately the same age. Many of the described Pennsylvanian species are closely related. Indeed, preliminary examination of collections in the United States National Museum suggests that *Amphiscapha* (*Amphiscapha*) *catilloides* (Conrad) and *A.* (*A.*) *subrugosus* (Meek and Worthen) may intergrade, or may better be relegated to subspecific rank. Larger collections must be studied before this problem can be solved.

FOREIGN PERMIAN SPECIES: *Euomphalus bifurcatus* Toula from the lower (?) Permian of Barents Island is probably an *Amphiscapha, sensu stricto*. The description mentions the carina distinctive of the genus, although it is not clearly indicated in the illustrations. *Amphiscapha peruviana* has been described by B. J. Chronic (1949, p. 149) from the lower Permian, Copacabana group, of northern Peru. Examination of type specimens has convinced the present writer that this is an undoubted member of the subgenus.

Euomphalus (*Schizostoma*) *oldhami* Reed (1944, p. 346) from the middle Productus limestone of India may be referred to *A.* (*Amphiscapha*), although better figures of the species are needed to be certain. The outer whorl surface is flattened, and there appears to be a distinct, well-ornamented carina. The species as figured is sinistral; no other sinistral representatives of this subgenus, or of any of the Euomphalacea for that matter, are known. It may be that the illustration was inadvertently reproduced in reverse.

AMERICAN PERMIAN SPECIES: *Amphiscapha* (*Amphiscapha*) *muricata* (Knight) in the northern mid-continent area ranges from upper Pennsvylvanian strata through the lower Wolfcamp of the region. So far as is now known, it does not occur west of north central Texas. *Amphiscapha* (*Amphiscapha*) *subrugosa* (Knight) has been doubtfully identified in the *Uddenites* zone of west Texas (Knight, 1934, p. 159).

RANGE OF THE SUBGENUS: Species referable to *A.* (*Amphiscapha*) have been described from beds as old as early middle Pennsylvanian. A lower Permian species has been described from Peru, and others are described herein.

Among Triassic species examined, *Euomphalus cassianus* Koken (1889, p. 416) appears to have the general shape of an *Amphiscapha, sensu stricto*. However, the growth lines shown indicate a distinct protrusion of the outer lip towards the aperture. Another picture of the species by Kittl (1891–1894, vol. 6, pl. 4, fig. 23), in which the magnification is given, suggests that this species may be based on juvenile specimens. If this be the case, then the species could be referred to almost any genus of low-spired euomphaloid. Until specimens of *Euomphalus cassianus* can be studied to see if they actually do belong to this genus, it seems best to conclude that *A.* (*Amphiscapha*) does not range above the lower Permian.

AMPHISCAPHA (CYLICIOSCAPHA) YOCHELSON, NEW SUBGENUS

TYPE SPECIES: *Amphiscapha* (*Cylicioscapha*) *texana* Yochelson, new species.

DIAGNOSIS: Discoidal gastropods with distinct revolving shelf on outer whorl face; spire not depressed; protoconch discoidal; outer angulation of upper whorl surface bearing a keel or a row of nodes; upper portion of outer whorl face nearly vertical in mature stage, abruptly turning horizontal for a short distance and then returning to vertical, so as to form a distinct revolving shelf; widely phaneromphalous, umbilical walls commonly arched; outer lip opisthocline above shelf, prosocline below.

DISCUSSION: This subgenus is readily separated from *Amphiscapha, sensu stricto*, by the distinct break in the profile of the outer whorl face, so that it is "stair-stepped" rather than smoothly curved. Three of the four known species of this subgenus bear distinct nodes on the upper surface. These three species also have smaller umbilical angles than most described species of *Amphiscapha, sensu stricto*.

This shell form is so distinctive that, whether future workers follow the writer in considering *Amphiscapha* as a full genus or reduce it to subgeneric rank, *Cylicioscapha* would seem to require at least subgeneric rank, no matter where it is placed among the Euomphalidae.

The shelf in juvenile stages is on the upper whorl surface, and only later does it migrate downward. This shelf may have served to channel exhalant water. Probably this feature is homologous with the upper keel of *Amphiscapha* (*Amphiscapha*), with the upper keel of the mature *A.* (*Cylicioscapha*) being a new development.

Within this subgenus, there is one clearly defined evolutionary trend. The earliest known species, undescribed, has a smooth upper keel. *Amphiscapha* (*Cylicioscapha*) *subquadrata* (Meek and Worthen) has the upper keel either coarsely serrated or nodose, with poorly developed nodes. The genotypic species is intermediate between this shape and the Leonard species, which is characterized by well-developed nodes on the upper surface.

Although the profile of the outer whorl face is quite characteristic of this subgenus, it has been imitated rather closely by juveniles of *Straparollus* (*Euomphalus*) *cornudanus* (Shumard), which have been subjected to simple compression. This compression has resulted in the cracking of the outer whorl face and outward bulging. On first glance, this feature is quite deceiving and is another example of the results of compression on discoidal shells [see also discussion under *Straparollus* (*Euomphalus*) *cornudanus*].

Examination of the type specimens of *Straparollus* (*Euomphalus*) *subquadratus* Meek and Worthen show that this species is undoubtedly a representative of this subgenus, but the species was not chosen as genotype because the types contain marcasite, which is slowly oxidizing and is causing the specimens to disintegrate. The holotype is now unrecognizable, but measures have been undertaken to preserve the paratype.

Foreign Permian Species: The following Permian species, listed in Branson (1948) is considered to be a representative of this species:

Phymatifer fragilis Yin

American Permian Species: *Amphiscapha* (*Cylicioscapha*) *subquadrata* (Meek and Worthen) has been reported from Permian strata of the Midwest and West by several authors, but no illustrations of specimens have been published, and occurrences cannot be confirmed. Charles A. White (1891, p. 25) described, as this species, specimens from the Military Crossing of the Big Wichita River, Baylor County, Texas. His illustration is that of *Straparollus* (*Euomphalus*) *cornudanus*, but there are fragments of three specimens of *A.* (*Cylicioscapha*) *texana*, new species, along with the *Euomphalus* in his collection. Apparently, he discussed one species and inadvertently figured another.

Range of the Subgenus: The oldest known representatives of this subgenus is an undescribed species from the Bend group of Texas. The youngest species known is from the Bone Spring limestone of middle Permian age.

No Triassic species are known that are definitely referable to the subgenus. However, *Stuorella tofanae* Leonardi and Fiscon (1948, p. 46, pl. 1, figs. 9a–c), certainly referred to the wrong genus, bears some similarity to the subgenus in having an upper keel and distinct "break" in the outer whorl face. Better illustrations are needed before this possible similarity can be discussed further.

PLANOTECTUS Yochelson, new genus

Type Species: *Planotectus cymbellatus* Yochelson, new species.

Diagnosis: Discoidal shells with a prominent vertical keel at outer margin of upper whorl surface and a rounded basal whorl surface; upper whorl surface a gently convex curve, nearly horizontal except for pronounced keel at edge; upper whorl surface distinctly wider than base; juncture of outer and basal whorl surfaces rounded; moderately phaneromphalous; upper lip developing a shallow, broad sinus on upper whorl surface.

Discussion: At first glance this appears to be quite a bizarre genus with its prominent keel above and rounded whorls below. In detail, the gently convex upper whorl surface is quite similar to that found in the juvenile stages of *Straparollus* (*Euomphalus*) *noncarinatus*, new species. Growth lines of this genus also follow the general euomphalid pattern. For these reasons it is referred to this family.

FOREIGN PERMIAN SPECIES: With the possible exceptions of *Euomphalus klobukowsii* Mansuy and *Euomphalus rectangulus* Mansuy, both from the Permian of Indo-China, no previously described species are referable to this genus. These species are at best only tentatively referred to the genus.

RANGE OF THE GENUS: At present this genus is known from only one species seemingly confined to the middle Permian. It is unknown from the Triassic.

FAMILY **OMPHALOTROCHIDAE** KNIGHT, 1945

DIAGNOSIS: Discoidal to trochiform gastropods developing a sinus in upper part of outer lip; outer lip commonly extending as far forward at juncture of upper whorl surface and outer whorl face as at suture, some genera developing a distinct forward-projecting prong of outer lip near periphery; outer lip prosocline above and opisthocline below; basal surface somewhat flattened; narrowly to widely phaneromphalous; ornamentation commonly restricted to such simple features as carinae.

DISCUSSION: This family includes several diverse genera, but they are all bound together by the presence of a sinus in the upper part of the outer lip. The universality of this feature suggests that it is a reflection of soft parts having physiological importance. Analogy with the respiratory function of the pleurotomarian slit is suggested.

The Euomphalidae, probable ancestors of the Omphalotrochidae, are believed to have been dibranchiate. The Omphalotrochidae could have been dibranchiate or could have progressed to the extent of having lost one ctenidium. Knight (oral communication) suggests that the latter may have been the case. Alternatively, the presence of the sinus itself may be evidence in favor of a dibranchiate condition, but there seems little conclusive evidence for one view or another at this time.

The family Omphalotrochidae is first known in the Devonian where it is represented by *Orecopia* Knight. The general shape of this genus suggests to the present writer possible derivation from *Straparollus*, *sensu stricto*. Unfortunately, there are no other representatives of the family known until close to the Pennsylvanian-Permian boundary (Russian C_3 Zone), and thus it is impossible to construct any meaningful family phylogeny at this time.

GENUS **OMPHALOTROCHUS** MEEK, 1864

TYPE SPECIES: *Euomphalus* (*Omphalotrochus*) *whitneyi* Meek, 1864.

DESCRIPTION: Large, trochiform to pagodiform gastropods with a well-developed sinus in upper part of outer lip; pleural angle widening with changing ontogenetic stage; outer lip bearing a relatively deep but rounded sinus in upper part, having portion of outer lip below this sinus projecting forward; moderately phaneromphalous; whorl profile in many specimens modified variously by several ridges and angulations, quite complex in some species; growth lines commonly impressed in late mature and gerontic stages.

DISCUSSION: As here restricted, *Omphalotrochus* excludes younger related Permian species, which have been placed in the new genus *Babylonites*. *Omphalotrochus* is characterized by having part of the outer whorl face nearly vertical, so that a mature whorl section has four or more sides. In *Babylonites*, there is no true outer whorl face, and the whorl section is triangular in all stages. *Omphalotrochus* is more widely phaneromphalous than is *Babylonites*. There is also a minor difference in the extreme juvenile stage of the two genera in that the protoconch whorls of *Omphalotrochus obtusispira* are discoidal and rounded, while in those species of *Babylonites* in which this character is known, the protoconch is low spired with flattened whorls.

The following species listed by Branson (1948) under *Omphalotrochus* are clearly not representatives of the genus. They seem best referred to *Glyptospira* H. P. Chronic and related genera.

Polytropis wettrawiensis Dietz
Turbo helicinus Geitnitz
Turbo minutus Brown
Turbo taylorianus King
Turbo thompsonianus King
Possibly *Littorina tunstallensis* Howse

FOREIGN PERMIAN SPECIES: The following species, mostly listed in Branson (1948), are referred to *Omphalotrochus:*

Euomphalus canaliculatus Trautschold (1879, p. 61, pl. 7, fig. 16)
Omphalotrochus gerthi Wanner
Omphalotrochus kalitavaensis Licharew (1940, p. 303, figs. 1a–c)
Omphalotrochus whitneyi rossicus Licharew
Solarium antiquus d'Orbigny

AMERICAN PERMIAN SPECIES: In addition to the genotype, *Omphalotrochus whitneyi* (Meek), *Pleurotomaria obtusispira* Shumard has been referred to this genus by Girty (1937, p. 202). The fragmentary specimen (U.S.N.M. No. 21720) which White (1891, p. 25) described as *Euomphalus* species from the Military Crossing of the Big Wichita River, Baylor County, Texas, is also an *Omphalotrochus*. Which species it represents, however, cannot be determined until better specimens are found.

It should be emphasized just how closely related many of the named species are. Indeed the writer has grave doubt as to the validity of several of the foreign species, but, in the absence of specimens to study, he hesitates to place any species in synonymy. If the American species studied are considered a norm for the genus, there is considerably more individual variation within species than has heretofore been recognized. The remarkable geographic distribution of some species of *Omphalotrochus* has been noted (Yochelson, 1954, p. 234).

RANGE OF THE GENUS: *Omphalotrochus* has been reported from beds as old as Silurian, but the reports are based on a misunderstanding of the generic characters. The genus is known only from beds of early Permian age, except for two areas, which are presently classified by workers in those areas as uppermost upper Pennsylvanian (Yochelson, 1954, p. 233). To digress for a moment from objectivity regarding range, there seems to be no good reason for not considering a zone of *Omphalotrochus* as marking basal Permian in the same sense that a zone of *Properrinites* or *Pseudoschwagerina* is now considered lower Permian by many American stratigraphers. A similar suggestion was made several years ago by Knight (Knight and others, 1940, p. 1129).

BABYLONITES YOCHELSON, NEW GENUS

TYPE SPECIES: *Babylonites carinatus* Yochelson, new species.

DIAGNOSIS: Trochiform gastropods with distinctly triangular whorl section; protoconch discoidal to depressed, with flattened whorls; profile of upper whorl surface very gently arched; upper and basal whorl surfaces in contact so that whorl section is triangular; base gently rounded or flattened; umbilicus deeply and narrowly phaneromphalous, always with steep walls and a more or less sharp circumbilical ridge; outer lip developing a sinus on upper surface, the most forward extension of lip at periphery not projecting forward beyond point of contact with upper suture.

DISCUSSION: In addition to the differences listed above, the forward-projecting salient in the outer lip is relatively insignificant when compared to that of *Omphalotrochus*. Further, in *Babylonites* the pleural angle remains relatively constant rather than increasing with age as in *Omphalotrochus*. Another less important distinction between the two genera is size, specimens of *Babylonites* being commonly less than one-half of the size of average specimens of *Omphalotrochus*.

Babylonites appears to be most closely related to *Discotropis*, and juvenile specimens of the two genera cannot be readily separated. Crushed specimens frequently mimic species of *Discotropis*, and all specimens must be examined closely for cracks and other evidence of crushing before identification. The height of the spire is one of the more obvious distinctions between these two genera, *Babylonites* including the relatively high-spired shells, while *Discotropis* includes the discoidal ones.

FOREIGN PERMIAN SPECIES: *Omphalotrochus* (?) species A of Knight (1953, pp. 88–89, pl. 24F, figs. 26, 27) from near El Antimonio, Sonora, Mexico, is clearly a representative of this genus.

AMERICAN PERMIAN SPECIES: *Omphalotrochus ferrieri* Girty and *O. conoideus* Girty, both from the Phosphoria formation, are referred to this genus. It is possible that these two species are actually conspecific. The names have been considered synonymous by Knight (1944, p. 467), but an examination of Girty's types and several large collections from the Phosphoria seems to indicate that the two forms may be separate, with *B. ferrieri* being a species with wide limits of variation.

RANGE OF THE GENUS: As presently known, this genus is found in beds of Leonard and Word age in the Permian. No Triassic species are known.

DISCOTROPIS YOCHELSON, NEW GENUS

TYPE SPECIES: *Discotropis publicus* Yochelson, new species.

DIAGNOSIS: Discoidal gastropods with prominent, nearly horizontal shelf or flange on whorl side; protoconch discoidal, the whorls rounded on upper surface; upper whorl surface bearing a vertical carina or keel at outer edge; outer whorl face variable among species, but always having a nearly horizontal flange or shelf in mature stage; base of whorl varying from rounded to flattened; widely phaneromphalous; ornamentation lacking.

DISCUSSION: This genus is very closely related to *Babylonites*. The general shell shape and the nearly discoidal nucleus suggest that they arose from a common stock. Indeed, juvenile specimens of the two cannot be placed as to genus with any degree of assurance. The most readily observable distinction between the two genera is shape, *Discotropis* including the discoidal to low-spired shells of moderate size, while *Babylonites* includes the larger, trochiform shells. Further, no mature specimens of *Babylonites* bear the peripheral frill so characteristic of *Discotropis*. It is suggested that this difference between *Discotropis* and *Babylonites* may be of such magnitude as to rule out the use of subgeneric rank for the two forms.

FOREIGN PERMIAN SPECIES: *Euomphalus solariformis* Delpey and *Euomphalus turritus* Delpey, listed in Branson (1948), both from the Permian of French Indo-China, appear to have a flange or frill developed on the whorl side. They are tentatively referred here to *Discotropis*.

AMERICAN PERMIAN SPECIES: *Euomphalus sulcifer* Girty and *E. sulcifer* variety *angulatus* Girty are referable to *Discotropis* (see below, p. 242).

TRIASSIC SPECIES: *Euomphalus telleri* Kittl (1891, p. 226) from the upper Triassic Saint Cassian beds of Austria may possibly be a species of *Discotropis*. *Euomphalus dentatus* Münster, *E. biarmatus* Klipstein, and *E. venustus* Münster, all as illustrated by Kittl, may constitute another related genus of discoidal Omphalotrochidae.

RANGE OF THE GENUS: In addition to the Leonard and Word species, described herein, there appears to be still another species represented by three specimens from the top of the *Uddenites* zone. The youngest species tentatively referred to the genus is early late Triassic in age.

DIPLOCONULA YOCHELSON, NEW GENUS

TYPE SPECIES: *Diploconula biconvexa* Yochelson, new species.

DIAGNOSIS: Low-spired, rudely biconvex gastropods having a very poorly developed sinus in upper part of outer lip; protoconch not certainly known, but probably discoidal; upper and lower whorl surfaces very gently convex, their rather abrupt juncture forming an acute angle; outer lip forming an exceedingly shallow sinus in upper surface of shell; base narrowly and deeply phaneromphalous; ornamentation lacking.

DISCUSSION: This genus is most difficult to assign as to family. It does have some resemblances to the Anomphalacea, but the juncture of lip and suture is nearly orthocline rather than distinctly prosocline. The sinus in the upper part of the outer lip, which is so characteristic of the Omphalotrochidae, is weakly developed. When one combines the labral sinus with the evidence of the probably planispiral protoconch and the slight overhang of juvenile whorls, such as is seen in some species of *Babylonites* and *Omphalotrochus*, reference of this genus to the family seems as least plausible.

There appear to be no previously described Permian species that are referable to *Diploconula*. None are known from Pennsylvanian and Triassic strata.

RANGE OF THE GENUS: As presently known, this genus is restricted to beds of middle Permian age in the Glass Mountains, where it is represented by a single species.

SUPERFAMILY TROCHONEMATACEA ZITTEL, 1895

DIAGNOSIS: Trochiform gastropods without a slit in outer lip; upper whorl surface flattened in most genera; distinct angulation formed at juncture of upper and outer whorl surfaces, a channel being developed within the angulation; anomphalous to minutely phaneromphalous, some genera with a sharp circumumbilical ridge; upper lip prosocline from suture, straight or gently sinuate across upper surface, orthocline on outer whorl face; ornamentation, where present, consisting of revolving lirae.

DISCUSSION: Several middle Ordovician gastropods, particularly *Trochonema* Salter and *Loxoplocus* Fischer, are almost identical homeomorphs except for the lack of a slit in the former genus. Within the subgenus *Loxoplocus* (*Lophospira*) Whitfield, there is a complete gradation from species with a slit to those which have only a sharp peripheral sinus. The information available, mostly unpublished, concerning intermediate forms between *Lophospira* and *Trochonema* leads one to the conclusion that the Trochonematacea were derived from the pleurotomariacean stock, by gradual conversion of the anal slit to a shallow sinus or to a channel within an angulation, occupying the same relative position in the outer lip.

If one admits that the slit, sinus, and channel are homologous, it necessarily follows that the trochonematid stock must have virtually the same internal anatomy as that of the early pleurotomarians. It follows then that two ctenidia were present in the same general position as in the pleurotomarians, and almost certainly the angulation at the outer edge, which is in the position of the pleurotomarian slit, must have had a homologous anal function. To support this idea, there is a channel within this angulation.

The Trochonematacea reached their acme in the Ordovician. Since then, the superfamily is known only from scattered species, representing several genera. Trochonemataceans are not certainly known in the Mesozoic.

FAMILY **TROCHONEMATIDAE** ZITTEL, 1895

DIAGNOSIS: Family with the characteristics of the superfamily.

DISCUSSION: In addition to *Cyclites* Knight, two other Permian genera are recognized that are referred to this family. *Trachyspira* Gemmellaro is known from Sicily; *Cyclobathmus* Knight is known from eastern Europe, western Europe and north central Texas in the Guadalupe Whitehorse sandstone. Neither of these genera has been observed in collections from west Texas and farther west. Properly speaking, *Cyclobathmus* should be treated here, but inasmuch as no additional specimens other than those examined by Knight (1940) are known, redescription does not seem warranted.

Trochonema cambodgensis Delpey, from the Permian of French Indo-China, may be a representative of this family; the illustrations and descriptions are not clear on several points. In any case, the species is certainly not a *Trochonema*.

GENUS **CYCLITES** KNIGHT, 1940

TYPE SPECIES: *Pleurotomaria multilineata* Girty, 1909 (= *Wortheniopsis depressa* Beede, 1907).

DIAGNOSIS: Low-spired, shouldered gastropods with orthocline outer lip; upper whorl surface flattened, ramp-like; profile of outer whorl face nearly vertical; minutely phaneromphalous; upper lip gently prosocline across upper whorl surface, orthocline on outer whorl face; columellar lip straight and without an inductura; ornamentation consisting of numerous revolving threads.

DISCUSSION: The absence of an apertural slit readily differentiates *Cyclites* from pleurotomarian genera of similar shape. The low subquadrate shape of this genus combined with the revolving threads distinguishes it from other Permian genera. The two closest related forms, *Cyclobathmus* Knight and *Trachyspira* Gemmellaro, are among other features, both higher spired than *Cyclites*.

FOREIGN PERMIAN SPECIES: No species referable to this genus are known.

AMERICAN PERMIAN SPECIES: *Pleurotomaria multilineata* Girty, and *Wortheniopsis? depressa* Beede, are referred to this genus. Knight (1940, pp. 310–312) has considered these two names to be synonymous. A re-examination of the types of each species by the present writer has convinced him that Knight is correct.

RANGE OF THE GENUS: As presently known, *Cyclites* is limited to the Permian Guadalupe series. There may be Triassic species referable to the genus, but, because identification of many of the trochonematid genera depends on the shape of the aperture, one hesitates to refer species to the genus from illustrations, which often do not show important details.

Superfamily PSEUDOPHORACEA Miller, 1889

Diagnosis: Trochiform gastropods with acute periphery; upper whorl surface flattened and basal whorl surface concave to flattened, joining or within a more or less sharp periphery, so that cross section of most genera is distinctly triangular; sutures shallow; upper lip prosocline; ornament not prominent.

Discussion: This superfamily as here interpreted consists of two families. One family, the Planitrochidae, contains six genera, which are low spired and do not develop a peripheral frill. This family is confined to the Ordovician and Silurian and is not treated further.

The origin of this superfamily is uncertain. *Raphistomina* Ulrich and Scofield, a pseudophoracean genus first appearing in the Ordovician, is quite similar to several primitive pleurotomarian genera. Because of this, derivation of the Pseudophoracea directly from the Pleurotomariacea is tentatively suggested.

Family PSEUDOPHORIDAE Miller, 1889

Diagnosis: Upper whorl face of genera extended in a frill covering base, in some cases the frill being interrupted to form spines; basal whorl surface flattened and covered by frill; upper lip of most genera strongly prosocline from suture to sharp periphery; ornamentation consisting most commonly of fine lirae on upper and basal whorl faces.

Discussion: Most genera referred to the family occur only in the Silurian, and several of these genera are known only from the type species, which in turn are represented only by the type lot of specimens. Construction of any phylogeny would be most difficult and should be deferred until better specimens of these genera have been described. In so far as this study is concerned, however, there seems to be no doubt that *Sallya*, new genus, in the Permian, was derived almost directly from *Pseudophorus* Meek, known from Silurian to Devonian.

No Triassic species referable to this family are known.

SALLYA Yochelson, new genus

Type Species: *Sallya linsa* Yochelson, new species.

Diagnosis: Conical gastropods with base concealed by a short frill; protoconch unknown; moderately high spired, the pleural angle expanding in gerontic stage of some species; sutures not impressed, inconspicuous; profile of upper whorl surface commonly straight, but some species characterized by slope markedly concave outward; periphery bearing a short frill extending downward below the level of the base; narrowly phaneromphalous without any kind of structure within the umbilicus; most species bearing lirae on base.

Discussion: This genus is similar in shape to *Eotrochus* Whitfield but lacks the flange-like growth on the columellar lip characteristic of that genus. It is less readily separated from *Pseudophorus* Meek, but seems to have a higher spire (smaller pleural angle) and possibly a shorter frill than that genus.

Foreign Permian Species: *Flemingella gigas* (Grabau) and *Flemingella tepeeformis* (Grabau), both from the Permian Jusu Honguer limestone of Mongolia, and *Trochus? anthracophilus* Roemer from the Permian of Sumatra, all as listed in Branson (1948), may be representatives of this genus. On the other hand, it seems more probable that they should be referred to the pleurotomarian genus *Euconospira* Ulrich. In each case, illustrations of specimens are so poor that the generic placement of the species cannot be determined.

American Permian Species: *Eotrochus? liratus* H. P. Chronic (1952, pp. 129–130), described from the Kaibab formation, is clearly a member of this genus.

Range of the Genus: As presently known, this genus is restricted to the Permian. Representatives of Pseudophoridae have been reported from the Mississippian of North America, but not as yet from the Pennsylvanian.

Superfamily ANOMPHALACEA Wenz, 1938

Diagnosis: Smooth, rotelliform gastropods with upper lip commonly prosocline; protoconch simple; shell characteristically low spired with rounded whorls, the body whorl deeply embracing penultimate whorl; narrowly phaneromphalous to cryptomphalous; upper lip prosocline without sinus or slit; surface smooth with faint growth lines.

DISCUSSION: Derivation of this superfamily is unknown, except that it undoubtedly arose from the pleurotomarian stock or from one of its offshoots. The presence of a channel in the parietal angle with none in the outer lip suggests most strongly that this group had evolved to the stage of loss of the right gill.

Genera referred to the Anomphalacea are most abundant in the Silurian. Probably this is a "monographic burst" (Cooper and Williams, 1952, p. 330) as the result of the work of Perner (1907, 1911). Perner's work has had similar effect on the distribution in time of genera of the Pseudophoracea.

FAMILY **ANOMPHALIDAE** WENZ, 1938

DIAGNOSIS: Family with the characteristics of the superfamily.

DISCUSSION: In addition to *Anomphalus* Meek and Worthen, two other genera doubtfully referred to Permian Anomphalidae are known. They are discussed briefly below.

Eiselia Dietz, from the Zechstein of Germany, is a poorly known genus. In fact, only the type specimen of the genotype species is known and that is lost (Knight, 1942, p. 109). For this reason, it seems best to restrict this genus to the type species. In any case, no forms resembling *Eiselia* have been observed in the Permian collections studied.

Sosiolytes Gemmellaro, from the Permian of Sicily, on the other hand, is a most distinct genus, being higher spired than other genera in the family. It lacks many typical anomphalid characters but seems to have more in common with the family than with genera referred to other families. The genus has not been reported outside Europe and has not been identified in the collections studied.

GENUS **ANOMPHALUS** MEEK AND WORTHEN, 1867

Antirotella COSSMANN, 1918, p. 79.

TYPE SPECIES: *Anomphalous rotulus* Meek and Worthen, 1867.

DIAGNOSIS: Smooth, rotelliform gastropods with rounded whorls embracing high on the shell; sutures shallow; basal whorl surface somewhat flattened; outer lip prosocline; umbilical condition varying from phaneromphalous to cryptomphalous; ornamentation, other than growth lines, lacking.

DISCUSSION: This genus and some of its allies were discussed in great detail by Knight (1933, pp. 41–45). Generic synonomy was subsequently revised (Knight, 1944, p. 471), and Knight's revision is followed here.

FOREIGN PERMIAN SPECIES: Recognition of species of this genus in the literature is difficult. In the Permian of west Texas there is an as yet unnamed, smooth, very low-spired pleurotomarian allied to *Colpites* Knight. Through convergence by simplification, this genus resembles *Anomphalus* and is extremely difficult to separate from it. Most illustrations of unornamented, low-spired, small gastropods listed in Branson (1948) are thought to be of species referred to this undescribed genus, but some of these may conceivably be *Anomphalus.*

Anomphalus minutus Grabau and *Anomphalus sundicus* Wanner, both as listed by Branson (1948), are not representatives of this genus. The former may be a microdomatacean and the latter is probably a platyceratid.

AMERICAN PERMIAN SPECIES: So far as is known no species previously described from the Permian of the United States are referable to this genus.

RANGE OF THE GENUS: As understood and diagnosed here, *Anomphalus* is considered to range from middle Devonian to lower Permian.

Haas (1953, pp. 78–80) has described three species from the upper Triassic of Peru, which he refers to *Anomphalus.* The two species that are described by him as new seem to be euomphalids of some sort rather than anomphalids. The third species, *Rotella helicoides* Münster, as figured by him and by Kittl (1891–1894, vol. 6, p. 242, pl. 6, figs. 1–3), may be a new genus referable to the pleurotomarians.

SUPERFAMILY **CRASPEDOSTOMATACEA** WENZ, 1938

DIAGNOSIS: Low-spired to high-spired gastropods commonly with an expanded aperture in mature or gerontic stage; sutures distinct; outer whorl face rounded; minutely to widely phaneromphalous; aperture orthocline to prosocline, thickened and expanded in mature or gerontic stage of some genera; transverse ornamentation most common.

DISCUSSION: This superfamily is most difficult to diagnose and is believed to be more artificial than others discussed in this paper. It includes the Craspedostomatidae, and three genera questionably joined in the family Codonocheilidae Miller, 1889 (Knight, Batten, and Yochelson, MS). These genera, *Codonocheilus* Whiteaves, *Dihelice* Schmidt, and *Scoliostoma* Braun, are all moderately high spired with twisted or expanded apertures. Probably they do not form a phylogenetic group, but they are so abnormal that placement of them in any other superfamily would be equally distressing. The family Codonocheilidae is confined to the Silurian and Devonian and is not discussed further.

FAMILY **CRASPEDOSTOMATIDAE** WENZ, 1938

DIAGNOSIS: Rotelliform to discoidal gastropods with nearly orthocline aperture; whorls commonly rounded; umbilicus narrowly to widely phaneromphalous; aperture nearly orthocline from suture to umbilicus; expanded in gerontic stage of some genera; ornamentation consisting of strong growth lines which in some genera reach the proportion of ribs.

DISCUSSION: This family includes at least three groups of genera treated here as the subfamilies Craspedostomatinae Wenz, 1938, Brochidinae, new subfamily and Dichostasinae, new subfamily. They have in common the occurrence of a thickened or expanded aperture in several of the genera. Again, this feature may be due to convergence and may not have any phylogenetic significance. Most of the Craspedostomatidae are poorly known monotypic genera, and when more specimens are found and described, the interrelations of the genera should be reëxamined.

The subfamily Craspedostomatinae is believed to be the most natural of the three subfamilies. It includes *Bucanospira* Ulrich, *Craspedostoma* Lindström, *Spirina* Kayser, and *Umbonellina* Koken. All genera are low spired and are characterized by an expanded aperture; all except the last bear relatively fine transverse ornamentation. The subfamily is confined to the Ordovician and Silurian and is not discussed further.

BROCHIDINAE YOCHELSON, NEW SUBFAMILY

DIAGNOSIS: Low-spired to depressed, discoidal gastropods with prominent transverse ribs; sutures distinct, deep; outer whorl surface well rounded; ornamentation consisting of numerous closely spaced, distinct, transverse ribs running from upper to basal suture.

DISCUSSION: The prominent transverse ribs formed by periodic thickening of the aperture are the most distinctive feature of this group. Two genera, *Temnospira* Perner and *Brochidium* Koken, are much lower spired than *Natiria* Phillips, the third member of the subfamily. It is through this last genus that the subfamily may be related to the Craspedostomatinae. The mature aperture of *Natiria* is not known, but that of the other two genera is thickened, and its exterior diameter is consequently expanded.

GENUS **BROCHIDIUM** KOKEN, 1889

TYPE SPECIES: *Ceratites cingulatum* Münster, 1841.

DIAGNOSIS: Small gastropods with numerous transverse ribs; protoconch smooth; shell exceedingly low spired, with several doubtfully referred species being higher spired; upper and basal sutures strongly impressed; outer and basal whorl surfaces well rounded; phaneromphalous in all growth stages; outer lip prosocline; aperture thickening at relatively short intervals so that numerous ridges protrude from general surface of shell.

DISCUSSION: The numerous transverse ribs make *Brochidium* a distinctive and easily identified genus. The genus is most similar to *Temnospira* Perner but seems to differ in having the transverse ribs more strongly developed. So far as it is known, *Brochidium* has never before been reported from the Paleozoic.

Wenz (1938, p. 198) notes that the species cited above as type was subsequently designated type by Cossmann (1915, 1918, no. 10, p. 137). The literature has not been examined for possible earlier citations. In passing, it might be noted that neither a redescription of *Ceratites cingulatum* (Koken, 1889, p. 434) nor its designation as a genotype is recorded in the Zoological Record.

RANGE OF THE GENUS: The species described herein extend the range of this genus downward into the Permian. *Brochidium* is well known in the Triassic, both from Europe and from South America. An undescribed species is known from the Triassic of Idaho. Lower Jurassic reports of its occurrence have not been investigated.

DICHOSTASINAE YOCHELSON, NEW SUBFAMILY

DIAGNOSIS: Low-spired gastropods with short transverse ridges on upper whorl surface; lower portion of outer whorl face and basal whorl surfaces well rounded; ornamentation consisting of thick, short, transverse ridges on upper whorl surface; aperture of genotypic species thickened.

DISCUSSION: This monobasic subfamily appears to have little in common with the other two subfamilies of the family except for the presence of the thickened aperture in one species. Either to raise the subfamily to higher taxonomic rank or to remove *Dichostasia* to another superfamily, however, is a move the author is not prepared to justify, and for the time being the subfamily is included in the Craspedostomatidae for want of a better resting place.

DICHOSTASIA YOCHELSON, NEW GENUS

TYPE SPECIES: *Dichostasia complex* Yochelson, new species.

DIAGNOSIS: Small, low-spired gastropods with short, coarse, rounded, transverse ridges on upper whorl surface; protoconch discoidal to slightly depressed, unornamented; sutures distinct, faintly impressed; upper whorl surface gently arched from near suture to near outer edge of upper surface; phaneromphalous in all growth stages; outer lip orthocline or gently prosocline; ornamentation consisting of rounded, relatively thick, transverse ridges on upper whorl surface and in some species one or more revolving costae on side of whorl.

DISCUSSION: This genus is readily separated from all other Permian genera known, by its characteristic low-spired shape and its ornamentation. As noted above, it does not appear to be closely related to any of the Permian genera. The genus is most similar to *Brochidium* in having a more or less uniform number of ribs on each whorl, but the ribs themselves are quite different in the two genera.

No described American or foreign species have been found in the Permian and Triassic literature examined that appear to be referable to this genus.

RANGE OF THE GENUS: As now known, this genus is restricted to the lower and middle Permian. *Euomphalus dentatus* Münster from the upper Triassic Saint Cassian beds, as figured by Kittl (1891–1894, vol. 6, pl. 4, figs. 17–19), bears a superficial resemblance to *Dichostasia*, but the aperture of that species is quite different, inasmuch as it lacks a pronounced thickening.

SUPERFAMILY PLATYCERATACEA HALL, 1859

DIAGNOSIS: Trochiform to capuliform gastropods characteristically irregular to a greater or lesser extent; most genera exhibiting irregularity in coiling, some being partly or totally uncoiled; apertural margin variable, with adventitious sinuses developed.

DISCUSSION: Bowsher (1955) has recently discussed the early phylogeny of this superfamily. He has traced it from *Naticonema* Perner through the various steps to the typical smooth *Platyceras*. In a general way the superfamily shows a trend towards loss of ornamentation through time. The smooth, unornamented specimens naturally are more difficult to classify than are those that are ornamented. Many modifications of the shell are believed to indicate a coprophagous habit. Although there is no direct indication of the number of ctenidia, by analogy with other prosobranchs that show no evidence of paired ctenidia, it seems reasonable that this superfamily had but a single ctenidium.

One unique Permian specimen preserves muscle scars (pl. 23, figs. 25 and 26). The scars are deeply pitted on the "columellar" side and continue as a relatively wide band around at least half of the circumference where they finally seem to die out. The specimen is only partly coiled and measures over 50 cm. from apex to aperture; probably the preservation of the muscle scars is a result of the large size of the living animal.

Once the occurrence of a muscle scar was established, a similar horseshoe-shaped groove was observed in several smaller completely uncoiled specimens (pl. 23, fig. 30).

Meek and Worthen (1868, p. 457, pl. 14, figs. 4a–c) have described and figured a steinkern of *Platyceras* (*Orthonychia?*) *subplicatum* from the Waverly of Ohio, which shows a horseshoe-shaped muscle scar. Knight (1934, p. 136) interprets this scar as two pits connected by a band. This would suggest paired muscles such as characterize the living Neritacea. The scars of the Permian specimens illustrated and others unfigured appear to represent a single muscle. It seems probable that only a single muscle characterized Mississippian platyceratids also.

The horseshoe-shaped muscle scar is common to many gastropods with cap-shaped shells (Yonge, 1953, p. 18). These gastropods are phylogenetically quite distinct, but ecologically related in that they all are clinging forms, varying from sedentary to being entirely incapable of movement in the adult stage. The Permian platycerataceans were almost certainly clingers as shown by numerous occurrences of older representatives on the superfamily of echinoderms (Bowsher, 1955, and others). The development of the horseshoe muscle coupled with uncoiling to produce a high cap-like shell gives an indication of just how closely they were adapted to the clinging habit.

Family **PLATYCERATIDAE** Hall, 1859

Diagnosis: With the characters of the superfamily.

Discussion: The irregularity in aperture and in coiling of the included genera is believed to be due to a coprophagous habit. Some of the more primitive species are relatively regular, as in *Cyclonema;* others are exceedingly irregular as in the Permian species of *Orthonychia* described herein. The irregularities of post-Ordovician species is commonly so marked that, lacking ornamentational clues, it is difficult to see just what are significant specific or even generic characters.

The large degree of individual variation shown in the Permian specimens suggests that workers previous to Bowsher (1955) have underestimated the influence of the substrate and the position of the gastropod on the echinoderm host in modification of the gastropod form. The many generic and specific names will probably be drastically reduced in number on critical restudy of this family.

Genus **PLATYCERAS** Conrad, 1840

Type Species: *Pileopsis vetusta* J. de C. Sowerby, 1829.

Description: Naticiform to capuliform, smooth or weakly ornamented gastropods, the protoconch varying from orthostrophic to vermiform and uncoiled; aperture more or less regular to irregular among individuals but without pronounced modification of the columellar lip; ornamentation, growth lines faintly impressed or, rarely, fine spiral lirae.

Discussion: *Platyceras* is comparable to *Straparollus* Montfort in that many of the species cluster around several shell forms. These shell forms are conveniently recognized as subgenera and are discriminated as follows:

Visitator Perner: Relatively high spired, outer whorl face flattened. The names *Saffordella* Dunbar, *Distemnostoma* Dunbar, and *Aulopea* Dunbar are junior synonyms

Platyostoma Conrad: Naticiform, outer whorl face well rounded

Tubomphalus Perner: Low spired, mature body whorl free

Praenatica Perner: Extremely low spired, widely explanate whorls, including *Prosigaretus* Perner

Platyceras Conrad: Protoconch tightly coiled, juvenile whorls in contact, body whorl uncoiled, including *Actita* Fahrenkohl and *Exogyroceras* Meek and Worthen

Orthonychia Hall: Protoconch vermiform, shell not coiled, commonly irregular, including *Igoceras* Hall, *Palaeocapulus* Grabau and Shimer, and *Geronticeras* Grabau

Further study may show that some of these forms are distinct enough to be regarded as separate genera.

Range of the Genus: The several subgenera of the genus outlined above extend the range of *Platyceras* from the Silurian to the Permian. The extinction of *Platyceras* may have been contemporaneous with the extinction of the camerate and inadunate crinoids (Bowsher, 1955, p. 9).

SUBGENUS **ORTHONYCHIA** HALL, 1843

Igoceras HALL, 1860, p. 330.

Palaeocapulus GRABAU AND SHIMER, 1909, p. 686.

Geronticeras GRABAU, 1936, p. 312.

TYPE SPECIES: *Platyceras (Orthonychia) subrecta* Hall.

DIAGNOSIS: Horn-shaped, twisted to incompletely coiled gastropods; in some species, perhaps all, protoconch vermiform followed by a rapid expansion of shell; apertural margin thickened slightly, if at all, oval to irregular; ornamentation lacking or fine longitudinal lirae.

DISCUSSION: This subgenus is separated from other subgenera of the genus in having all whorls out of coiled contact. It differs from other subgenera in lacking ornamentation. Actually the relationships between the subgenus *Platyceras* and *Orthonychia* are probably much more complex than would be inferred from the first sentence of this discussion. Assuming that *Platyceras* in the broad sense represents a phyletic line and not the end products of several lines, one still faces considerable problems in attempting to divide this group. Of the subgenera noted previously, *Orthonychia* and *Platyceras, sensu stricto*, are most difficult to separate.

Igoceras Hall is an uncoiled, nearly tube-like form, quite similar to the type species of *Orthonychia*. Certainly they are congeneric, if not conspecific; Knight (1944, p. 473) referred *Igoceras* to the synonymy of *Orthonychia*. *Palaeocapulus* Grabau and Shimer, on the other hand, is rapidly expanding, nearly bilaterally symmetrical and partially but openly coiled. If one places emphasis on the early ontogeny, then *Palaeocapulus* must go into the synonymy of *Orthonychia;* Knight (1941, pp. 278; 1944, p. 473) has followed this course.

Geronticeras from the Permian of China is described in part (Grabau, 1936, p. 312) as follows: "shells [that] have entirely lost the power of coiling though a partial but very loose enrolling of the apical (early) portion is maintained.... Neither transverse ribs nor the remains of spirals are known and spines are likewise absent." Illustrations of the genotype agree with this description, and the conclusion seems unescapable that this also is a subjective synonym of *Orthonychia*.

The original description of *Geronticeras* is followed by a description of three species, *G. latum*, *G. separatum*, and *G. dubium*, each based on a single specimen. All three "species" find parallels in the west Texas collection. Knight (1941, p. 129) suggested that the name *Geronticeras* was a synonym of *Platyceras* in the broad sense and subsequently placed it under *Orthonychia* (Knight, 1944, p. 473).

Actually the Permian specimens studied, being partially coiled, are almost perfectly intermediate between the type species of *Platyceras* and the type of *Orthonychia*. It seems better to expand *Orthonychia* to include both tube-like and more normally expanding horn-like forms than to name still another subgenus. Further study of other Paleozoic platyceratids may show that tendency to coil is a significant feature.

In the past most species of smooth platyceratids have been based on single or few individuals, "species" being recognized on characters which are now thought to be influenced exclusively by the substrate. In some cases splitting has been extreme. To cite a classic example from the Permian, C. Wanner (1922) named 11 new species, recognized four unnamed species, two unnamed varieties of his new species, and two earlier named species from 26 specimens, 12 of these groups being represented at one locality. Subsequently, in studying much larger collections, he (C. Wanner, 1942, pp. 192–196) recognized nine of his species and *Capulus wanneri* Hamlet from the same beds to be growth forms of one species. At the same time he introduced the use of trinomials for these growth forms.

The treatment of the western Texas platyceratids is based on the premise that most of the variations seen are growth forms. This procedure may be over-cautious, but until there is a clearer concept of what characters, if any, are of specific nature in this group, it seems best not to introduce numerous formal names. It seems almost superfluous to suggest that pre-Permian platyceratid species are also badly in need of a revision based on the study of large populations.

Within the large Permian collections studied, there are two specimens that are well coiled for at least one whorl. One must then either extend the range of *Platyceras* from the Mississippian, where it is well known, or assume that some peculiarity of attachment caused these two specimens to coil. The latter explanation is preferred.

FOREIGN PERMIAN SPECIES: Without commitment as to status as species, the following Permian forms listed by Branson (1948) appear to be referable to *Orthonychia:*

Capulus complicatus Wanner
Capulus dalpiazi Greco
Capulus fucinii Greco
Capulus laevis Toula
Capulus sosiensis Greco
Capulus varians Wanner
Capulus varians abundans Wanner
Capulus varians latus Wanner
Capulus varians pretiosus Wanner
Capulus varians sundaicus Wanner
Capulus varians tortus Wanner
Palaeocapulus permianus Grabau
Pileopsis ? alta Dana
Pileopsis ? tenella Dana
Platyceras cornu-capella Etheridge
Platyceras gracile Mansuy
Platyceras khammonense Mansuy
Platyceras producti Frech
Platyceras ungula Etheridge
Platyceras? wanneri (Delpey)

Strophostylus indicus (Waagen) and *Capulus minimus* Toula are not platyceratids, but superficially resemble *Holopea* Hall. *Strophostylus sargalensis* Reed (1944, p. 345) is unrecognizable as anything other than the steinkern of a coiled gastropod. *Platyceras* (*Orthonychia*) *permocarbonaricus* (Stuckenberg) is somewhat unique in that it appears to be coiled for the first several whorls. Should the subgenus *Platyceras, sensu stricto*, be recognized in the Permian, then Stuckenberg's species is more properly referred to it.

AMERICAN PERMIAN SPECIES: As near as can be determined, there has been only one report of Permian platyceratids in the United States. Knight (1953, p. 90), in describing an *Orthonychia* species from El Antimonio, Mexico, notes the occurrence of many specimens in the Leonard and Word formations of the Glass Mountains.

RANGE OF THE SUBGENUS: The type species of *Orthonychia* occurs in the lower Devonian, and specimens that may tentatively be referred to the subgenus have been reported from the Silurian. As treated here, *Orthonychia* ranges at least into the Word epoch of the Permian.

DESCRIPTION OF SPECIES

SUPERFAMILY EUOMPHALACEA KONINCK, 1881

FAMILY EUOMPHALIDAE KONINCK, 1881

GENUS STRAPAROLLUS MONTFORT, 1810

SUBGENUS EUOMPHALUS SOWERBY, 1814

Straparollus (Euomphalus) pernodosus Meek and Worthen

Plate 9, figures 1, 2

Straparollus (*Euomphalus*) *pernodosus* MEEK AND WORTHEN, 1870, p. 45; 1873, p. 604, pl. 29, fig. 14.

Non Euomphalus pernodosus White, 1877, p. 158, pl. 12, figs. 2a–b. *Non Euomphalus pernodosus* Reagen, 1904, p. 243, pl., figs. 14a–14e.

Non Euomphalus (*Phymatifer*) *pernodosus* Reed, 1925, p. 64, pl. 10, fig. 1.

DESCRIPTION: Discoidal gastropods with distinct nodes along basal angulation and none on upper keel; protoconch unknown; upper whorl surface not certainly known, but seemingly rising gradually from suture to near edge, then turning abruptly upward to form a distinct, broad upper keel, this keel being somewhat rugose but without nodes, outer whorl face seemingly bulging gently near mid-whorl and then curving in very slightly to a broad basal angulation, below which shoulder bending sharply inward and gradually upward to the umbilicus; widely phaneromphalous, umbilical angle near 110 degrees; upper lip opisthocline, forming a 70-degree angle with upper keel; outer lip prosocline, inclined backward 30 degrees from vertical, near basal angulation steepening slightly towards vertical; basal lip bending back parasigmoidally at inner edge of angulation and finally proceeding prosocline into umbilicus; ornamentation, prominent, regularly spaced nodes on basal angulation, the nodes decreasing in relative height, compared to total width of shell, towards the body whorl.

MEASUREMENTS: The estimated measurements of the holotype of *Straparollus* (*Euomphalus*) *pernodosus* Meek and Worthen are: height, 20 mm.; width, 55 mm.

DISCUSSION: The description given above is based on an examination of the holotype (I.G.S. No. 2867). No paratypes are known, and presumably this specimen is the only one that was available to Meek and Worthen.

The middle Pennsylvanian species is included here in a study of Permian *Euomphalus*, because there has been considerable uncertainty as to just what this species included, several authors having incorrectly identified it as occurring in the Permian. Also, it is the only American Pennsylvanian species of *Euomphalus* known not illustrated and discussed by Knight (1934).

Study of Pennsylvanian species suggests some similarity between *Straparollus* (*E.*) *plummeri* Knight and *S.* (*E.*) *pernodosus* Meek and Worthen. One distinction between these two appears to be the presence of nodes on the basal angulation of the latter species. *Straparollus* (*Euomphalus*) *serratus* Knight may doubtfully be associated with *S.* (*E.*) *pernodosus*. It is probably from this group of species that *S.* (*E.*) *cornudanus* (Shumard) arose in the lower Permian, and this species in turn gave rise to *S.* (*E.*) *kaibabensis* (H. P. Chronic) in the middle Permian.

HYPODIGM: A single mashed and distorted specimen. Most references to this species in the Pennsylvanian literature of North America do not include illustrations, and the several authors may not have been dealing with this species.

OCCURRENCE: Lower coal measures, Alton, Illinois. Dr. Charles Collinson (written communication) suggests that the lithology of the specimen may be that of the bituminous shale overlying Colchester (no. 2) coal of the Carbondale formation.

NUMBERED SPECIMEN: Holotype, I.G.S. No. 2867.

Straparollus (Euomphalus) cornudanus
(Shumard)

Plate 9, figures 3–8; plate 10, figures 1–8

Straparollus cornudanus SHUMARD, 1859, pp. 400–401.

Euomphalus subquadratus Meek and Worthen, WHITE, 1891, pl. 3, fig. 9, not p. 25.

DESCRIPTION: Discoidal gastropods without distinct abundant nodes on upper angulation; upper sutures distinct, not impressed except in gerontic stage; upper whorl surface rising outward from suture to upper angulation, following a curve gently concave outward at an angle of 15 degrees to 20 degrees from the horizontal, the angle of slope flattening with age, upper angulation bearing an indistinct keel, which is commonly irregularly serrated, rarely regularly crenulated for part of a mature whorl, outer edge of keel and upper one-sixth of outer whorl face inclined outward 15 degrees from vertical, the remainder being a moderately well-rounded convex curve with the periphery being just above mid-whorl, the outer whorl face curving rather sharply into a broad, well-rounded, nodose lower shoulder, basal whorl surface flattened, turning upward towards vertical just before reaching umbilical sutures; widely phaneromphalous, umbilical angle approaching 120 degrees; outer lip nearly orthocline from suture to upper shoulder except in gerontic stage where there is development of a shallow sinus near edge, corresponding with reduction of keel, outer lip opisthocline 10 degrees to 20 degrees from the vertical for one-fourth of distance down outer whorl face below which point bending prosocline 15 degrees from vertical and continuing downward at this inclination, basal lip prosocline into umbilicus following a curve gently concave forward, the curve becoming more pronounced near basal suture; ornamentation consisting of regularly spaced nodes on basal shoulder, the nodes becoming smaller with age and disappearing on the gerontic body whorl, and irregular crenulations or serrations of the upper keel, these crenulations being most pronounced in the mature stage.

DISCUSSION: The regularly spaced nodes on the basal angulation separate this species from all other American Pennsylvanian and Permian *Euomphalus* except *Straparollus* (*Euomphalus*) *pernodosus* Meek and Worthen, *S.* (*E.*) *serratus* Knight, and *S.* (*E.*) *kaibabensis* (H. P. Chronic). *Straparollus* (*E.*) *cornudanus* differs from *S.* (*E.*) *pernodosus* in having the upper lip nearly orthocline rather than strongly prosocline. Other possible differences are masked by the poor preservation of the only known specimen of *S.* (*E.*) *pernodosus*. *Straparollus* (*E.*) *cornudanus* seemingly is higher spired than *S.* (*E.*)

TABLE 2

MEASUREMENTS (IN MILLIMETERS) OF *Straparollus* (*Euomphalus*) *cornudanus* (SHUMARD)

	Height	Width	H.A.	W.A.	V.	Locality
Figured hypotype	5.7	15.8	6.0	4.8	—	51
Figured hypotype	15.8	41.3	—	—	—	51
Figured hypotype	15.1	44.1	14.0	13.0	—	55
Figured hypotype	21.7	51.6	—	—	—	9863
Figured hypotype	21.9	54.0	19.5	17.9	83°19′	9863
Figured hypotype	22.3	61.7	22.1	22.0	84°28′	9863
	16.5	40.2	—	—	—	391
	7.4	19.2	—	—	—	55
	15.5	39.8	—	—	82°11′	712b
	8.7	19.6	—	—	83°14′	712c
	15.3	39.1	—	—	—	51
	18.5	48.8	—	—	—	51
	4.9	13.7	—	—	—	53
	3.4	9.8	—	—	—	53
	4.3	10.2	—	—	—	9863
	4.8	11.5	—	—	—	9863
	7.1	16.1	—	—	—	9863
	8.9	19.5	—	—	83° 0′	9863
	9.9	21.8	—	—	82°15′	9863
	16.9	40.1	—	—	—	9863
	7.3	18.4	—	—	—	9863
	8.0	27.1	—	—	—	9863
	18.5	44.6	—	—	—	9863
	17.0	47.2	—	—	—	9863
	17.1	46.4	—	—	81°13′	9863
	17.6	47.7	—	—	—	9863
	19.6	46.8	—	—	84°13′	9863
	19.1	48.0	—	—	—	9863
	22.3	55.0	—	—	83°14′	9853
	18.4	49.5	—	—	—	9863
	18.2	50.5	—	—	—	9863
	16.3	45.1	—	—	—	9863
	22.0	48.5	—	—	—	9863
	18.2	45.7	—	—	—	9863
	17.1	43.2	—	—	—	9863
	20.3	49.9	—	—	—	9863
	19.5	50.8	—	—	—	9863
	16.1	38.7	—	—	—	9863

Total height-total width, U.S.G.S. 9863

$N=27$ $Sy=14.26$ mm.
$Mx=15.78$ mm. $r=0.94$
$My=14.26$ mm. $ORx=4.3$ mm.–22.3 mm.
$Sx=5.49$ mm. $ORy=10.2$ mm.–55.0 mm.

serratus, but the only known specimen of this species is mashed, and it is difficult to judge the former height.

Straparollus (*Euomphalus*) *cornudanus* differs from *S.* (*E.*) *kaibabensis* in having the upper keel irregularly serrated rather than regularly nodose. It should be noted that those few specimens of *S.* (*E.*) *cornudanus* that develop more or less regular serrations for part of one whorl approach the most irregular known specimens of *S.* (*E.*) *kaibabensis*. Extreme caution should be used in identifying incomplete specimens. Juvenile specimens of these two species show the most distinct differences in the ornamentation of the upper keel.

Straparollus cornudanus Shumard was described, without illustrations, on specimens from the "dark limestone of the Coal Measures, Sierra Cornudas, and four miles west of Sierra Hueco, El Paso county, Texas." Attempts to locate Shumard's collection have been unsuccessful, and it is the opinion of several persons consulted that his specimens have been lost by fire. In so far as the literature has been investigated, there are no references to the species except the original diagnosis. Nevertheless, Shumard's description is so complete that there is little hesitancy in identifying specimens with his species. The only sediments exposed in the Cornudas Mountains are portions of the Hueco limestone (P. B. King, personal communication), and as only one species of *Euomphalus* is known from the Hueco, this is further evidence as to the correctness of the subsequent identification.

None of the silicified specimens of the species examined show signs of color banding. However, many calcareous specimens from locality U.S.G.S. 9863, Clyde formation, are differentially colored, being nearly black near the upper and lower keels. There is also a narrow dark band at the upper suture. Approximately two-thirds of the upper whorl surface, the center portion of the side, and most of the umbilicus are brown; the umbilical portion of the shell is much lighter than the upper whorl surface. This pattern is constant on all specimens observed, and is similar to the coloration observed in other upper Paleozoic euomphalids.

Straparollus (*Euomphalus*) *cornudanus* is the only Permian *Euomphalus* studied of which there were non-silicified specimens, and some comment can be made concerning its shell structure. In general, study of polished transverse sections has revealed essentially the same features of the euomphaloid shell as are noted by Knight (1934, pp. 141–142).

The outer shell layer is composed of almost black laminae in echelon arrangement, each individual lamina being composed of numerous small prisms. The laminae are arranged tangentially to the inner shell layer, except at the upper and lower keel where the layer appears to be massive (see Knight, 1934, p. 142). This layer varies considerably in thickness, being thinnest on the outer whorl face.

The inner shell layer is of more constant thickness than the outer layer. It is approximately half as thick at the umbilicus as it is on the lower half of the outer whorl face, the area of greatest width. This layer at present consists of recrystallized calcite in prisms normal to the inner edge of the layer. Four or five concentric rings can be observed in cross section of this layer; their function is not known.

Study of the polished cross sections has revealed one other fact of general interest. Specimens that appear to be perfectly preserved have been found on being sectioned to have the inner whorls compressed. This is shown by the broken walls of the mature whorls mashed inward by the juvenile whorls above (see pl. 10, fig. 7).

Once this concept of compression of specimens, which externally appear to be perfectly preserved, was established, several of the more perplexing aspects of the silicified specimens were solved. First examination of the collections had suggested that there were at least two groups present, differing in the height/width ratio, curvature of the outer whorl face, and placement of periphery. Height/width ratio varied in these specimens from 0.33 to 0.42. Now all specimens examined are considered to be a single species, with the differences observed due to compression.

In a more general application of this principle, it is suggested that much of the variability of some discoidal fossil gastropods is spurious. Height of spire, curvature of side, shape of whorl profile, and shape of umbilical walls are all features that could be subject to change by compression. Undoubtedly, many spurious species have been erected, especially in the lower Paleozoic where specimens are few and hard to come by. The discoidal shell form may suffer pronounced change during diagenesis of the enclosing matrix.

HYPODIGM: The holotype or syntypes of Shumard, whereabouts unknown, the other specimens illustrated in the synonymy given, and 362 specimens as listed below. Preservation varies greatly, with many specimens collected from surface outcrops of the Hueco limestone being poorly preserved.

OCCURRENCE: *Admiral formation:* U.S.G.S.

9802, one. *Clyde formation:* U.S.G.S. 9842, two; U.S.G.S. 9844, two; U.S.G.S. 9847, two; U.S.G.S. 9848, 27; U.S.G.S. 9854, two; U.S.G.S. 9860, one; U.S.G.S. 9861, five; U.S.G.S. 9863, 73; U.S.G.S. 9884, four. *Hueco limestone:* U.S.N.M. 712a, five; U.S.N.M. 712b, eight; U.S.N.M. 712c, 10; U.S.N.M. 712g, seven; U.S.N.M. 719, five; U.S.N.M. 721, 11; A.M.N.H. 51, 10; A.M.N.H. 53, three; A.M.N.H. 55, four; A.M.N.H. 391, two; P.U. 37, 42; P.U. 37R, 11; P.U. 47, 40; P.U. 57a, one; P.U. 61a, one; U.S.G.S. 6937, 10; U.S.G.S. 7003a, 34; U.S.G.S. 7028, two; U.S.G.S. 14424, 30; U.S.G.S. 14430, 10; U.S.G.S. 14432, 36; U.S.G.S. 14437, 39; U.S.G.S. 14438, four. *Gym limestone:* U.S.N.M. 723, one; U.S.N.M. 724, two. *Colina limestone:* U.S.G.S. 8488, nine; U.S.G.S. 8971, 16. *Hess limestone member of Leonard formation:* U.S.N.M. 3358, one.

NUMBERED SPECIMENS: Figured hypotypes, U.S.N.M. Nos. 119100a–119100c, 119101a, 119101b, 119102; unfigured hypotypes, U.S.N.M. Nos. 119100d–119100rrr.

Straparollus (Euomphalus) glabribasis
Yochelson, new species

Plate 11, figures 16–23

DESCRIPTION: Discoidal gastropods with sharp lower angulation and linear umbilical sutures; protoconch simple, discoidal, depressed; upper sutures indistinct; upper whorl surface in juvenile stage gently arched, the greatest relief being near the middle of the upper surface, in mature stage, the upper whorl surface rising outward from suture at an angle of 5 degrees to 10 degrees from horizontal, except near outer edge, where there is an abrupt upward bend to form a narrow vertical keel on edge of whorl, the outer edge of this keel being inclined slightly inward; profile of outer whorl face a gently convex curve, almost straight, so that in all stages except the gerontic there is a faint shallow indentation just below the keel; juvenile stage having base narrower than upper surface so that outer whorl face slopes inward; mature stage having outer whorl face vertical, and gerontic stage having base wider than upper surface so that outer whorl face slopes outward; junction of basal and outer whorl surfaces marked by a sharp angulation without nodes or a keel, the angle of juncture commonly near 50 degrees in mature specimens; widely phaneromphalous with linear sutures and smooth walls in umbilicus, the umbilical angle varying from 90 degrees in juvenile stage to 125 degrees in gerontic stage; upper lip prosocline, forming a 60-degree angle with tangent to suture for two-thirds of the distance of upper whorl surface, then bending abruptly opisthocline to form a shallow sinus and meeting the keel at a 70-degree angle; outer lip bending prosocline at keel, proceeding down outer whorl face inclined 15 degrees from vertical; basal lip prosocline, curving towards orthocline near the basal suture; ornamentation lacking, except for low serrations of keel of

TABLE 3
MEASUREMENTS (IN MILLIMETERS) OF *Straparollus* (*Euomphalus*) *glabribasis* YOCHELSON, NEW SPECIES

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	6.8	16.9	6.8	—	84°19′	625
Figured paratype	5.0	10.9	5.0	3.5	—	625
Figured paratype	7.7	19.1	7.1	5.8	84° 9′	625
Figured paratype	7.8	20.0	7.8	6.0	84°31′	625
Figured paratype	8.6	28.4	—	—	—	625
	4.6	11.8	4.6	4.4	84°10′	625
	5.5	14.3	5.5	—	—	625
	6.1	16.0	6.1	4.5	84° 9′	625
	6.5	17.3	6.5	—	—	625
	7.3	18.2	—	—	—	625
	8.4	19.2	8.7	—	—	625

some specimens, which appear to be random in occurrence and in size.

DISCUSSION: The sharp angulation formed at the juncture of base and side and the essentially smooth-walled umbilicus readily differentiate this species from described Pennsylvanian and Permian forms. This species is closest superficially to *Straparollus* (*Euomphalus*) *serratus* Knight but lacks the nodes on the base that characterize that species. The smooth-walled umbilicus of *S.* (*E.*) *levibasis* is quite similar to, if not identical with, that of *Amphiscapha* (*Cyclioscapha*) *williamsi*, a species occurring at the same locality. These two species are readily separated by the presence of nodes on the upper angulation of the latter.

Several specimens in the hypodigm are relatively lower spired than the characteristic form. Accordingly they have a shallower umbilicus and a larger umbilical angle. In so far as they can be observed, in all other respects, these specimens have all other characteristics of the species. It may be that larger collections will show specimens are of a sympatric species, but for the present the writer prefers to consider them as belonging to a single variable species. Several other specimens have the upper keel serrated, but again this feature is not considered significant.

HYPODIGM: Thirty-five specimens as listed below. All are silicified and most are incomplete, although a few specimens are quite well preserved.

OCCURRENCE: *Bone spring limestone*: A.M.N.H. 655, 30; U.S.N.M. 716, one; P.U. 5, one; U.S.G.S. 8539, three.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27937:1; figured paratypes, A.M.N.H. Nos. 27937:2, 27937:3, 27937:4, 27937:5.

Straparollus (Euomphalus) kaibabensis
(H. P. Chronic)

Plate 10, figures 9–16

Euomphalus kaibabensis H. P. CHRONIC, 1952, pp. 126–127, pl. 4, figs. 15–16c.

Euomphalus pernodosus Meek and Worthen, WHITE, 1877, p. 158, pl. 12, figs. 2a–b.

DESCRIPTION: Discoidal gastropods with nodose upper and lower angulations; upper sutures distinct, moderately deep, but not channeled; profile of upper whorl surface nearly straight, rising from suture to edge at approximately 15 degrees from the vertical, the angle increasing slightly with age except in gerontic stage where body whorl slips downward, the outer edge bearing an upper angulation, which is distinctly and regularly nodose; outer whorl face inclined 15 degrees from the vertical on outer edge of angulation, below which the face becomes smoothly rounded in a convex curve, with the periphery just above center of side, this convex curve continuing to upper edge of lower angulation, there turning inward 15 degrees from the vertical, the lower angulation being somewhat more rounded than the upper one, but also bearing regularly spaced nodes; basal whorl profile beyond shoulder into umbilicus smoothly rounded; widely phaneromphalous, umbilical angle approaching 110 degrees, basal sutures distinct; upper lip nearly orthocline across upper whorl surface, except gently prosocline between nodes; outer lip at shoulder bending opisthocline for one-sixth of distance down outer whorl face, then turning prosocline approximately 20 degrees from the vertical and continuing downward, turning to near orthocline just above lower shoulder, basal lip crossing shoulder and proceeding into umbilicus, prosocline following a curve gently concave forward; ornamentation consisting of distinct, regularly spaced nodes on upper and lower shoulders, in mature stage, those on the upper shoulder being nearly twice the height of those below, the nodes being proportionately larger in juvenile stage than adult stage, in some specimens the nodes of lower shoulder disappearing and those of upper shoulder becoming smaller in late mature and gerontic stages.

DISCUSSION: The character of the nodose upper keel readily separates this species from all other described American Pennsylvanian and Permian species, except *Straparollus* (*Euomphalus*) *cornudanus*. This species is closely related to *S.* (*E.*) *kaibabensis* and is almost certainly its ancestor. *Straparollus* (*E.*) *kaibabensis* may be separated from *S.* (*E.*) *cornudanus* in the character of the ornamentation of the upper shoulder, which is distinctly nodose in the former species and rugose in the latter. In the juvenile stage of

TABLE 4

MEASUREMENTS (IN MILLIMETERS) OF *Straparollus* (*Euomphalus*) *kaibabensis* (H. P. CHRONIC)

	Height	Width	Locality
Figured hypotype	8.3	20.0	703
Figured hypotype	12.6	35.9	703
Figured hypotype	10.3	23[a]	8522
Figured hypotype	19.2	45.9	San Andres Mts.
Figured hypotype	19.8	—	702
	9.9	24.3	703
	12.4	30.2	703
	14.7	34.8	703
	10.6	31.0	703
	13.3	34.2	703
	8.7	21.5	702
	11.6	25.3	702
	9.0	24.0	702

Total height-total width, U.S.N.M. 703

$N = 7$	$Sy = 4.46$ mm.
$Mx = 11.14$ mm.	$r = 0.75$
$My = 29.14$ mm.	$ORx = 8.3$ mm.–14.7 mm.
$Sx = 2.1$ mm.	$ORy = 20.0$ mm.–35.9 mm.

[a] Estimated.

S. (*E.*) *kaibabensis* the nodes are more pronounced, and the two species can be readily separated. Those mature specimens of *S.* (*E.*) *cornudanus* that develop occasional nodes are most difficult to identify. As individuals of the extremes of each species nearly intergrade, the wisest procedure for future work seems to be to identify only suites of specimens.

The nodes on the lower whorl surface are not arranged directly below those on the upper whorl surface. Rather, they occur on the same growth lines so that the lower nodes occur behind those above. This is the same pattern followed in *S.* (*E.*) *cornudanus* by the rugosities of the upper shoulder and nodes of the lower shoulder.

Specimens of this species have been noted by H. P. Chronic (1952, p. 127) in the San Andres and Fort Apache formations. This study has confirmed Chronic's identifications. Fort Apache specimens are being described by Stephen Winters, Florida State College, Tallahassee, Florida.

HYPODIGM: The specimens illustrated in the synonymy given and 67 specimens as listed below. All specimens are silicified; preservation varies from poor to excellent.

OCCURRENCE: *Leonard formation:* U.S.N.M. 702, six; U.S.N.M. 702a, one; U.S.N.M. 703a, one; U.S.N.M. 703b, three. *Word formation:* U.S.N.M. 703, 35; U.S.N.M. 703c, three; A.M.N.H. 503, eight. *Colina limestone:* U.S.G.S. 8522, four. *One Tree Peak, San Andres Mountains, San Andres formation:* U.S.N.M. sect. 29, T. 18 S., R. 16 E., seven.

NUMBERED SPECIES: Figured hypotypes, U.S.N.M. Nos. 119103, 119104a, 119104b, 119105a, 119106; unfigured hypotypes, U.S.N.M. Nos. 119104c–119104t, 119105b–119105e.

Straparollus (Euomphalus) levicarinatus
Yochelson, new species

Plate 11, figures 1–6, 8, 9

Euomphalus sulcifer Girty, NEWELL AND OTHERS, 1953, pl. 23, figs. 21–23.

DESCRIPTION: Discoidal gastropods without a prominent keel on upper angulation; sutures distinct, slightly impressed; upper whorl surface generally flat, but with more relief in juvenile stages; upper whorl surface rising from suture in a curve gently convex outward, reaching maximum height near middle of upper whorl surface and then curving downward so that there is a shallow indentation near outer edge of whorl, the outer edge being raised, not so high as the center portion, to form a narrow keel; outer whorl face below keel inclined 15 degrees from the vertical for one-sixth of total length, next gently arched to periphery near mid-whorl, below this point curving smoothly inward to outer edge of basal whorl surface, flattened and nearly horizontal to edge of umbilicus in mature stage, at which point curving abruptly inward; widely phaneromphalous, umbilical angle near 90 degrees; upper lip prosocline, forming a 70-degree angle tangent to suture for one-third of the distance of upper whorl surface, then abruptly bending opisthocline in a wide shallow sinus and proceeding forward, forming approximately the same angle with outer edge; outer lip prosocline 10 degrees from the vertical; basal lip gently prosocline; ornamentation lacking.

DISCUSSION: The weak development of the keel on the upper surface serves to differentiate this species quite readily from other Permian *Euomphalus* species. Mississippian and Pennsylvanian species that are as simple and unornamented as this species are low spired and do not have the discoidal shape and flattened upper surface so characteristic of *Straparollus* (*Euomphalus*) *levicarinatus*.

Specimens of this species undergo several striking ontogenetic changes. In the juvenile stage, the upper whorl surface is more strongly arched than is the upper whorl surface in the mature stage. In the juvenile stage the basal whorl surface is relatively well rounded, and the edge of the umbilicus is poorly differentiated. With increasing age, the basal surface becomes more flattened and the umbilicus more clearly differentiated. In addition, the outer edge of the upper surface may project outward a fraction more than the corresponding edge of the lower surface, or vice versa, but differences in this feature seem to be due to individual variation rather than to ontogenetic change.

HYPODIGM: The specimens illustrated in the synonymy given and 40 specimens as listed below. All specimens are silicified, and most are well preserved.

OCCURRENCE: *Word formation:* U.S.N.M. 703, two; U.S.N.M. 706c, three. *Cherry Canyon formation:* A.M.N.H. 512, 21; A.M.N.H. 519, three; U.S.N.M. 728, 12. *Bell Canyon formation:* A.M.N.H. 537, one.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27936:1; figured paratypes, A.M.N.H. Nos. 27936:2–27936:4; unfigured paratypes, U.S.N.M. Nos. 119107a–119107m.

?Straparollus (Euomphalus) species 1

Plate 11, figures 7, 10, 11

DISCUSSION: Besides those species of this genus described herein, there may be at least one additional species from the west Texas Permian area. The protoconch of this species is discoidal, and the upper whorl surface is nearly flat, rising near the edge of the whorl to form a low, thickened keel. The profile of the outer whorl face is slightly concave between the upper keel and an equally thickened horizontal projection at the base and is nearly at right angles to the upper and basal surfaces. The basal whorl surface is flat, giving a distinct subquadrate profile. The umbilicus is deep and narrow and has straight walls. Growth lines and other features are unknown.

This species is placed in the Euomphalidae, because it more closely resembles this group than any other known group of upper Paleozoic gastropods. The species is more narrowly phaneromphalous than most species of *Straparollus* (*Euomphalus*) and distinctly different in this respect from the widely phaneromphalous *Amphiscapha,* which it otherwise resembles in some of its gross features. This form probably represents a new genus, but the specimen upon which the description is based does not warrant a specific name, let alone a generic name.

MEASUREMENTS: The measurements of the figured specimen of ?*Straparollus* (*Euomphalus*) species 1 from U.S.N.M. 707b are: height, 3.9 mm.; width, 9.4 mm.

HYPODIGM: One very coarsely silicified broken specimen as listed below.

OCCURRENCE: *Leonard formation:* U.S.N.M. 707b, one.

NUMBERED SPECIMEN: Figured specimen, U.S.N.M. No. 119108.

Straparollus (Euomphalus) species indeterminate

Plate 11, figures 12–15

DISCUSSION: In many of the collections studied, numerous specimens with apparently

TABLE 5

Measurements (in Millimeters) of *Straparollus* (*Euomphalus*) *levicarinatus* Yochelson, New Species

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	10.1	17.5	5.1	5.0	84° 6′	512
Figured paratype	5.4	11.6	3.9	3.5	86°51′	512
Figured paratype	3.4	9.7	3.1	2.8	—	512
Figured paratype	2.3	7.9	2.3	2.1	83° 1′	512
Unfigured paratype	5.8	15.4	5.1	4.7	83°29′	728
Unfigured paratype	3.0	8.3	2.8	2.6	84°16′	728
Unfigured paratype	5.3	14.2	4.6	4.5	—	728
Unfigured paratype	3.2	9.1	—	—	83°57′	728
Unfigured paratype	3.2	8.6	2.8	2.6	84° 2′	728
Unfigured paratype	4.4	12.5	4.1	3.8	83°15′	728
Unfigured paratype	2.3	6.1	—	—	83°23′	728
Unfigured paratype	1.7	4.5	1.5	1.3	84°18′	728
	4.3	10.8	—	—	83°53′	706c
	5.0	14.2	4.7	4.5	85°53′	706c
	6.3	14.7	5.2	4.5	—	706c
	3.2	8.3	—	—	—	706c
	3.9	10.1	—	—	—	706c
	3.9	9.9	3.6	3.2	84°27′	706c
	3.5	8.6	3.3	3.1	85°45′	706c
	3.0	8.2	3.0	2.7	84°38′	706c
	3.4	9.6	3.1	3.2	84°39′	706c
	5.1	12.0	4.5	4.4	84°30′	706c
	2.6	7.7	2.5	2.1	—	512
	3.4	9.2	3.0	2.6	84°25′	512
	4.1	10.5	3.2	2.9	84° 4′	512
	4.4	14.8	4.1	3.9	84°33′	512
	3.9	10.7	3.4	3.2	83°29′	512
	4.8	12.5	—	—	—	512
	4.4	12.3	4.1	3.9	83°44′	512
	4.5	14.5	4.5	4.2	—	512
	5.3	13.5	4.7	4.3	—	512
	4.5	11.8	4.1	3.7	83° 9′	512
	6.0	15.2	—	—	—	512
	2.3	6.3	—	—	—	512
	3.9	10.1	3.6	3.1	—	512
	3.8	10.4	—	—	—	512
	4.1	12.0	—	—	79°46′	512
	2.5	7.2	2.3	2.3	84°55′	512
	5.3	13.7	4.5	4.2	—	512

Height aperture-width aperture, A.M.N.H. 512

$N=16$ $Sy=0.90$ mm.
$Mx=$ 3.44 mm. $r=0.89$
$My=$ 3.19 mm. $ORx=2.3$ mm.–5.1 mm.
$Sx=$ 0.98 mm. $ORy=2.1$ mm.–5.0 mm.

Total height-total width, A.M.N.H. 512

$N=21$ $Sy=2.87$ mm.
$Mx=$ 4.02 mm. $r=0.79$
$My=$10.88 mm. $ORx=2.3$ mm.–10.1 mm.
$Sx=$ 1.81 mm. $ORy=6.3$ mm.–17.5 mm.

well-rounded whorls are present. Some of these specimens have distinct, nearly vertical lirae on these whorls. At the beginning of the present study, these specimens were referred to *Straparollus, sensu stricto*. Subsequent examination of two large collections of *Straparollus* (*Euomphalus*) *glabribasis* and *S.* (*E.*) *kaibabensis*, respectively, which also contained specimens with rounded whorls, have convinced the writer that these "*Straparollus, sensu stricto*" are more properly referred to *Straparollus* (*Euomphalus*).

Genera of the family Euomphalidae, in common with many other gastropod genera, have two distinct shell layers. During the silicification process there often appears to be differential action of natural solutions on the two shell layers. The specimens with rounded whorls in the collections studied are euomphalids that have not had the outer shell layer silicified, and this layer has consequently been dissolved during the etching process. Frequently only the inner shell layer, or more likely the interface between the inner and other layers, is the only part silicified.

Examination of several collections of Mississippian gastropods has shown that this loss of the outer shell layer is more common than has generally been supposed. Silicified specimens etched in nature are as subject to this loss as are those prepared in the laboratory. Non-silicified specimens are also subject to the process.

The clear-cut illustrations of this phenomenon provided by Permian specimens make it pertinent to caution other workers against being confused by this phenomenon and erecting too many species on incomplete specimens. Newell (1938, p. 17) has coined the term "subinternal molds" for those specimens of pectinoids that have had the outer shell layer removed. It is suggested that definition of this term be modified to include all fossils that have the outer shell layer removed, because it so succinctly describes the true condition of the fossil.

Knight (1934, p. 141) has discussed a pseudo-sinus on the inner shell layers of an exfoliated specimen described by Ulrich and Scofield (1897, p. 1027). Presumably this partially exfoliated specimen is another example of a subinternal mold.

The specimens figured are from a population of *S.* (*E.*) *kaibabensis* and probably that species. Even so, the wisest course seems to be to leave them as indeterminate specimens. From these and other observations, it is the writer's opinion that in no case can species of *Straparollus* (*Euomphalus*) be discriminated on the subinternal mold alone.

NUMBERED SPECIMENS: Figured specimens, U.S.N.M. Nos. 119109a–119109d.

LEPTOMPHALUS YOCHELSON, NEW SUBGENUS

Straparollus (Leptomphalus) micidus
Yochelson, new species
Plate 12, figures 1–4

DESCRIPTION: Widely phaneromphalous discoidal gastropods with poorly developed upper whorl angulation; spire depressed in juvenile stage, young shells being almost bilaterally symmetrical in cross section; upper sutures distinct, deeply impressed; upper whorl surface arched from suture to near outer edge where there is a flattened, poorly developed angulation at highest point on the surface, below this angulation the surface being inclined outward 45 degrees for a short distance, then turning towards horizontal before curving into the relatively well-rounded outer whorl face; periphery just above mid-whorl, below which the outer whorl face curves inward to a poorly developed angulation marking the juncture of outer and basal whorl surfaces; very widely phaneromphalous, umbilical angle approaching 150 degrees; basal sutures shallow, moderately wide, umbilical walls flattened; growth lines not certainly known, but seemingly orthocline on upper and basal surfaces; ornamentation lacking.

DISCUSSION: The low height/width ratio and the widely phaneromphalous umbilicus readily separate *Straparollus* (*Leptomphalus*) *micidus* from all species of *Euomphalus* occurring in the Permian fauna studied. The rather well-rounded whorl shape differentiates it from all species of *Amphiscapha*. There is a possibility that the poor development of the shoulder is spurious and that this species is actually based on subinternal molds, as the earliest whorls of the species are not quite in contact. This possibility has been seriously considered, but it seems improbable because the specimens show little

TABLE 6

MEASUREMENTS (IN MILLIMETERS) OF *Straparollus* (*Leptomphalus*) *micidus* YOCHELSON, NEW SPECIES

	Height	Width	Locality
Holotype	4.2	15.1	369
Figured paratype	2.1	6.4	369
	1.9	6.0	369
	2.9	8.4	369
	3.2	10.8	369
	3.4	12.8	369
	3.7	13.3	369
	3.5	13.7	369
	3.8	13.8	369
	3.9	14.7	369
	3.9	14.8	369
	3.7	15.0	369
	4.0	15.0	369
	4.4	17.0	369

individual variation or breakage, features that are quite common among groups of subinternal molds studied.

HYPODIGM: Twenty specimens, as listed below. All specimens are silicified and are well preserved.

OCCURRENCE: *Bone Spring limestone:* A.M.N.H. 369, 20.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27938:1; figured paratype, A.M.N.H. No. 27938:2.

GENUS AMPHISCAPHA KNIGHT, 1942

SUBGENUS AMPHISCAPHA KNIGHT, 1942

Amphiscapha (Amphiscapha) muricata (Knight), 1934

Plate 12, figures 5–8

Straparollus (*Euomphalus*) *rugosus* Hall not Sowerby, MEEK, 1872, p. 230, pl. 6, figs. 5a–b, pl. 11, figs. 4a–b.

Straparollus (*Euomphalus*) *muricatus* KNIGHT, 1934, p. 160, pl. 21, figs. 3a–f, pl. 26, fig. 3.

Straparollus (*Amphiscapha*) *muricatus* (Knight) KNIGHT, 1944, p. 465, pl. 180, figs. 40–42.

DESCRIPTION: Discoidal gastropods with horizontally projecting flange on base; protoconch simple, smooth; upper sutures distinct, impressed; upper whorl surface rising from suture, inclined outward 20 degrees from vertical for one-fourth of total height of whorl, then bending rather abruptly to 10 degrees to 20 degrees from the horizontal and continuing straight for most of distance of upper whorl surface, near the outer edge bending upward to a relatively narrow keel, the outer edge of the keel being vertical or inclined slightly inward; outer whorl face below keel bending abruptly outward to 10 degrees from vertical, so that there is a shallow depression, and continuing very gently arched to just above base where there is an abrupt turn outward to form a distinct horizontally directed flange; basal whorl surface horizontal across base of flange and outer half of whorl, then gradually curving gently upward into umbilicus; very widely phaneromphalous, umbilical angle approaching 170 degrees, basal sutures distinct; upper lip orthocline from suture, swinging very slightly backward to form a 70-degree angle with inner edge of keel, bending opisthocline across upper edge of keel; outer lip prosocline 20 degrees from vertical on outer edge of keel to indentation on outer whorl face, at which point turning to nearly orthocline and continuing straight to base, bending opisthocline just above flange, basal lip gently prosocline on under side of flange and swinging towards opisthocline following a concave curve to form a 70-degree angle with basal suture; ornamentation lacking, the outer keel and basal flange commonly being quite smooth and free of rugosities except in gerontic stage.

DISCUSSION: *Amphiscapha* (*Amphiscapha*) *muricata* differs from other species in the presence of the horizontal flange at the base. It is most similar to *A.* (*A.*) *subrugosa* (Meek and Worthen) but differs from that species in having the upper keel relatively smooth rather than rugose. In immature specimens, or those in which the flange is poorly developed, this is the most distinguishing character. Some specimens of *A.* (*A.*) *subrugosa*

TABLE 7

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Amphiscapha*) *muricata* (KNIGHT)

	Height	Width	Locality
Figured hypotype	4.2	13.8	9880
Figured hypotype	5.3	17.3	9880
	—	14.3	9880
	5.7	17.0	9880

have an incipient flange developed, but not to the extent that it is present in *A.* (*A.*) *muricata.*

In Kansas, *A.* (*A.*) *muricata* is known to range from beds at least as high as the Crouse limestone of the Council Grove group, Wolfcamp age, down to the Dover limestone of the Wabaunsee group, Virgil age. Meek (1872, p. 270) identified *Straparollus* (*Euomphalus*) *rugosus* Hall (=*subrugosus* Meek and Worthen) from beds at Nebraska City, Nebraska, that are now called Langdon shale, the formation immediately underlying the Dover limestone. Knight (1934, p. 157) referred these specimens to *S.* (*E.*) *subrugosus* Meek and Worthen, but a restudy of the specimens (U.S.N.M. Nos. 6510, 6543, and 6552) suggests that they are more properly referred to *A.* (*A.*) *muricata.*

Although the characteristic basal flange makes *A.* (*A.*) *muricata* easy to identify, the species is readily subject to misidentification. Specimens of other species occurring in shale are commonly broken and compressed downward. Frequently this compression causes the outer whorl face to bulge outward near the base, simulating a poorly developed basal flange.

In addition to the occurrences noted below, the writer has seen specimens in United States Geological Survey collections from the Franklin Mountains near El Paso, Texas. Locality data accompanying these specimens are too incomplete to warrant their being included here.

HYPODIGM: Nineteen specimens as listed below. Several individuals are crushed, but preservation of most is good.

OCCURRENCE: *Pueblo formation:* U.S.G.S. 9880, nine. *Obregon formation, "Ambocoelia" zone below Waldrip limestone No. 1:* U.S.N.M., 3 miles southwest of Rockwood, on Bull Creek, Coleman County, Texas, five. *Chaffin formation, Crystal Falls limestone member:* U.S.N.M., 4.9 miles north of Lake Cisco, Eastland County, Texas, five.

NUMBERED SPECIMENS: Figured hypotypes, U.S.N.M. Nos. 119110a, 119110b; unfigured hypotypes, U.S.N.M. Nos. 119110c–119110h.

Amphiscapha (Amphiscapha) gigantea
Yochelson, new species

Plate 12, figures 9–16

DESCRIPTION: Large, very widely phaneromphalous, discoidal gastropods with sharp keel on outer edge of upper whorl surface; protoconch unknown; sutures distinct, but not strongly impressed except in mature stage; upper whorl surface arched following a sigmoidal curve in juvenile stage, in early mature stage flattened, inclined 15 degrees from horizontal and in mature stage inclined 30 degrees from suture for short distance, then bending to 15 degrees from horizontal and continuing at almost the same inclination to near outer edge of upper whorl surface, there rising rather abruptly to form a distinct, relatively sharp upper keel; outer whorl face nearly vertical in juvenile stage, becoming very gently arched, inclined 10 degrees outward from vertical in mature stage, the lowest part of outer whorl face bearing a distinct, horizontally directed bourrelet, almost a flange; basal surface of this bourrelet indistinctly set off from rest of basal whorl surface which is more strongly inclined upward and is gently rounded near basal sutures; very widely phaneromphalous, umbilical angle approaching 160 degrees, basal sutures not impressed; upper lip gently prosocline in juvenile stage and nearly orthocline in mature stage, a few gerontic individuals having the upper lip following a convex forward curve to juncture with keel, at which point they bend forward; outer lip prosocline 5 degrees to 10 degrees from vertical; basal lip gently prosocline for approximately half of basal whorl surface, then swinging to opisthocline near suture; ornamentation lacking, the upper keel and lower angulation being smooth except in large mature stage where they then develop slight rugosities.

DISCUSSION: *Amphiscapha* (*Amphiscapha*) *gigantea* differs from *A.* (*A.*) *muricata* (Knight) in lacking a horizontal basal flange. It differs from *A.* (*A.*) *catilloides* (Conrad), *A.* (*A.*) *subrugosa* (Meek and Worthen), and *A.* (*A.*) *subsulcata* (Knight) in having the upper keel smooth rather than serrated or rugose. It is strikingly different from most species in its large size at maturity; the rather sharp upper keel of the species is quite diagnostic of juvenile specimens.

In connection with this species, it is appropriate to comment on *Straparollus* (*Euomphalus*) *hollingsworthi* Knight. Knight (1934, p. 155) suggested that species was

TABLE 8

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Amphiscapha*) *gigantea* YOCHELSON, NEW SPECIES

	Height	Width	Locality
Holotype	6.2	17.9	42-T-18
Figured paratype	9.7	30.8	9802
Figured paratype	—	31.7	9802
Figured paratype	11.7	37.1	9802
Figured paratype	9.8	34.4	South of Coleman
Unfigured paratype	8.2	24.6	South of Coleman
Unfigured paratype	8.2	24.8	South of Coleman
Unfigured paratype	7.4	22.3	9802

closely related to the group of species that now are referred to *Amphiscapha*, but he assigned *S.* (*E.*) *hollingsworthi* to *Euomphalus* because of a slight rounding and thickening of the lower keel in mature stage coupled with a slight elevation of the spire. A reëxamination of the type specimens suggests that the outer half of the body whorl of the holotype has been pressed downward by the weight of overlying sediments. This has also resulted in a slight flattening of the basal keel so that it appears to be rounded. In light of this interpretation, *S.* (*E.*) *hollingsworthi* Knight is now referrred to *Amphiscapha*.

Amphiscapha (*Amphiscapha*) *gigantea* is most closely related to *A.* (*A.*) *hollingsworthi* (Knight). It differs from that species in having the umbilicus shallower and the spire proportionally more depressed. The upper keel of *A.* (*A.*) *gigantea* also appears to be distinctly narrower than that of *A.* (*A.*) *hollingsworthi*.

HYPODIGM: Fifty-three specimens, as listed below. All were collected on the outcrop, and most are coated with matrix.

OCCURRENCE: *Putnam formation, Coleman Junction limestone member:* U.S.N.M., Sante Fe railway cut, 1 mile west of C. L. Hoover's farm house, 4 miles south of Coleman, Texas, three. *Admiral formation:* P.C. 42-T-18, four; P.C. 42-T-18-111.1, four; U.S.G.S. 9802, 26. *Clyde formation:* U.S.G.S. 9848, eight; U.S.G.S. 9863, 10.

NUMBERED SPECIMENS: Holotype, B.E.G. No. 13556; figured paratypes, U.S.N.M. Nos. 119111a–119111c, 119112a; unfigured paratypes, U.S.N.M. Nos. 119111d, 119112b–119112c.

Amphiscapha (Amphiscapha) proxima
Yochelson, new species

Plate 12, figures 17–26

DESCRIPTION: Discoidal gastropods with low rounded keel on outer edge of upper whorl surface; upper sutures distinct, slightly impressed; upper whorl surface gently arched, rising from suture inclined 45 degrees for one-fourth of total width of upper whorl surface, gradually bending to near 30 degrees from horizontal in some specimens, at outer edge bending up abruptly to form a low but distinct keel on upper angulation, the keel being smoothly rounded and without crenulations; outer whorl face with a distinct indentation at base of upper and lower angulations, these indentations becoming fainter in the mature stage, gently arched in a convex curve between the indentations, the periphery being below mid-whorl; basal angulation distinct, but not bearing a keel; basal whorl surface very gently arched, nearly flat; basal sutures very slightly impressed; widely phaneromphalous; umbilical angle 150 degrees to 175 degrees; upper lip nearly orthocline, bending gently forward at inner edge of upper keel; outer lip prosocline 5 degrees from vertical; basal lip prosocline, sweeping into umbilicus following a curve very gently forward; ornamentation lacking, the upper keel and basal angulation smooth except in gerontic stage.

DISCUSSION: *Amphiscapha* (*Amphiscapha*) *proxima* is closely related to *A.* (*A.*) *catilloides* (Conrad), but differs from that species in having a much more nearly vertical outer whorl face. It differs from *A.* (*A.*) *subrugosa* (Meek and Worthen) in having

TABLE 9

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Amphiscapha*) *proxima* YOCHELSON, NEW SPECIES

	Height	Width	V.	Locality
Holotype	3.8	11.9	84°13′	712j
Figured paratype	3.4	11.0	84° 4′	712j
Figured paratype	4.4	12.5	83°34′	712j
Unfigured paratype	3.0	9.5	84°39′	712h
Unfigured paratype	3.2	9.7	84°39′	712h
Unfigured paratype	3.1	8.6	83°40′	712h
Unfigured paratype	3.7	11.2	—	712h
Unfigured paratype	3.2	8.4	—	712h
Unfigured paratype	3.3	9.8	84°11′	712h
Unfigured paratype	3.8	10.5	84°28′	712h
Unfigured paratype	3.3	10.7	85°33′	712h
Unfigured paratype	2.1	6.3	83°23′	712h
Unfigured paratype	4.0	12.3	—	712h
Unfigured paratype	3.7	10.1	—	712h
Unfigured paratype	3.4	10.2	—	712h
Unfigured paratype	3.7	10.9	81°49′	712h
Unfigured paratype	3.5	11.4	—	712h
Unfigured paratype	3.1	8.2	84° 7′	712h

Total height-total width, U.S.N.M. 712h

$N=15$	$Sy=1.06$ mm.
$Mx=$ 3.31 mm.	$r=0.75$
$My=$ 9.90 mm.	$ORx=2.1$ mm.–4.0 mm.
$Sx=$ 0.40 mm.	$ORy=6.3$ mm.–11.4 mm.

the upper keel smooth rather than irregularly serrated and in not having the mature body whorl produced downward. *Amphiscapha* (*A.*) *hollingsworthi* (Knight) differs in having a relatively much deeper umbilicus; *A.* (*A.*) *gigantea*, besides being much larger, has a more pronounced upper keel. *Amphiscapha* (*A.*) *proxima* differs from *A.* (*A.*) *reedsi* (Knight) principally in size, mature specimens of the latter species being less than two-thirds of the size of the former.

Amphiscapha (*A.*) *peruviana* B. J. Chronic appears to be closely related to *A.* (*A.*) *proxima*. Specimens of the Peruvian species are all silicified, and it is difficult to compare silicified and non-silicified material. The upper surface of *A.* (*A.*) *proxima* is more rounded than that of *A.* (*A.*) *peruviana*. *Amphiscapha* (*A.*) *peruviana*, on the other hand, has the basal keel more pronounced, so that the outer whorl face appears to be concave rather than convex.

This species shows considerable variation in the umbilical angle and correspondingly in the depth of impression of the sutures. This variation appears to be random in distribution and may be due to slight compression of the inner whorls, too slight to cause obvious distortion of the shell.

Five specimens from the Cylde formation, U.S.G.S. 9858, are similar in some respects to *A.* (*A.*) *proxima*, but have been excluded from the hypodigm. Several of the specimens appear to have a larger height/width ratio than typical members of the species. Growth lines on the outer whorl face are different, in that the Clyde specimens have the lines prosocline 10 degrees to 15 degrees from the vertical. The material is of such a nature that these specimens can neither be considered a new species nor identified as conspecific with *A.* (*A.*) *proxima*.

HYPODIGM: Sixty-eight specimens, as listed below. Most were collected free from the outcrop and are well preserved. The single Arizona specimen is poor and is only tentatively referred to this species.

OCCURRENCE: *Hueco limestone:* U.S.N.M.

712h, 57; U.S.N.M. 712i, three; U.S.N.M. 712j, five; P.U. 24, one; U.S.N.M. 712c, one. *Earp formation:* U.S.G.S. 8529, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119113; figured paratypes, U.S.N.M. Nos. 119114a, 119114b; unfigured paratypes, U.S.N.M. Nos. 119114c, 119114d, 119115a–119115ddd.

Amphiscapha (Amphiscapha) dextrata
Yochelson, new species

Plate 13, figures 1, 2, and 5

DESCRIPTION: Discoidal gastropods with upper surface wider than base; protoconch unknown; sutures distinct, slightly impressed; upper whorl surface flattened, rising 5 degrees to 10 degrees from horizontal to near outer edge of upper surface; there turning abruptly upward to form a sharp, relatively high keel; the outer edge of keel inclined inward 5 degrees from vertical; outer whorl surface indented slightly below keel, gently arched to another indentation just above the base, the periphery being near mid-whorl, a small bourrelet being developed at the basal angulation; base narrower than upper surface so that outer whorl surface inclines inward at approximately 20 degrees from vertical; basal whorl surface very gently arched, nearly flattened; very widely phaneromphalous, umbilical angle approaching 150 degrees; basal whorl surface distinct, narrow; upper lip opisthocline following a gently convex forward curve across upper whorl surface, unknown crossing keel; outer lip not certainly known but believed to be prosocline 10 degrees to 15 degrees from vertical on lower part of outer whorl face; basal lip nearly orthocline into umbilicus; ornamentation lacking, the upper keel being sharp, narrow, and smooth, and the basal keel being wider, but also remarkably smooth.

DISCUSSION: This species is readily distinguished from all others referred to this genus, as it is the only species known in which the base is distinctly narrower than the upper surface. Occasional juvenile specimens of some species of *Straparollus* (*Euomphalus*) have the upper surface wider than the base, but they are relatively much higher spired and have a distinctly deeper umbilicus.

All specimens of this species are poorly preserved, but they are so distinct that a formal name seems warranted. A fragment of a whorl from the Gym limestone has a vertical outer whorl face, but other specimens are quite characteristic. The unusual shape is definitely considered not to be a phenomenon of silicification. The rounding of the whorls in the umbilicus casts some doubt as to the proper biologic placement of the species, but it certainly has more in common with *Amphiscapha* than with *Straparollus* (*Euomphalus*).

HYPODIGM: Five silicified specimens, as listed below. The Hueco specimen is best preserved, but is incomplete.

OCCURRENCE: *Hueco limestone:* A.M.N.H. 51, one. *Gym limestone:* U.S.N.M. 724, four.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119116; unfigured paratypes, U.S.N.M. Nos. 119117a–119117d.

CYLICIOSCAPHA YOCHELSON, NEW SUBGENUS

Amphiscapha (Cylicioscapha) texana
Yochelson, new species

Plate 13, figures 7–11, 15

Euomphalus subquadratus Meek and Worthen, WHITE, 1891, p. 25, not pl. 3, fig. 9.

DESCRIPTION: Discoidal gastropods with nodose upper keel and slightly arched basal whorls; protoconch simple, smooth for at least the first three whorls; upper sutures

TABLE 10

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Amphiscapha*) *dextrata* YOCHELSON, NEW SPECIES

	Height	Width	Locality
Holotype	4.3	13.3	51
Unfigured paratype	3.0	8.6	724
Unfigured paratype	2.9	8.4	724

impressed; upper whorl surface strongly arched from suture, gradually flattening for approximately one-third of width and then bending strongly downward near outer edge of upper surface, the flattened area being interrupted periodically by the development of nodes; outer whorl face nearly vertical just below edge of upper surface, abruptly turning horizontally and then vertically so that an exceedingly narrow revolving shelf is formed, this shelf protruding as a thread in the earlier stages; the face below this shelf in mature stage is gently arched, inclined outward 5 degrees to 10 degrees from vertical to periphery at thickened, rugose basal angulation, the shelf quite indistinct in the gerontic stage, with the outer whorl face inclined more strongly outward; basal whorl surface gently arched, bending abruptly inward near suture; very widely phaneromphalous, umbilical angle approaching 140 degrees; outer lip orthocline to gently prosocline at suture, swinging gradually in a gently sigmoidal curve to opisthocline, forming an 80-degree angle with outer edge of upper whorl surface; outer lip opisthocline 5 degrees to 10 degrees from vertical to revolving shelf, bending abruptly to prosocline and continuing straight down side inclined 5 degrees behind vertical, near midwhorl gradually bending more strongly prosocline; basal lip prosocline, curving slightly near suture; ornamentation consisting of distinct nodes on upper shoulder, there being approximately as much space between nodes as the width of the preceding nodes, the nodes elongated rather than well rounded, with the side of the node farthest from the aperture being the steepest. The measurement of height in this species and *A.* (*C.*) *williamsi* was taken at the top of the node.

DISCUSSION: *Amphiscapha* (*Cylicioscapha*) *texana* differs from *A.* (*C.*) *subquadrata* (Meek and Worthen) in having the keel rugose to

TABLE 11

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Cylicioscapha*) *texana* YOCHELSON, NEW SPECIES

	Height	Width	V.	Locality
Holotype	9.0	19.7	84°46′	West of Perrin
Figured paratype	9.6	23.9	83°31′	West of Perrin
Figured paratype	12.0	—	—	Military Crossing
Unfigured paratype	5.7	12.8	—	West of Perrin
Unfigured paratype	6.5	15.1	—	West of Perrin
Unfigured paratype	5.5	12.7	82°32′	West of Perrin
Unfigured paratype	6.5	13.8	—	West of Perrin
Unfigured paratype	5.8	13.7	—	West of Perrin
Unfigured paratype	6.8	15.7	—	West of Perrin
Unfigured paratype	6.4	15.6	83° 2′	West of Perrin
Unfigured paratype	6.7	14.9	—	West of Perrin
Unfigured paratype	7.7	17.4	—	West of Perrin
Unfigured paratype	8.7	19.3	82°10′	West of Perrin
Unfigured paratype	9.0	17.8	—	West of Perrin
Unfigured paratype	7.0	15.9	82°15′	West of Perrin
Unfigured paratype	11.1	22.2	83°59′	West of Perrin
Unfigured paratype	10.7	21.4	—	West of Perrin
Unfigured paratype	17.7	13.9	82°52′	West of Perrin
Unfigured paratype	6.7	15.2	—	West of Perrin
Unfigured paratype	10.0	23.4	—	West of Perrin
	7.1	16.9	82°38′	Bridgeport
	15.9	35.0	82°38′	Bridgeport
	8.4	20.2	—	Southwest of Perrin
	11.5	21.5	83°31′	Southwest of Perrin
	8.3	19.9	—	Southwest of Perrin
	11.7	24.0	83°24′	Southwest of Perrin
	12.3	23.6	—	Southwest of Perrin

nodose, whereas in the latter species the keel is commonly crenulated, with only occasional rugosities developed. A paratype of the Meek and Worthen species is figured for comparison in plate 13, figures 3 and 4. *Amphiscapha* (*Cylicioscapha*) *texana* is closely related to *A.* (*C.*) *williamsi* but the latter species differs in having the rugosities of the keel less well rounded.

The largest population of this species shows much variation in the depth of depression of the earlier whorls and depth of the umbilicus. These two interrelated features are believed to be modified greatly by the result of simple compaction. The measurements presented show almost as much variation in height/width ratio as those of *Straparollus* (*Euomphalus*) *cornudanus* (Shumard) and serve further to confirm the suggestion that discoidal gastropods are poorly suited for measurement because of the inherent weakness of this shell form to deformation.

Although this is predominantly a Pennsylvanian species, it does occur in lower Permian strata, as shown by the specimens from the Military Crossing of the Big Wichita River. White (1891, p. 25) discussed these specimens but figured specimens of *Straparollus* (*Euomphalus*) *cornudanus* (Shumard).

HYPODIGM: Twenty-eight specimens, as listed below. All specimens were collected from shales and are well preserved.

OCCURRENCE: *Wolf Mountain shale:* U.S.N.M., from small washes on west side of road, 3 miles west of Perrin, Texas, on old Mineral Wells–Jacksboro road, 19; U.S.N.M., 3.5 miles southwest of Perrin, Texas, five. *Belle Plains formation:* U.S.N.M. Military Crossing of the Big Wichita River, three. *Wolfcamp formation:* U.S.N.M. 3360, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119118; figured paratypes, U.S.N.M. Nos. 119119a, 119120a; unfigured paratypes, U.S.N.M. Nos. 119119b–119119s, 119120b–119120c.

Amphiscapha (Cylicioscapha) williamsi
Yochelson, new species

Plate 13, figures 12–14, 16–19

DESCRIPTION: Discoidal gastropods with well-rounded nodes on upper shoulder; protoconch simple, unornamented; sutures distinct and channeled; upper whorl surface rising nearly vertically out of channel for a short distance, then bending to 45 degrees from horizontal and proceeding upward and outward to edge of whorl, near center of upper whorl surface the inclination of surface changing, approaching horizontal on areas between nodes on upper angulation or steepening to 60 degrees from horizontal to form inner face of nodes; outer whorl face vertical just below nodes, there turning abruptly to horizontal to form a distinct "break" in the face and then returning to vertical, the horizontal area being little more than a niche in mature face, but being relatively broader in juvenile stage and inclined slightly upward and outward to form a distinct revolving thread, below niche or thread, the outer whorl face being inclined strongly inward in juvenile stage, nearly vertical, gently arched in mature stage, and inclined gently outward in gerontic stage, the outer and basal surfaces meeting in a relatively sharp angulation, the angle near 50 degrees; widely phaneromphalous, umbilical angle near 135 degrees in mature stage, the umbilical walls smooth and straight, with linear sutures; upper lip gently prosocline to suture for one-sixth of upper whorl surface, then swinging more strongly backward, following a convex forward curve to form a 60-degree angle with outer edge of upper whorl surface; outer lip opisthocline 20 degrees to 30 degrees from vertical to revolving thread, there bending abruptly prosocline to 50 degrees from vertical and proceeding down outer whorl face; basal lip straight, prosocline, except near basal suture where lip swings forward; ornamentation consisting of distinct and regularly spaced nodes on the upper shoulder, the nodes beginning on the third observable whorl and retaining the same proportional height and spacing throughout all growth stages, the interspaces being very slightly wider than the nodes.

DISCUSSION: *Amphiscapha* (*Cylicioscapha*) *williamsi* is the youngest known species of the subgenus and as such is the end member of a distinct evolutionary line. This line begins in the Bend group, where an undescribed species of the subgenus has a smooth upper keel. *Amphiscapha* (*Cylicioscapha*) *subquadrata* (Meek and Worthen) has the upper

TABLE 12

MEASUREMENTS (IN MILLIMETERS) OF *Amphiscapha* (*Cylicioscapha*) *williamsi* YOCHELSON, NEW SPECIES

	Height	Width	V.	Locality
Holotype	8.6	18.0	83°34′	625
Figured paratype	18[a]	39.8	—	625
Figured paratype	3.0	9.1	84°34′	625

[a]Estimated.

keel crenulated and nodose, but this keel is not quite so nodose as that of *A.* (*C.*) *texana*. *Amphiscapha* (*Cylicioscapha*) *williamsi* is closely related to this latter species but differs in having the keel broken into distinct, well-rounded, relatively high nodes. The two species are most clearly separated, however, by the character of the umbilical walls which are slightly arched in *A.* (*C.*) *texana* and flat in *A.* (*C.*) *williamsi*.

Incomplete specimens of *A.* (*C.*) *williamsi*, having only the umbilicus preserved, cannot be separated from specimens of *Straparollus* (*Euomphalus*) *glabribasis*. These two species occur at the same locality.

HYPODIGM: Six silicified specimens, as listed below, two of which are excellently preserved.

OCCURRENCE: *Bone Spring limestone:* A.M.N.H. 625, six.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27939:1; figured paratypes, A.M.N.H. Nos. 27939:2, 27939:3.

PLANOTECTUS YOCHELSON, NEW GENUS

Planotectus cymbellatus Yochelson, new species

Plate 13, figures 20–24

DESCRIPTION: Discoidal gastropods with shallow sinus in upper lip and a prominent sharp keel on outer edge of upper whorl surface; upper surface essentially flat throughout all growth stages; upper sutures shallow, moderately distinct; upper whorl surface gently arched in mature stage, being highest near center of upper surface and lowest just below keel, there being relatively more relief in juvenile stages, rising abruptly from revolving indentation near periphery to form a sharp, narrow keel at the periphery, inclined outward 10 degrees from vertical, the keel beginning in juvenile stage as a horizontal flange but bending upward within three whorls; outer whorl face inclined inward nearly 20 degrees from vertical, some specimens showing a faint indentation just below outer face of keel, curving inward abruptly to base; basal whorl surface slightly flattened before bending up into umbilicus; widely phaneromphalous, umbilical angle near 90 degrees; upper lip gently prosocline leaving suture; gradually curving forward so as to form a wide shallow sinus on upper whorl surface, forming a 70-degree angle with keel; outer lip prosocline 15 degrees from vertical, turning to 10 degrees from vertical halfway down outer whorl face; basal lip prosocline, turning to orthocline near umbilicus.

DISCUSSION: The general shape described above, with the flattened upper whorl surface and rounded basal surface, serves to differentiate *Planotectus cymbellatus* from all other discoidal gastropods known in the Permian fauna studied. The shape of the mature shell is very nearly unique among Paleozoic gastropods, but the juvenile shell shows some similarities to that of *Straparollus* (*Euomphalus*) *levicarinatus*, new species.

OCCURRENCE: Ten specimens, as listed below. All are silicified, and most are well-preserved.

HYPODIGM: *Leonard formation:* U.S.N.M. 702un, one. *Word formation:* U.S.N.M. 706c, six. *Cherry Canyon formation:* U.S.N.M. 728, one; A.M.N.H. 512, two.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119121; figured paratype A.M.N.H. No. 27940:1.

FAMILY OMPHALOTROCHIDAE KNIGHT, 1945

GENUS OMPHALOTROCHUS MEEK, 1864

Omphalotrochus whitneyi (Meek)

Plate 14, figures 1–3

Euomphalus (*Omphalotrochus*) *whitneyi* MEEK, 1864, p. 15, pl. 2, figs. 8, 8a.

TABLE 13

MEASUREMENTS (IN MILLIMETERS) OF *Planotectus cymbellatus* YOCHELSON, NEW SPECIES

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	7.2	19.0	6.9	6.0	84°59′	728
Figured paratype	3.1	8.9	3.1	—	82°58′	512
	5.5	15.6	5.5	4.8	—	512
	2.4	6.1	6.1	—	—	706c
	5.7	13.0	5.7	—	—	706c
	5.5	16.1	5.5	—	—	706c

Omphalotrochus whitneyi (Meek), GRABAU, 1934, p. 164, figs. 2, 3.

Omphalotrochus whitneyi (Meek), KNIGHT, 1941, pp. 214, 215, pl. 77, figs. 1–5.

Omphalotrochus whitneyi (Meek), KNIGHT, 1944, p. 469, pl. 191, fig. 21.

DISCUSSION: Although this species is not present in the southwestern United States and thus is not strictly within the province of this paper, restudy of four specimens examined by Knight (1941, p. 214) has contributed additional information which serves to supplement Knight's description. Because of the large number of new species described within this genus, it seems advisable to add to our knowledge of the type species.

Although this species has a distinct forward projection of the lip above the periphery, there is less of a prong developed in this species than in any of the other species studied. The sinus also is closer to the periphery than in *Omphalotrochus wolfcampensis*, the most similar species. Examination of the base of several species suggests that the growth lines are more arcuate than in all other species examined except *O. hessensis*. This character is probably of little value in the segregation of species.

In addition to the specimen figured by Knight, one specimen from Stanford University shows the profile of the outer whorl face as distinctly concave between the outer edge of the upper surface and the periphery. A similar profile is characteristic of *O. wolfcampensis* but is less pronounced in that species.

One specimen figured herein (pl. 14, fig. 3) is 59.5 mm. in width. The other figured hypotype (pl. 14, figs. 1, 2) is incomplete but measures nearly 100 mm. in width and probably was 115 to 120 mm. wide in life. This approaches the size of some of the largest specimens of *O. cochisensis*. The species apparently undergoes little ontogenetic change, as the course of the outer lip in the immature specimen, illustrated by Knight (1941), and the largest specimen examined are almost identical.

In connection with the status of the specimen figured by Knight, the following quotation from a letter by Dr. Joseph H. Peck, Jr., of the University of California is pertinent: "Some confusion surrounds this specimen. It is not from the locality mentioned by Dr. Knight, but is part of the original California Geological Survey material examined by Meek. The story briefly is this: In 1933 Dr. Harry E. Wheeler, then a student at Stanford, borrowed a number of California Survey fossils from Bass Ranch for his thesis. Inadvertently, this loan was misidentified as a donation and some of the specimens were placed in the Stanford Type Collection, among them the specimen *Omphalotrochus* in question. It was then later borrowed by Dr. Knight and credited to Stanford." The specimen is now in the Museum of Paleontology, University of California, and catalogued as number 34606.

Dr. Peck has supplied additional information about the type locality. The following information is taken from an unpublished thesis by H. Wheeler: "The Old Bass Ranch was located on Bayha Creek at the water gap through the McCloud limestone. *O. whitneyi* occurs in the basal McCloud (along with *Pseudoschwagerina robusta* and *Clisiophyllum gabbi*), both to the north and south of the gap."

HYPODIGM: The specimens illustrated in the synonymy listed and three additional specimens from Stanford University.

OCCURRENCE: Knight (1944, p. 467) reports the occurrence of *O. whitneyi* as southwest United States. This clearly is a slip of the pen, because, so far as we now know, the species does not range farther east than California.

All recorded specimens of the species are from the basal McCloud limestone, S.U. 445 (west side of limestone knoll in the SE. ¼ SE. ¼ sect. 15, T. 33 N., R. 4 W., Mount Diablo Baseline and Meridian at 1100 feet elevation, Redding quadrangle, Shasta County, California), except for one specimen found reworked in the upper Triassic of Grant County, Oregon (Wheeler, 1934, p. 69).

NUMBERED SPECIMENS: Hypotypes, S.U. Nos. 5110, 5113, 6522; M.P.U.C. No. 34606.

Omphalotrochus cochisensis Yochelson, new species

Plate 17, figures 1–6; plate 18, figures 15, 16

DESCRIPTION: Trochiform gastropods developing a subquadrate whorl profile in mature stage; protoconch unknown; juvenile stages poorly known but probably similar to those of *Omphalotrochus obtusispira*, except that the outer whorl face is somewhat narrower and is not so strongly inclined as in *O. obtusispira;* upper whorl surface of early mature whorls flattened, inclined downward 60 degrees from vertical to juncture with thickened periphery, gradually developing a ridge approximately one-third of the distance down this area, this ridge in the mature stage marking the boundary of a flattened, nearly horizontal shelf extending for nearly half of the upper whorl surface, at the end of which surface the shelf bends abruptly 30 degrees from vertical and continues downward, near the periphery, bending sharply outward to form a narrow, nearly horizontal shelf, this narrow shelf disappearing in the gerontic stage, crossing well-rounded periphery and turning abruptly inward into the almost horizontal base; moderately phaneromphalous, the umbilical walls gently curved, nearly vertical; upper lip in early mature stage prosocline, forming a 60-degree angle tangent to the suture for one-third of the distance down the side of the whorl, then bending forward at change in slope, proceeding opisthocline to form a 40-degree angle with periphery, although some specimens do have a shallow but distinct sinus, rather than a V at edge of upper shelf, outer lip below periphery bending prosocline to a 45-degree angle and continuing straight across outer one-third of base, there turning to almost radial and proceeding into umbilicus; juncture of columellar and basal lip thickened; ornamentation lacking.

DISCUSSION: The subquadrate profile of the mature whorl readily separates *Omphalotrochus cochisensis* from all other species of the genus. The common V shape rather than U shape of the growth lines at the upper angulation is also quite distinctive. The species is further noteworthy for the extreme size of individuals. Almost all specimens are larger than those of other species. One specimen (pl. 17, fig. 4) is probably the largest upper Paleozoic gastropod on record.

The species is most similar to *O. obtusi-*

TABLE 14

MEASUREMENTS (IN MILLIMETERS) OF *Omphalotrochus cochisensis* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	53[a]	66.4	115°[a]	22.1	25.8	9860
Paratype	—	72.4	—	24.4	—	199-T-2
Paratype	—	74.6	115°[a]	29.9	30.3	8502
Paratype	73[a]	—	—	31.6	—	8532
Paratype	—	170[a]	—	—	—	8503
Paratype	67[a]	68.1	95°[a]	25.0	—	5314

[a]Estimated.

spira (Shumard). Some specimens with the mature whorl profile less typically developed approach the limits of the variation of *O. obtusispira* (Shumard) and are separated from that species with the greatest difficulty. The two species occur in the same horizon in north central Texas, and a single specimen of *O. cochisensis* has been tentatively identified from the Hueco limestone. It may be that the two species occur in Cochise County, Arizona, but all specimens not clearly *O. cochisensis* are poorly preserved, and the question cannot be resolved at this time. Ontogeny of the two species appears to be similar, but the juvenile whorls of *O. cochisensis* are poorly known. It is the considered opinion of the writer that juvenile specimens of these two species cannot be separated with any degree of certainty, at least until more is known of the development of *O. cochisensis*.

It should be noted that the characteristic subquadrate whorl shape does not develop at the same growth stage in all specimens. Those from north central Texas show this shape earlier than some specimens from Arizona. Few of the Arizona specimens have the mature shape at the same growth stage as the north-central Texas ones. Others are intermediate to the largest individual figured. Whether or not these specimens that develop this shape at different growth stages represent subspecies cannot be determined from the material in hand.

Omphalotrochus cochinsensis has been identified in a collection made by F. K. G. Müllerried in southern Chiapas, Mexico. The collection is now in the possession of the Instituto Geologico de Mexico.

HYPODIGM: Thirty-six specimens, as listed below. All from Arizona are silicified, and most are poorly preserved and incomplete.

OCCURRENCE: *Colina limestone:* U.S.G.S. 8488, one; U.S.G.S. 8501, five; U.S.G.S. 8502, two; U.S.G.S. 8503, five; U.S.G.S. 8513, 10; U.S.G.S. 8527, three; U.S.G.S. 8532, one. *Horizon not certainly known, but possibly Colina limestone:* U.S.G.S. 5314, one; U.S.G.S. 5315, one; U.S.G.S. 8188, six. *Hueco limestone:* U.S.N.M. 712, one. *Clyde formation:* U.S.G.S. 9860, one; B.E.G. 4100, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119127; figured paratypes, U.S.N.M. Nos. 119128–119131, B.E.G. No. 13558.

Omphalotrochus obtusispira (Shumard)

Plate 15, figures 1–13

Pleurotomaria obtusispira SHUMARD, 1859, p. 401.

Omphalotrochus obtusispira (Shumard), GIRTY, 1937, p. 202, pl. 33, figs. 1–17.

Omphalotrochus obtusispira (Shumard), KNIGHT, 1944, p. 467, pl. 191, figs. 12–15.

Omphalotrochus obtusispira (Shumard), B. J. CHRONIC, 1949, p. 150, pl. 29, figs. 17, 18.

DESCRIPTION: Large trochiform gastropods with a pronounced forward-projecting prong and a complex but generally rounded whorl shape; protoconch simple, with rounded whorls, planispiral, not depressed; sutures distinct, strongly impressed and overhung until approximately the fifth whorl, where the sutures then become smoother; pleural angle expanding abruptly at maturity, the profile of the mature specimen thus appearing concave; whorl shape varying with age, the upper whorl surface of the juvenile stage being inclined downward and strongly outward, almost straight, to the thickened periphery, below periphery the basal whorl surface being inclined strongly inward for a short distance, then bending more or less abruptly to horizontal, the profile gradually becoming more complex, so that in the mature stage the upper whorl surface begins straight, inclined nearly 30 degrees from horizontal for a short distance, then bends more strongly downward, some specimens having a shallow revolving depression between these two areas, following a distinctly convex upward curve outward and then downward, some specimens having a broad revolving depression in the center of this curved area, turning abruptly outward to almost horizontal just before the periphery; outer whorl face nearly vertical below periphery, next bending inward to a shallow depression similar to that above, and finally becoming distinctly flattened on the basal whorl surface; moderately widely phaneromphalous, the umbilical walls slightly curved; outer lip prosocline, nearly normal to suture across area near suture, then turning backward for approximately one-third of curved

TABLE 15

MEASUREMENTS (IN MILLIMETERS) OF *Omphalotrochus obtusispira* (SHUMARD)

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Hypotype	4.0	7.4	—	2.5	2.5	53
Hypotype	9.0	10.8	67°	4.5	4.5	53
Hypotype	15.6	18.5	66°	7.0	7.8	53
Hypotype	43.0[a]	—	102°	18.5	20.1	53
Hypotype	37.0	65.4	121°	17.7	18.8	53
Hypotype	40.0[a]	43[a]	74°	15.4	—	51
Hypotype	—	59.1	98°	19.9	21.0	19-T-21

[a] Estimated.

area, next bending so as to form a wide shallow sinus and proceeding opisthocline to form a 40-degree angle with periphery, outer lip bending abruptly prosocline to 45 degrees for approximately one-third of distance across basal whorl surface, the basal lip finally bending forward but proceeding backward into umbilicus at a low angle; columellar lip not reflexed, juncture of columellar and basal lip slightly thickened; no ornamentation other than occasional rugose growth lines.

DISCUSSION: This species is most closely related to *Omphalotrochus cochisensis*, but differs in having a more rounded whorl shape in the mature stage and in being smaller. Juveniles of the two species are separated with great difficulty, but *O. obtusispira* is thought to have had the early sutures more strongly impressed.

Besides the typical "Chinaman's-hat" shape, the pronounced prong of the aperture readily separates this species from low-spired forms. The sinus is deeper and the prong smaller than in *O. hessensis*, the only other species superficially similar.

In detail, the whorl profile of *Omphalotrochus obtusispira* is quite variable among specimens. A full and rather detailed discussion of this variation has been given by Girty (1937, pp. 204–208). Illustrations have been provided here of most of the common variants. Little need be added to Girty's comments except to note that all the various ridges, troughs, and angulations on the upper and outer whorl surfaces described by him have been found on specimens forming the basis for the description of the species given. More collections are needed to determine if any of the forms illustrated are characteristic of a particular stratigraphic level in the Hueco limestone.

This variation is the result of at least three factors: (1) there is pronounced ontogenetic change, so much so that juveniles and mature adults lacking the younger whorls would probably be classed as separate genera; (2) there appears to be considerable individual variation among specimens; (3) the thin shell and the complex whorl profile make the specimens particularly susceptible to slight changes caused by compression during diagenesis of the enclosing rock. Silicification, sometimes with loss of one shell layer, causes still another complication.

The problem of a type for this species is quite vexing, as Shumard did not illustrate his description. In so far as can be determinded, all Shumard's original specimens have been lost or destroyed. Girty was the first person to illustrate the species, but all the mature specimens that he figured are from several hundred miles away from the Sierra Hueco, Shumard's type locality. Presumably these specimens may not be available as neotypes. The species is rather fully illustrated so that a subsequent worker may designate a neotype if it should ever become necessary.

Two large collections of silicified specimens from the Hueco limestone (A.M.N.H. 51 and 53) contain a relatively large number of juveniles and few adults. However, except for the specimens illustrated, most specimens are too incomplete to be measured accurately. All specimens weathered free and collected from the outcrop are too poor to be measured.

HYPODIGM: The holotype or syntypes, the specimens illustrated in the synonymy listed, and 185 specimens as listed below. Preservation varies considerably; the hypodigm includes specimens etched in the laboratory that are in excellent condition and specimens collected on the outcrop that are somewhat weathered.

OCCURRENCE: *Gym limestone*: U.S.N.M. 722, one; U.S.N.M. 724, one; U.S.N.M. 726, one. *Hueco limestone:* U.S.N.M. 712a, six; U.S.N.M. 712b, one; U.S.N.M. 712g, four; U.S.N.M. 719, two; U.S.N.M. 720, one; A.M.N.H. 51, 30; A.M.N.H. 53, 45; A.M.N.H. 391, three; U.S.G.S. 2915 green, four; U.S.G.S. 2925 green, nine; U.S.G.S. 6721, 12; U.S.G.S. 7004, one; U.S.G.S. 7007, one; U.S.G.S. 7050, one; U.S.G.S. 14425, one; U.S.G.S. 14426, one; U.S.G.S. 14431, three; U.S.G.S. 14437, 11; P.U. 47, 12; P.U. 61A, one; Y.P.M. (half a mile north of Hueco Inn), one. *Belle Plains formation:* B.E.G. 10973, one. *Clyde formation:* B.E.G. 4075, three; B.E.G. 10874, 11; B.E.G. 8505, one; U.S.G.S. 9847, one; U.S.G.S. 9859, one; B.E.G. 10769, 13. *U.S.N.M. Sedwick limestone member of Moran formation near Stacy, McCulloch County, Texas:* One.

NUMBERED SPECIMENS: Girty's hypotypes are catalogued as U.S.N.M. Nos. 118631–118637. Hypotypes illustrated in the present paper are U.S.N.M. Nos. 119126a–119126e, 119129, and B.E.G. No. 13557.

Omphalotrochus alleni Yochelson, new species

Plate 15, figures 14–16

DESCRIPTION: Large trochiform gastropods with the outher whorl face inclined distinctly inward from vertical; protoconch and early whorls unknown; shell possibly low spired; sutures distinct in mature stage, not impressed; upper whorl surface consisting of a flattened portion inclined 30 degrees from horizontal for the upper one-third of width and gently concave portion inclined 50 degrees to 60 degrees from horizontal for much of the remaining width, the juncture of these surfaces being slightly thickened, the outer edge of the lower surface turning abruptly to nearly horizontal at the periphery; below the periphery, the outer whorl face nearly straight, inclined inward 30 degrees from vertical for a short distance, then curving strongly inward so that most of the basal whorl surface is flattened; moderately phaneromphalous, umbilical angle not certainly known, but less than 90 degrees, upper lip prosocline, forming a 70-degree angle with tangent to suture for one-fourth of the distance of upper whorl surface, then bending to form an extremely shallow sinus, and after curving foward, proceeding opisthocline, forming a 60-degree angle with periphery, crossing periphery and bending prosocline inclined 45 degrees from vertical, the basal lip not certainly known but seemingly proceeding backward, forming a 20-degree angle with edge of umbilicus; ornamentation lacking.

MEASUREMENTS: The width of the holotype, from U.S.N.M. 707o, is 78.5 mm.

DISCUSSION: The shallow but distinct sinus of the upper lip coupled with the strong inward inclination of the outer whorl face readily separates this species from other omphalotrochids. *Omphalotrochus alleni* is most similar to *O. cochisensis* and *O. hessensis*, but differs from the first species in lacking a subquadrate whorl section and from the second in lacking a moderately rounded whorl section. The possibility that the holotype of this species may be a gerontic representative of another species has been considered but rejected.

HYPODIGM: A single incomplete specimen, as listed below. Most of the lower surface of the specimen was covered with an ironstone quartz pebble conglomerate, and the methods required to clean away some of this hard matrix have resulted in damage to the base.

OCCURRENCE: *Wolfcamp formation:* U.S.N.M. 707o, one.

NUMBERED SPECIMEN: Holotype, U.S.N.M. No. 119132.

Omphalotrochus wolfcampensis Yochelson, new species

Plate 14, figures 4–10

DESCRIPTION: Trochiform gastropods bearing a shallow sinus in upper lip and having a concave profile to outer whorl face; protoconch unknown; sutures distinct, not impressed, the early mature whorls embracing whorl above near center of outer whorl face so that suture is just overhung by previous whorl; whorl form varying considerably with age, the upper whorl surface inclined downward, nearly flat in juvenile stage, the upper whorl surface of mature stage flattened, nearly horizontal for a short distance from suture to a striation or faint depression on surface, there bending downward and continuing straight outward, inclined 30 degrees from horizontal, abruptly bending downward and then outward in a distinct revolving depression near the rounded, somewhat thickened outer edge; outer whorl face nearly vertical for a short distance below edge, next bending outward, following a concave curve to periphery, there bending rather abruptly inward so that most of basal whorl surface is distinctly flattened; moderately phaneromphalous, the umbilical walls straight, inclined outward; upper lip prosocline, forming a 70-degree angle with tangent to suture, curving gently backward from striation below suture for approximately two-thirds of width of inclined surface, then turning opisthocline, forming a 45-degree angle with outer edge of upper surface; outer lip prosocline 30 degrees from vertical to below periphery, there bending forward and proceeding nearly radially into umbilicus following a gently parasigmoidal curve; juncture of columellar and basal lips thickened, columellar lip slightly thickened; ornamentation lacking.

Discussion: The large pleural angle and the generally simple whorl shape serve to separate this species readily from all other American *Omphalotrochus* species studied. The early mature whorls do not have a triangular profile such as is characteristic of *Omphalotrochus obtusispira* (Shumard). Rather, *O. wolfcampensis* has a distinct outer whorl face developed early in its ontogeny. The upper lip develops a relatively shallow sinus high on the whorl, and the prong below is shorter than that of most species. This sinus is relatively deeper than that characteristic of *O. whitneyi* (Meek), the most similar species.

Poorly preserved and incomplete specimens from the Gouldbusk limestone member of the Moran formation of north central Texas bear some similarity to *O. wolfcampensis*. Better specimens are needed to determine if these are conspecific with *O. wolfcampensis*.

Hypodigm: Twenty-nine specimens as listed below. Most are poorly preserved and crushed, although several incomplete specimens show accurate profiles. Most specimens are silicified.

Occurrence: *Wolfcamp formation:* Y.P.M. 91, one; Y.P.M. 93, seven; U.S.N.M. 701d, one; U.S.N.M. 701h, one; U.S.N.M. 702x, one; U.S.N.M. 706x, one; U.S.N.M. 708r, two; U.S.N.M. 708s, one; U.S.N.M. 708t, eight; U.S.N.M. 3360, four; K.U. 7419, one. *Red Eagle limestone, half a mile east of Burbank, one-fourth mile south of Santa Fe Railroad Quarry, Osage County, Oklahoma:* U.S.N.M., one.

Numbered Specimens: Holotype, Y.P.M. No. 17113; figured paratypes, Y.P.M. No. 17114, U.S.N.M. Nos. 119122, 119123a, 119124; unfigured paratypes, U.S.N.M. Nos. 119123b–119123h.

Omphalotrochus hessensis Yochelson, new species

Plate 16, figures 1–7

Description: Trochiform gastropods with a long prong on outer whorl face and with the sutures of juvenile whorls strongly impressed;

TABLE 16

Measurements of *Omphalotrochus wolfcampensis* Yochelson, New Species

	Height	Width	H.A.	W.A.	Locality
Holotype	>35	55.5	20.3	21.1	93
Paratype	>20	32.8	11.9	—	708t
Paratype	25[a]	25.6	—	—	708t
Paratype	—	37.2	8.0	—	3360
Paratype	>25	38.5	11.3	—	701d
Unfigured paratype	15.2	20.7	—	—	702x
Unfigured paratype	>27	44.4	11.9	—	708t

[a] Estimated.

protoconch unknown; sutures distinct, distinctly overhung by earlier whorls up to the mature stage; whorl shape changing markedly with growth stage, the juvenile stage being marked by an upper whorl surface that is gently arched outward and strongly downward to near edge, where there is a distinct upward turn so as to form a thickened rounded periphery; bending strongly inward below periphery, the more mature stage developing a flattened area for the upper one-fifth of the upper whorl surface, having the outer edge less strongly produced upward and having the outer whorl face more nearly vertical; the mature whorl horizontal from suture for a short distance, at the edge of this area there being a thickened ridge, below ridge, the shell bending downward and outward, following a concave upward curve for a short distance to a thickened, ill-defined ridge, continuing downward and gradually flattening to the thickened edge of the upper whorl surface, below which the outer whorl face continues downward, vertical or following a concave outward curve to well-rounded periphery, there finally turning strongly inward and downward, following a convex outward curve to umbilicus; moderately widely phaneromphalous, the umbilical walls being nearly straight, but without a distinct funicle; upper lip in mature stage prosocline, forming an 80-degree angle with tangent to suture to uppermost ridge, then curving backward in a shallow but distinct sinus to near the center of second ridge, next proceeding forward, forming a 20-degree angle with edge, thus forming a distinct prong, the outer lip orthocline to just above periphery, there turning strongly prosocline 40 degrees from horizontal, and the basal lip being inclined strongly backward for one-third of the distance to umbilicus and finally following a sinuate course into the umbilicus; columellar lip arcuate, not reflexed, slightly thickened at juncture with basal lip, becoming less so with increasing maturity; ornamentation consisting of rugosities of some growth lines in mature and gerontic individuals, some specimens also developing rugosities on the periphery which may result in distinct crenulations or even incipient spines.

Discussion: The strong impression of the sutures in the juvenile stage serve to separate this species from other *Omphalotrochus*, except one poorly known species from the Bone Spring limestone. To a lesser extent this feature is present in *O. obtusispira* (Shumard) and *O. cochisensis*, but the pleural angle of these two species is generally smaller and the overhang of the individual whorls is less well developed. Although there are only two specimens of *O. hessensis* well enough preserved for the pleural angle to be measured at all growth stages, there appears to be less change of this angle with increasing maturity in the species than in the other species observed.

The shape of the aperture with its extremely shallow sinus and prominent prong at the juncture of upper and outer whorl faces separates this species from *O. wolfcampensis* and *O. whitneyi* (Meek). Growth lines are different on the base of all three of these species, being most sinuate on *O. hessensis*.

One of the more interesting aspects of this species is the large variation among individuals. Specimens vary particularly from one another in the character of the outer edge of the upper whorl face. In some specimens, this

TABLE 17

Measurements (in Millimeters) of *Omphalotrochus hessensis* Yochelson, New Species

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	65[a]	84.0	96°	27.3	—	702f
Paratype	—	76.0	—	—	—	702d
Paratype	—	75.5	—	—	—	702d
Unfigured paratype	56[a]	73.3	100°	25.7	27.8	702d

[a] Estimated.

area is smooth, in others it is wrinkled, and in still others it is so crenulated that short scoop-like spines opening anteriorly have been formed. In this feature, *Omphalotrochus hessensis* converges towards *O. spinosus*, but in most other characters these two species are quite different.

HYPODIGM: Twenty-two specimens, as listed below. Most specimens from the Hess limestone member of the Leonard formation are only fairly preserved, but a few are excellent. The specimen from the Hueco limestone is incomplete and is only tentatively referred to the species.

OCCURRENCE: *Hueco limestone:* A.M.N.H. 700, one. *Colina limestone* (?): U.S.G.S. 5314, five. *Leonard formation, Hess limestone member:* U.S.N.M. 702d, 11; U.S.N.M. 702f, one; U.S.G.S. 6690, four.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119133; figured partypes, U.S.N.M. Nos. 119134a, 119134b, 119135a, 119135b; unfigured paratypes, U.S.N.M. Nos. 119134c–119134j, 119135c.

Omphalotrochus spinosus Yochelson, new species

Plate 14, figures 11–13

DESCRIPTION: Trochiform gastropods with large, short, spout-like spines on periphery; protoconch and early whorls unknown, but shell seemingly low spired; sutures distinct between spines of whorl above, otherwise covered; whorl shape essentially simple, curving outward and downward from suture, flattening to horizontal near periphery, then turning to vertical on outer whorl face, below which bending sharply inward so that basal whorl surface is flattened, this simple profile being interrupted by the periodic development of spines, the spines starting above what would be the periphery and proceeding strongly outward, their outer edge pointed in juvenile stage but somewhat blunted in mature stage, the basal edge of the spines inclined inward and downward to juncture with bottom of vertical outer whorl face; the base of the spine often concave, and the front of the spines always open, forming a channel; widely phaneromphalous, the umbilical walls straight, inclined inward; outer lip curving gently to near center of upper whorl surface and then gently prosocline, the basal lip being somewhat more parasigmoidal; outer lip nearly vertical on outer whorl face or bending outward and backward to form a spine; the spine having its upper edge projecting forward above the lower; juncture of basal and columellar lips thickened; no ornamentation other than wide spines spaced closely and evenly.

MEASUREMENTS: The measurements of the holotype, from A.M.N.H. 628, are: width, 50 mm.; H.A., 15.6 mm.; W.A., 16.9 mm.

DISCUSSION: *Omphalotrochus spinosus* is readily separated from all other known species of the genus by the pronounced development of spines. This feature is developed to a much smaller degree in *O. hessensis*, and that species differs further in developing a pronounced prong on the outer whorl face. The character of the umbilicus and umbilical walls of this species shows similarities to *O. wolfcampensis*.

The remarkable spines of this species may have developed from a crenulated prong on the outer whorl face, such as is seen in *O. hessensis*. The outer whorl face continued to develop within each spine, possibly after it had reached a large size, so that none of the spines on the holotype open posteriorly into the shell. The spines were possibly used in directing water out of the mantle cavity, and as the animal continued to grow, new spines were developed and then subsequently sealed.

HYPODIGM: A single incomplete silicified specimen as listed below.

OCCURRENCE: One specimen, A.M.N.H. 628, Bone Spring limestone.

NUMBERED SPECIMEN: Holotype, A.M.N.H. No. 27941:1.

Omphalotrochus species

Plate 18, figures 11–14

In addition to *Omphalotrochus spinosus*, another species of this genus is known from beds just above the boundary of the Hueco limestone in the Sierra Diablo. Of the few specimens known, most are incomplete juveniles, and the species does not warrant a formal name.

In the juvenile stages, specimens have sutures strongly impressed, so that the whorl shape is similar to that of young *O. obtusispira*. At a slightly later stage, the basal whorl surface becomes rounded, and there is a pronounced thickening of the juncture of the basal and columellar lips. In the mature stage the basal surface is somewhat more flattened. Growth lines in the mature stage form a 70-degree angle to the tangent of the suture and proceed backward for the upper one-third of the upper whorl surface, there bending forward and proceeding to periphery.

HYPODIGM: Sixteen specimens, as listed below. All are silicified, and all are incomplete.

OCCURRENCE: *Bone Spring limestone:* U.S.N.M. 716, five; A.M.N.H. 625, nine; A.M.N.H. 629, two.

NUMBERED SPECIMENS: Figured specimens, U.S.N.M. Nos. 119136a, 119136b, A.M.N.H. No. 27942:1.

BABYLONITES YOCHELSON, NEW GENUS

Babylonites turritus Yochelson, new species

Plate 18, figures 1–10

DESCRIPTION: Trochiform gastropods with thickened periphery; protoconch probably planispiral, with flattened whorls; sutures distinct, not impressed; pleural angle seemingly variable among specimens; upper whorl surface from suture flattened, gently convex outward to near periphery, this surface becoming more distinctly convex in mature stage, with greatest curvature at above middle of this segment, the periphery commonly thickened and bluntly irregular, or with a shallow depression in the thickened area so as to give the appearance of a peripheral carina, below periphery the basal whorl surface gently arched, almost flat in mature stage; moderately phaneromphalous; the umbilicial walls vertical or inclined outward so that there is a stair-step appearance when umbilicus is examined; upper lip prosocline, forming a 60-degree angle with tangent to suture for upper one-third of whorl surface, gradually curving in a broad sinus, becoming opisthocline to a sharp peripheral salient corresponding to the prong of *Omphalotrochus*, forming an angle of 60 degrees to 70 degrees with periphery; basal lip generally prosocline but bearing a broad, exceedingly shallow sinus; columellar lip not thickened; ornamentation lacking; color pattern consisting of a dark band on base surrounding umbilicus and a similar dark band near periphery, extending upward to just above periphery with lighter areas between these two regions.

DISCUSSION: *Babylonites turritus* is readily separated from *B. carinatus* by its straight or convex rather than concave upper whorl surface and by its wider umbilicus. The "carina" sometimes developed by a depression in the thickened periphery of this species is not nearly so distinct as is the carina of *B. carinatus*. Development of a sharpened periphery such as characterizes *B. acutus* seems to be a feature that is limited to the gerontic stage of *B. turritus*, and even then the periphery is not so sharp as in the latter species. This species is separated with great difficulty from *B. conicus* but appears to differ in having the periphery less well rounded and in being somewhat higher spired than *B. conicus*.

Babylonites turritus is so variable that certain specimens exhibit some of the distin-

TABLE 18

MEASUREMENTS (IN MILLIMETERS) OF *Babylonites turritus* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	—	38[a]	68°	12.8	14[a]	702
Figured paratype	—	23.0	61°	6.6	—	707q
Figured paratype	14.0	16[a]	58°	6.1	—	707q
Figured paratype	22[a]	25.5	65°	8.6	—	20G
Figured paratype	23[a]	30.9	67°	9[a]	10.5	702
Figured paratype	11[a]	19.0	79°	6.2	7.9	702
Unfigured paratype	13[a]	19.8	81°	—	—	702
Unfigured paratype	14[a]	20.2	70°	—	—	702

[a] Estimated.

guishing characteristics of other species described herein and, consequently, this species is difficult to characterize. It can be distinguished in that a sample of several specimens will show many individual differences, whereas specimens of other *Babylonites* species will be remarkably constant in their characters.

Much of the basis for description of this species is derived from study of two collections from U.S.N.M. 702 and 707q, both Leonard formation. When first examined, these two collections presented an astounding variety of shell forms from high spired to lenticular. After much study, the most logical explanation for this variation seemed to be that this was a species which was somewhat variable in pleural angle and character of periphery, features that were quite constant in other species of the genus. Differential compaction subsequently had emphasized differences by modifying the shape of individual shells. Some lenticular specimens show radial cracks indicative of crushing, but others do not.

It was assumed that only one species was present, so these two collections were then used as a standard for variation, both natural and that caused by fossilization. On the basis of this standard, other smaller collections were referred to this species. It is freely admitted that the results are not entirely satisfactory, but it seemed better that one variable species be named, than that the 10 or 12 otherwise necessary to include these specimens should be named. Supplementary evidence in favor of one variable species is that the same color pattern is on all specimens from U.S.N.M. 707q on and several specimens from U.S.N.M. 702 (Cooper, personal comunication). Study of a large suite of specimens of *B. ferrieri* (Girty) suggests that it is at least as variable as *B. turritus*.

HYPODIGM: Seventy-four specimens, as listed below. Most are crushed, and many are incomplete or beekitized so as to obscure finer details.

OCCURRENCE: *Bone Spring limestone:* P.U. 5, four; P.U. 20G, 13; A.M.N.H. 592, two; U.S.G.S. 7055, three. *Leonard formation:* U.S.N.M. 702, 18; U.S.N.M. 702b, two; U.S.N.M. 702un, two; U.S.N.M. 703a, two; U.S.N.M. 703b, two; U.S.N.M. 703d, four; U.S.N.M. 707q, 15; Y.P.M. 2, three; Y.P.M. 7, one; Y.P.M. 128, one; Y.P.M. 174, three. *Word formation:* U.S.N.M. 703, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119137; figured paratypes, U.S.N.M. Nos. 119138a, 119138b, 119139a, 119139b, 119140; unfigured paratypes, U.S.N.M. Nos. 119139c–119139s.

Babylonites carinatus Yochelson, new species

Plate 19, figures 1–9

DESCRIPTION: Trochiform gastropods with prominent carina on upper whorl surface parallel to periphery; protoconch low spired, with flattened whorls; sutures shallow, partially concealed by slight eave-like overhang of edge of preceding whorl; upper whorl surface gently concave, inclined 30-degrees from vertical to two-thirds of the distance down from the suture, then flattening abruptly, this flattening being followed by a rapid steepening so as to form a prominent sharp carina, the slope below carina following a curve strongly concave upward to periphery, some specimens having carina gradually flattening with age until it is no longer present in gerontic stage; juncture of upper and basal surfaces forming an extremely sharp periphery; basal whorl surface distinctly flattened, to edge of sharp circumbilical angulation; narrowly phaneromphalous, becoming more restricted in mature and gerontic stages of some specimens; upper lip from suture gently prosocline, gradually curving and then sweeping forward, following a shallow concave curve to the carina, the center of the sinus formed being halfway between suture and carina, crossing carina and proceeding orthocline to periphery; basal lip prosocline, following a gentle parasigmoidal curve along inner two-thirds of basal surface; juncture of columellar and lower lips thickened; columellar lip reflexed and thickened; ornamentation consisting of one revolving carina parallel to periphery.

DISCUSSION: The sharp periphery of the whorl readily separates this species from *Babylonites conicus*, while the distinct carina paralleling the edge differentiates it from most other known species.

The species appears to be most closely related to *B. conicus* and *B. acutus*, but in addition to the differences noted above, *B. carinatus* can be distinguished by its slightly smaller pleural angle. The umbilical opening

TABLE 19

MEASUREMENTS (IN MILLIMETERS) OF *Babylonites carinatus* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	21[a]	26.9	67°	8.8	12.1	706b
Figured paratype	—	51.9	66°	16.3	23.8	706b
Figured paratype	46[a]	32[a]	81°	—	—	706e
Figured paratype	—	14[a]	67°	—	—	706e
Figured paratype	—	22.8	63°	8.1	—	18
Figured paratype	4.6	8.0	91°	2.3	3.6	706
Figured paratype	2.7	5.8	108°	1.8	2.7	706

[a] Estimated.

is considerably narrower in this species than in other species of the genus. In the mature stage, the umbilical opening of some specimens is restricted by the thickening of the basal and columellar lips.

The specimen figured by Knight (1953) from Sonora differs from *B. carinatus* in having a smaller pleural angle. In view of the constancy of this angle exhibited by the west Texas specimens, it seems probable that the Sonora specimen is a new species. The Mexican specimen is incomplete and does not warrant a formal name or additional description and illustration.

HYPODIGM: Seventy-nine specimens, as listed below. All except four of the Yale specimens have been etched in the laboratory and all are quite good, although most are broken specimens.

OCCURRENCE: *Word formation:* K.U. 11, five; K.U. 18, three; U.S.N.M. 706, one; U.S.N.M. 706b, 30; U.S.N.M. 706c, 11; U.S.N.M. 706e, six; Y.P.M. 4, one; Y.P.M. 142, one; Y.P.M. 242, one; Y.P.M. 252, two; A.M.N.H. 505, three. *Cherry Canyon formation:* A.M.N.H. 512, four; A.M.N.H. 537, two; A.M.N.H. 600, two; K.U. 31, one; U.S.N.M. 728, six.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119141; figured paratypes, U.S.N.M. Nos. 119142a, 119142b, 119143a, 119143b, 119144a, 119144b; unfigured paratypes, U.S.N.M. Nos. 119142c–119142s.

Babylonites acutus Yochelson, new species

Plate 19, figures 10–17

DESCRIPTION: Trochiform gastropods with sharpened periphery in mature stage; protoconch unknown; sutures distinct, just overhung by earlier whorls in juvenile stage; upper whorl surface profile very gently arched for most early growth stages, inclined nearly 30 degrees from vertical just before reaching periphery, bending upward slightly and then downward again to form a low carina, the carina becoming less distinct with age and not present in the gerontic stage of some specimens; the profile of the mature whorl following a convex curve, diverging most markedly from straight near the upper suture; the juncture of upper and basal whorl surfaces exceedingly sharp, with the basal surface gently arched in the juvenile stage but distinctly flattened in maturity; moderately phaneromphalous, the umbilical walls inclined outward; upper lip prosocline from suture for one-fourth of upper surface, then gradually curving forward and proceeding straight down whorl, forming an 80-degree angle with periphery, the result being to form a shallow asymmetric sinus on upper whorl surface; basal lip generally prosocline, becoming gently parasigmoidal just before joining umbilicus; columellar lip seemingly not thickened or reflexed; ornamentation consisting of carina near periphery.

DISCUSSION: The sharpened periphery readily separates this species from *Babylonites conicus* and *B. ferrieri* (Girty). At first glance, *B. acutus* appears to be closely related to, if not conspecific with, *B. carinatus*, but the two species can be readily separated by several features. The umbilicus of this species is much wider, the pleural angle is slightly larger, the eave-like overhang is absent, and the sinus of the growth lines is much shal-

TABLE 20

MEASUREMENTS (IN MILLIMETERS) OF *Babylonites acutus* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	12.5	18[a]	68°	6.5	8.0	706
Figured paratype	34[a]	38.1	68°	11.8	13.9	Mexico
Figured paratype	23[a]	27.8	72°	10.0	11.4	706c
Figured paratype	—	31[a]	71°	12.2	17.2	707e
Unfigured paratype	15.1	19.4	65°	6.2	—	706c
Unfigured paratype	6.7	9.1	72°	7.0	5.5	706c

[a] Estimated.

lower and located higher on the whorl than in *B. carinatus*. The carina in the side appears to be much closer to the periphery in *B. acutus* than in *B. carinatus*, but this feature may not be significant. In spite of these differences, it seems best not to attempt to refer isolated juveniles to one species or the other. The umbilicus is relatively narrower than that of *B. conoideus* (Girty).

The single Mexican specimen listed below has a smaller pleural angle and a more pronounced carina than is typical of the species. Growth lines and umbilicus are similar to those of the west Texas specimens.

HYPODIGM: Nineteen specimens, as listed below. All but the Mexican specimen are silicified, and most, though incomplete, are moderately well preserved.

OCCURRENCE: *Word formation:* U.S.N.M. 706, one; U.S.N.M. 706c, 12; U.S.N.M. 707e, three; K.U. 27, two. *Monos formation:* U.S.N.M., arroyo near Aguaje, 2 miles east of Puerto de las Sardinas, Las Delicias, Coahuila, Mexico, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119145; figured paratypes, U.S.N.M. Nos. 119146a, 119147a, 119148; unfigured paratypes, U.S.N.M. Nos. 119146b–119146m, 119147b–119147d.

Babylonites conicus Yochelson, new species

Plate 19, figures 18–23

DESCRIPTION: Conical gastropods with periphery thickened and well rounded; protoconch probably low spired; suture shallow, distinct, just overhung by rounded periphery of whorl above; upper whorl surface very gently convex, inclined outward 30 degrees to 40 degrees from vertical to near edge of whorl where there is an abrupt turn outward to periphery, which is thickened and rather well rounded; basal whorl surface gently convex, almost flat to near edge of sharp circumbilical angulation; narrowly phaneromphalous, the umbilical walls straight, inclined outward; upper lip prosocline from suture, curving backward for one-third of the distance of the whorl surface, then curving smoothly forward opisthocline along remainder of upper whorl surface, turning either vertical or gently prosocline at periphery, the basal lip being prosocline, nearly radial to umbilicus in juvenile stage, or following a gently parasigmoidal curve in late mature stage; junction of columellar lip and basal lip slightly thickened; columellar lip thickened and very slightly reflexed; ornamentation lacking.

DISCUSSION: Besides lack of a carina parallel to the edge, *Babylonites conicus* differs from *B. carinatus* in being significantly lower spired, although this may not be evident from measurement of the pleural angle. The thickened, well-rounded periphery separates it from *B. acutus*, *B. conoideus* (Girty), and *B. ferrieri* (Girty). This periphery is somewhat more rounded than that found in specimens of *B. conicus* that have this suture developed.

HYPODIGM: Twenty-six specimens, as listed below. Almost all have been etched in the laboratory, and the preservation is generally good, although most specimens are incomplete.

OCCURRENCE: *Word formation:* K.U. 11, one; K.U. 18, one; U.S.N.M. 706b, 17;

TABLE 21

Measurements (in Millimeters) of *Babylonites conicus* Yochelson, New Species

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	—	26.5	67°	8.4	10.7	706c
Figured paratype	15[a]	19.0	76°	6.8	8.4	18
Figured paratype	—	18.6	75°	6.3	7.3	706b
Unfigured paratype	—	19.4	66°	6.4	8.5	706b

[a] Estimated.

U.S.N.M. 706c, two; U.S.N.M. 706e, one. *Cherry Canyon formation:* A.M.N.H. 512, four.

Numbered Specimens: Holotype, U.S.N.M. No. 119149; figured paratypes, U.S.N.M. Nos. 119150a–119150b; unfigured paratypes, U.S.N.M. Nos. 119150c–119150q.

DISCOTROPIS Yochelson, new genus

Discotropis girtyi Yochelson, new species

Plate 20, figures 1–7

Description: Low-spired gastropods with shelf on outer whorl face; sutures narrow, shallow; upper whorl surface changing markedly with growth stage as follows: juvenile stage having a distinct but rounded keel rising above suture, the surface then falling outward and downward along outer side of keel, abruptly turning horizontal to form a ramp or shelf for most of upper whorl surface; mature upper whorl surface beginning level with previous suture, not rising to a keel, then following a sigmoidal curve downward and outward, a shelf being formed at the periphery, the net result being to produce a low-spired rather than a discoidal shell; below periphery, outer whorl face curving inward and smoothly joining distinctly flattened basal whorl surface, the juvenile whorls having shelf relatively lower so that basal surface is even less curved; moderately widely phaneromphalous, the umbilicus having fairly steep walls that are more sharply delineated in mature stages, but not developing a sharp circumbilical angulation; upper lip prosocline, forming a 60-degree angle tangent to surface, with suture gradually curving backward for one-third of upper whorl surface, then swinging forward and proceeding opisthocline to periphery, forming a 50-degree angle with it, crossing periphery and turning prosocline for a short distance, basal lip gently prosocline and proceeding straight, nearly radial, into umbilicus; ornamentation lacking.

TABLE 22

Measurements (in Millimeters) of *Discotropis girtyi* Yochelson, New Species

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	9.2	20.3	5.8	6.9	—	3
Figured paratype	4.9	17.0	4.8	5.7	85°22′	3
Figured paratype	4.0	14[a]	—	—	—	3
Figured paratype	3.3	9.3	3.2	—	—	433
	6.7	13.7	4.4	—	—	433
	4.7	11.1	3.7	4.3	84°14′	433
	3.8	10.7	3.1	—	85°38′	433
	4.0	9.2	—	—	—	433
	7.8	19.3	—	—	—	433

[a] Estimated.

DISCUSSION: The low spire of the mature shell and the oblique outer whorl face readily separate *Discotropis girtyi* from all other species of this genus. *Discotropis girtyi* is quite similar and closely related to *D. publicus*, with ontogenetic development of the shelf on the outer whorl face being similar in both species. They are considered to be separate species because of the low spire of *D. girtyi;* this distinction cannot be recognized in juvenile specimens. *Discotropis girtyi* appears to be more narrowly phaneromphalous than *D. publicus*, but it is doubtful if this difference can be used to identify isolated immature specimens.

Silicified inner shell layers found associated with specimens of this species at several localities show that this genus is also subject to the differential silicification which is so common in the Euomphalidae. These specimens also suggest the presence of two or more distinct shell layers.

HYPODIGM: Twenty specimens, as listed below. All are silicified, and most are in a fair state of preservation.

OCCURRENCE: *Bone Spring limestone:* A.M.N.H. 433, 12; A.M.N.H. 592, one; P.U. 3, seven.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119151; figured paratypes, U.S.N.M. Nos. 119152a, 119152b, A.M.N.H. No. 27943:1; unfigured paratypes, U.S.N.M. Nos. 119152c–119152f.

Discotropis sulcifer (Girty)

Plate 20, figures 8–19

Euomphalus sulcifer GIRTY, 1909, p. 482, pl. 16, figs. 23–24a.

Euomphalus sulcifer variety *angulatus* GIRTY, 1909, p. 483, pl. 16, figs. 25–25a.

Non Euomphalus sulcifer Girty, NEWELL AND OTHERS, 1953, pl. 23, figs. 21–23.

Non Euomphalus sulcifer angulatus Girty, NEWELL AND OTHERS, 1953, pl. 23, fig. 40.

DESCRIPTION: Low-spired, widely phaneromphalous gastropods with flange low on side of whorl; protoconch discoidal, with rounded whorls, gradually developing a flange on outer whorl face; upper sutures distinct, commonly not impressed; whorl profile from suture straight for three-fifths of upper whorl surface, rising at an angle of 30 degrees from horizontal in juvenile stage, approaching horizontal in mature stage and inclined downward in late mature and gerontic stages where body whorl is produced downward at upper edge of outer whorl face, bending abruptly downward, nearly vertical for approximately half of the distance of preceding area and next bending abruptly outward to form a nearly horizontal flange, the over-all effect being to give a distinctly angulated profile in early mature specimens, crossing flange to periphery and proceeding straight inward along under surface of flange to basal whorl surface proper, the juncture of these two separated by a narrow depression in some specimens, the basal whorl surface gently arched; widely phaneromphalous, the umbilical angle approaching 90 degrees in mature stage; upper lip varying from nearly orthocline in juvenile stage to prosocline, forming a 60-degree angle with tangent to suture in mature stage, gradually curving, crossing upper surface so as to form almost a right angle with outer edge of upper whorl surface, outer lip opisthocline, 10 degrees to 15 degrees forward of vertical, bending forward at juncture with flange and proceeding opisthocline, forming a 50-degree angle with periphery, basal lip following same inclination on basal surface of flange to juncture with base, there turning to nearly radial and proceeding into umbilicus; ornamentation lacking.

DISCUSSION: *Discotropis sulcifer* is readily separated from *D. girtyi* and *D. publicus* in being much more widely phaneromphalous. The shell is low spired and thus bears some similarity to that of *D. girtyi*, but the shape, with a nearly vertical outer whorl face and a pronounced flange low on the wall, is quite distinctive and different. This flange appears to be lower than in other species of the genus, and consequently the basal surface in the juvenile stage is more flattened. Even so, extreme caution should be used in identifying immature specimens with this species.

Preparation of one of the cotypes of *Euomphalus sulcifer* Girty has revealed that the "peripheral rim" is in reality a flange on the side, mashed and bent upward so that it appears to be part of the upper surface. The specimen, thus interpreted, is similar to *Euomphalus sulcifer* variety *angulatus*, and the names accordingly have been synonymized. The species, thus interpreted, is clearly referable to *Discotropis*.

If the atypical specimen illustrated in plate

TABLE 23

MEASUREMENTS (IN MILLIMETERS) OF *Discotropis sulcifer* (GIRTY)

	Height	Width	H.A.	W.A.	Locality
Lectotype	12[a]	—	—	—	2930
Paratype	14[a]	—	—	—	2930
Hypotype	5.7	14.7	4.1	—	703
Hypotype	3.8	8[a]	—	—	703
Hypotype	7.4	19.0	5.0	6.7	703a
Hypotype	3.5	10.9	3.6	—	707e
	3.7	11.9	3.2	4.1	707e
	2.6	9.2	2.6	3.5	707e

[a] Estimated.

20, figures 12–14, is of the same species as other associated specimens figured, then the holotype of *Euomphalus sulcifer* variety *angulatus* is also of the same species. The cotypes of *Euomphalus sulcifer* also apparently belong to this group. While it is certainly not a good practice to identify specimens with types as poor as these, in the present case there is an exceedingly high probability that this identification is correct.

HYPODIGM: Twenty-four specimens, as listed below. Most are silicified, and many are incomplete, although several specimens are in excellent condition. Each of the three primary types listed below is concealed in part by limestone matrix, and one has been damaged by rough preparation work.

OCCURRENCE: *Leonard formation:* U.S.N.M. 702, one; U.S.N.M. 703, seven; U.S.N.M. 703a, two; U.S.N.M. 703b, one. *Word formation:* U.S.N.M. 707e, 10. *So-called Dark limestone, possibly Bell Canyon formation:* U.S.G.S. green 2930, three.

NUMBERED SPECIMENS: The syntype of *Euomphalus sulcifer* showing the upper surface is here designated as lectotype. Lectotype, U.S.N.M. No. 119153; lectoparatype, U.S.N.M. No. 118366; figured hypotypes, U.S.N.M. Nos. 119154a, 119154b; unfigured hypotypes, U.S.N.M. No. 119154c–119154h, 119155b, 119156b–119156j. The holotype of *Euomphalus sulcifer* variety *angulatus* Girty is U.S.N.M. No. 118367.

Discotropis publicus Yochelson, new species

Plate 21, figures 1–11

Euomphalus sulcifer angulatus Girty, NEWELL AND OTHERS, 1953, pl. 23, fig. 40.

DESCRIPTION: Moderately widely phaneromphalous, planispiral gastropods with upper whorl surface of all whorls rising to essentially the same deviation; protoconch planispiral, with rounded whorls, very slightly depressed; sutures narrow, shallow, indistinct; upper whorl surface rising straight from suture at approximately a 30-degree angle in early maturity to a vertical keel, at a lower angle to horizontal in earlier, postnuclear whorls, the keel rising to approximately the same elevation in all growth stages, below peripheral keel outer whorl face is straight, inclined approximately 30 degrees outward from vertical for almost half of its total distance, then turning abruptly outward so that a nearly horizontal shelf is formed, turning sharply downward below this shelf and curving smoothly into a flattened base following a curve convex outward, except in juvenile stages having a horizontal under surface to shelf so that shelf protrudes from side of whorl as a distinct flange; moderately widely phaneromphalous, umbilical angle varying from near 90 degrees in juvenile stage to almost 60 degrees in mature stage, the walls and edge of umbilicus becoming steeper and sharper with maturity; upper lip prosocline, forming a 60-degree angle with tangent to suture and proceeding across upper whorl surface to keel, outer lip below keel opisthocline 20 degrees from vertical to near shelf, there then being a slight increase in the forward curvature, opisthocline crossing shelf, forming a 60-degree angle with periphery, bending to prosocline and continuing down lower half of outer whorl face, turning smoothly at base and proceeding prosocline straight into umbilicus; ornamentation lacking.

DISCUSSION: The gentle slope of the upper whorl surface, combined with the relatively constant height of the keel, readily distinguishes this species from others referred to the genus. In particular, *Discotropis publicus* is lower spired than *D. girtyi* and more narrowly phaneromphalous than *D. sulcifer* (Girty).

One of the most interesting features of the ontogeny of this species is the horizontal shelf on the outer whorl face. From the growth series shown on plate 21 it may be seen that the juvenile stage is characterized by a distinct flange. The next step is a rapid filling out of the lower half of the whorl, so that the flange effect is almost lost. In spite of this rapid early growth, the distinct shelf is not complete until near maturity. Coupled with this remarkable change of the side, the umbilicus naturally changes markedly. In the early stages of growth, all whorls are rounded; in maturity, the umbilical walls steepen.

Even though complete observations have been made on only a few species of the west Texas fauna, there appears to be considerable ontogenetic change in all species of Permian Omphalotrochidae. Indeed, it seems reasonable to state that in most cases species cannot be differentiated with any certainty from juvenile specimens alone.

For some unknown reason at A.M.N.H. 512, where this species is so abundant, *Babylonites carinatus* is rare. In the Glass Mountains where *B. carinatus* is more common, *Discotropis publicus* is uncommon.

HYPODIGM: One hundred and sixty-eight specimens, as listed below. All are silicified, and preservation of many specimens is excellent.

TABLE 24

MEASUREMENTS (IN MILLIMETERS) OF *Discotropic publicus* YOCHELSON, NEW SPECIES

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	6.3	14.8	5.4	4.9	—	512
Figured paratype	1.6	5.1	1.6	1.6	82° 3′	512
Figured paratype	2.3	6.6	2.3	2.3	83°19′	512
Figured paratype	2.5	8.0	2.5	2.6	84°30′	512
Figured paratype	3.5	11.3	3.5	3.6	—	512
Figured paratype	5.7	13.1	—	—	85°15′	512
Figured paratype	8.5	18.2	7.7	6.6	—	512
Figured paratype	13.2	31.4	11.3	9.7	—	512
Unfigured paratype	8.0	22.0	7.3	6.3	—	728
Unfigured paratype	5.0	14.2	4.5	4.7	84°20′	728
Unfigured paratype	6.0	15.2	5.3	5.0	—	728
Unfigured paratype	3.2	8.0	3.1	3.2	—	728
Unfigured paratype	5.1	13.3	4.7	4.4	—	728
Unfigured paratype	5.5	12.9	5.5	5.5	84° 2′	728
Unfigured paratype	5.5	13.2	5.5	4.4	85° 0′	728
Unfigured paratype	5.8	14.5	5.7	4.8	—	728
Unfigured paratype	1.9	5.7	1.9	1.9	82°54′	728
Unfigured paratype	2.5	7.5	—	—	83°38′	728
Unfigured paratype	4.6	12.3	4.4	4.1	83°44′	728
Unfigured paratype	4.8	12.8	4.5	4.4	84°22′	728
Unfigured paratype	4.2	11.3	4.2	3.9	—	728
Unfigured paratype	5.2	11.7	—	—	85°43′	728
Unfigured paratype	6.1	14.2	—	—	—	728
Unfigured paratype	5.7	13.2	5.4	4.7	—	728
Unfigured paratype	5.6	14.0	5.3	5.4	85°18′	728
Unfigured paratype	2.5	7.7	2.5	2.9	83°48′	728
Unfigured paratype	5.3	13.7	5.0	4.7	—	728

TABLE 24—(*continued*)

	Height	Width	H.A.	W.A.	V.	Locality
Unfigured paratype	5.4	12.8	5.4	4.2	—	728
Unfigured paratype	5.1	13.2	—	—	—	728
Unfigured paratype	4.1	11.2	3.9	3.9	84° 6′	728
Unfigured paratype	1.6	8.6	—	—	84° 2′	728
Unfigured paratype	7.8	2.8	2.5	2.7	84°22′	728
Unfigured paratype	4.7	12.3	4.4	4.0	—	728
Unfigured paratype	2.3	6.6	2.3	2.2	—	728
Unfigured paratype	3.6	10.5	3.1	2.9	84°46′	728
Unfigured paratype	3.7	9.8	3.6	3.6	—	728
Unfigured paratype	5.1	12.5	4.7	4.1	—	728
Unfigured paratype	3.9	12.5	—	—	—	728
Unfigured paratype	2.8	8.8	2.6	2.6	82°29′	728
Unfigured paratype	—	7.9	—	—	83°20′	728
Unfigured paratype	2.5	7.6	2.5	2.6	84°35′	728
Unfigured paratype	2.3	7.0	2.2	2.2	84°32′	728
Unfigured paratype	3.8	11.1	3.7	3.6	84°24′	728
	5.4	13.5	5.0	4.4	—	512
	6.9	15.4	6.3	5.0	—	512
	3.4	9.1	2.6	3.2	—	512
	5.1	13.2	5.1	3.5	—	512
	4.4	12.9	4.1	4.1	—	512
	3.5	9.9	2.9	3.4	85°56′	512
	3.2	9.2	3.2	3.2	83°37′	512
	2.2	6.6	2.2	2.3	—	512
	6.1	14.9	5.7	4.7	—	512
	4.4	10.2	—	—	85°42′	512
	4.3	12.5	—	—	—	512
	3.9	11.1	—	—	—	512
	3.1	8.9	2.8	2.9	84°39′	512
	4.2	12.6	4.1	4.1	—	512
	3.4	8.8	3.4	3.2	83°19′	512
	3.7	10.1	3.5	3.6	—	512
	3.5	10.1	—	—	85°18′	512
	5.1	12.2	—	—	84°36′	512
	2.7	7.7	2.7	2.5	—	512
	4.7	12.5	4.3	3.4	84°26′	512
	2.0	6.6	2.0	2.2	—	512
	6.6	15.8	—	—	—	512
	6.5	15.6	5.6	4.8	—	512
	3.8	10.1	3.8	3.5	—	512
	3.5	10.5	3.4	3.4	84°46′	512
	2.7	9.1	2.6	2.8	—	512
	4.5	12.3	4.5	4.2	—	512
	4.1	10.8	3.6	3.6	85°15′	512
	2.2	6.3	2.0	2.2	—	512
	3.8	11.1	3.4	3.6	84°23′	512
	3.8	12.8	—	—	—	512
	3.4	10.4	3.1	3.1	84°25′	512
	4.4	11.1	3.7	3.6	—	512
	3.1	9.2	3.1	3.2	83°37′	512
	3.6	10.5	3.2	3.5	—	512
	4.1	10.5	—	—	85°58′	512
	3.7	10.4	3.5	3.6	—	512
	3.1	9.8	—	—	—	512

TABLE 24—(*continued*)

	Height	Width	H.A.	W.A.	V.	Locality
	2.6	7.4	2.2	2.5	82°40′	512
	2.2	7.9	—	—	—	512
	2.2	6.7	2.1	2.2	83°59′	512
	2.8	8.9	2.6	2.6	—	512
	2.3	7.9	2.2	2.2	79°17′	512
	3.1	8.2	2.8	2.5	80°52′	512
	4.5	11.6	—	—	—	512
	4.5	11.4	—	—	84°15′	512
	2.9	9.0	—	—	—	512
	2.5	8.0	—	—	85°26′	512
	3.5	10.2	3.0	3.2	84°58′	512
	3.1	9.8	3.1	3.4	—	512
	3.6	9.7	3.6	3.2	—	512
	2.3	7.6	2.3	2.6	84°12′	512
	2.9	8.3	2.8	3.1	84°16′	512
	3.1	9.7	2.9	3.1	—	512
	1.6	5.3	—	—	83°46′	512
	2.3	7.2	2.3	2.3	—	512
	1.9	5.5	1.8	1.6	84° 0′	512
	1.8	6.0	—	—	83°53′	512
	7.9	14.4	—	—	—	512
	1.9	5.5	—	—	—	512
	1.3	3.8	—	—	82°15′	512

Height aperture-width aperture, A.M.N.H. 512 and U.S.N.M. 728

$N=$ 75	$Sy=1.07$ mm.
$Mx=$ 3.54 mm.	$r=0.89$
$My=$ 3.46 mm.	$ORx=1.6$ mm.–7.7 mm.
$Sx=$ 1.33 mm.	$ORy=1.6$ mm.–6.6 mm.

Total height-total width, A.M.N.H. 512 and U.S.N.M. 728

$N=102$	$Sy=3.14$ mm.
$Mx=$ 3.81 mm.	$r=0.94$
$My=$ 10.49 mm.	$ORx=1.3$ mm.–8.0 mm.
$Sx=$ 1.55 mm.	$ORy=3.8$ mm.–22.0 mm.

OCCURRENCE: *Cherry Canyon formation:* U.S.N.M. 728, 57; A.M.N.H. 512, 84; A.M.N.H. 519, five; A.M.N.H. 600, two. *Bell Canyon formation:* A.M.N.H. 537, six; A.M.N.H. 397, six. *Word formation:* A.M.N.H. 505, one; U.S.N.M. 706b, one; U.S.N.M. 706c, six; Y.P.M. 4, one.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27944:1; figured paratypes, A.M.N.H. Nos. 27944:2–27944:8; unfigured paratypes, U.S.N.M. Nos. 119157a–119157hhh.

Discotropis species 1

Plate 20, figures 20–22

DISCUSSION: What may be still another species of *Discotropis* has been observed in the collections from west Texas. The specimens are generally similar to *D. publicus* in gross size and shape, but differ in having the juvenile whorls slightly raised rather than level or depressed. The upper whorl surface is correspondingly ramp-like and nearly horizontal, rather than strongly inclined upward. The outer whorl is nearly vertical as in the juvenile stages of *D. sulcifer*, but the flange is somewhat higher on the whorl than in that species. The base is gently arched, and the umbilicus is moderately phaneromphalous, quite as in *D. publicus*. Growth lines are not certainly known, except on the base, but again they are similar to those of the latter species. Because the small number of specimens available for study give little idea as to whether or not the differences noted are due only to individual variation, it seems best not to apply a formal name at this time.

MEASUREMENTS: The measurements of the figured specimen, from U.S.N.M. 706, are: height, 6.2 mm.; width, 13.9 mm. Those of an unfigured specimen from P.U. 53 are: height, 5 mm. (estimated); width, 11.8 mm.

HYPODIGM: Two well-preserved, silicified, but beekitized specimens, as listed below.

OCCURRENCE: *Word formation:* U.S.N.M. 706, one. *Bone Spring limestone:* P.U. 53, one.

NUMBERED SPECIMEN: Figured specimen, U.S.N.M. No. 119158.

Discotropis species 2

Plate 21, figures 12, 13

DISCUSSION: A single specimen from the west Texas area differs markedly from the other species described and deserves mention here without, however, being formally named. The gross shape of the specimen is similar to that of *Discotropis publicus*, but the upper surface is poorly known and the flange is shorter and higher on the whorl side. The most striking difference in shape is in the umbilicus, which is very widely phaneromphalous, with deep sutures, but flattened whorls, reminiscent of species of *Amphiscapha*. Growth lines are poorly known, being opisthocline just above flange and prosocline below. The outer edge of the basal surface is regularly and closely serrated or nodose. If this species is correctly referred to *Discotropis*, it is the only known species that shows any sort of ornamentation.

MEASUREMENTS: The measurements of the figured specimen, from U.S.N.M. 703a, are: height, 15.0 mm.; width, 5.1 mm.

HYPODIGM: A single silicified specimen, as listed below, the upper surface of which is covered by adhering silica.

OCCURRENCE: *Leonard formation:* U.S.N.M. 703a, one.

NUMBERED SPECIMEN: Figured specimen, U.S.N.M. No. 119159.

?Discotropis species 3

Plate 21, figures 14, 15

DISCUSSION: In addition to those species that are described herein, another species, somewhat atypical of the genus, is known. The specimen has an aperture similar to that of typical *Discotropis*, but the flange is poorly developed, and it may be that this represents a new genus. In any case, the material in hand does not warrant a formal name.

Protoconch and juvenile whorls are unknown. The mature upper whorl surface is markedly concave between the suture and the outer edge of the upper whorl surface, this outer edge being thickened and moderately well rounded. The outer whorl face is concave beneath the overhang of this thickened edge, but gradually curves outward to near mid-whorl, there bending abruptly horizontal to form a narrow shelf. Below this shelf, the outer whorl face curves in rapidly to join the flattened base. The specimen is phaneromphalous, with the umbilicus less open than in other species of the genus described.

Growth lines are prosocline on upper surface, forming nearly a 60-degree angle, with tangent to suture, turning to orthocline at thickened edge. Below this edge, growth lines are opisthocline, inclined nearly 45 degrees to shelf, turning to gently prosocline below shelf and proceeding almost straight into umbilicus.

MEASUREMENTS: The measurements of the figured specimen, from A.M.N.H. 410, are: height, 8 mm. (estimated); width, 14.0 mm.

HYPODIGM: A single incomplete, but moderately well-preserved silicified shell. Associated fragments of large gastropods are indeterminable.

OCCURRENCE: *Bell Canyon formation:* A.M.N.H. 410, one.

NUMBERED SPECIMEN: Figured specimen, A.M.N.H. No. 27945:1.

DIPLOCONULA YOCHELSON, NEW GENUS

Diploconula biconvexa Yochelson, new species

Plate 21, figures 16–23

DESCRIPTION: Low-spired gastropods, rudely biconvex in cross section but with largest proportion of height above mid-whorl; protoconch not certainly known, but probably discoidal with rounded whorls in most mature portion; upper sutures distinct, in some specimens overhung by periphery of whorl above, upper whorl surface following a curve very slightly convex outward from suture to relatively sharp periphery, the periphery becoming somewhat more rounded in mature stage; upper and basal whorl sur-

TABLE 25

MEASUREMENTS (IN MILLIMETERS) OF *Diploconula biconvexa* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	Locality
Holotype	10[a]	16.0	93°	702
Figured paratype	12[a]	17.4	91°	128
Figured paratype	8[a]	12.3	99°	703
Figured paratype	3.7	8.7	103°	703
Figured paratype	10[a]	16.5	100°	22-T-11
Unfigured paratype	2.9	6.5	119°	703
Unfigured paratype	4.1	7.7	104°	703
Unfigured paratype	6.2	6.0	107°	703
Unfigured paratype	6[a]	10.6	109°	702
	—	17.4	99°	702a
	4.2	8.3	110°	703d
	3.7	7.0	116°	703d
	5.1	8.5	106°	703d
	7[a]	14.3	93°	703d

[a] Estimated.

faces joining at an angle of nearly 60 degrees; basal whorl surface convex outward for a short distance below periphery, then flattened, very gently arched to rounded edge of umbilicus; deeply and narrowly phaneromphalous, the umbilicus becoming restricted in mature stage; upper lip prosocline, forming an 80-degree angle with tangent to suture and for one-fourth distance of upper whorl surface, curving gently forward and then proceeding nearly orthocline almost to periphery, the net effect being to produce a gently parasigmoidal, very nearly straight growth line on upper surface; basal lip forming a 60-degree angle with basal edge of periphery and proceeding gently prosocline into the umbilicus, the basal lip becoming gently parasigmoidal in gerontic stage; lower portion of columellar lip and inner portion of basal lip thickening in mature stage and projecting into the umbilicus and partially sealing it; ornamentation lacking.

DISCUSSION: The rudely biconvex cross section of this species readily separates it from other non-pleurotomarian species known in the Permian. Small specimens in which the basal surface is flattened are quite similar to juveniles of *Babylonites*, and one must be extremely cautious in identifying single small specimens.

Diploconula biconvexa exhibits some little variation both in the pleural angle and in the stage at which the umbilicus becomes restricted. Even when not restricted, the umbilicus is hardly more than quite narrow. This characteristic umbilicus serves further to separate the species from species of *Babylonites* and *Discotropis*.

HYPODIGM: Fifty-four specimens, as listed below. All are silicified, and most of those specimens that show gross shape do not show growth lines because of beekitization.

OCCURRENCE: *Leonard formation:* U.S.N.M. 702, six; U.S.N.M. 702a, one; U.S.N.M. 703b, one; U.S.N.M. 707b, three; A.M.N.H. 500, one; Y.P.M. 128, one. *Word formation:* U.S.N.M. 703c, four; U.S.N.M. 703, 21; U.S.N.M. 703d, 11; A.M.N.H. 503, two; P.C. 22-T-11, three.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119160; figured paratypes, U.S.N.M. Nos. 119162a, 119162b, Y.P.M. No. 17115, B.E.G. No. 13559; unfigured paratypes, U.S.N.M. Nos. 119161a–119161e, 119162c–119162t.

SUPERFAMILY **TROCHONEMATACEA** ZITTEL, 1895

FAMILY **TROCHONEMATIDAE** ZITTEL, 1895

GENUS **CYCLITES** KNIGHT, 1942

Cyclites costatus Yochelson, new species

Plate 21, figures 24–27, 29, 30

DESCRIPTION: Low-spired gastropods with three or four large revolving costae on outer whorl face below upper angulation; protoconch simple, smooth; sutures distinct, not impressed; whorl surface, except irregularities caused by ornamentation, ramp-like, inclined downward and strongly outward, following an exceedingly gentle convex curve to near upper angulation, then bending upward so that there is a distinct shallow depression parallel to well-rounded upper angulation; outer whorl face with a revolving depression similar to that on upper whorl surface, below this depression the face continuing straight, inclined outward 5 degrees to 10 degrees from vertical to near base, there turning rather abruptly but smoothly inward; basal whorl surface flattened for a short distance before bending up into umbilicus; narrowly phaneromphalous, the umbilicus becoming more open in late mature stage; upper lip prosocline, forming a 60-degree angle with tangent to the suture, following a gently convex forward curve across upper whorl surface; outer lip prosocline, 45 degrees from vertical; basal lip prosocline, turning to near orthocline in umbilicus; columellar lip arcuate, not thickened; ornamentation consisting of two large revolving costae on ramp, three or four costae on outer whorl face, and three on base and numerous extremely fine revolving lirae on upper and outer whorl surfaces.

DISCUSSION: *Cyclites costatus* is closely related to *C. depressa* (Beede) but differs from that species in having stronger and fewer revolving lirae. *Cyclites costatus* also appears to be higher spired than *C. depressa*, but all known specimens of the latter are abraded, and this difference may be more apparent than real.

HYPODIGM: Twenty-seven specimens, as listed below. All are silicified, and most are moderately well preserved.

OCCURRENCE: *Cherry Canyon formation:* U.S.N.M. 728, 14; A.M.N.H. 512, 12; A.M.N.H. 519, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119167; figured paratypes, U.S.N.M. No. 119168a, A.M.N.H. No. 27946:1; unfigured paratypes, U.S.N.M. Nos. 119168b–119168n.

TABLE 26

MEASUREMENTS (IN MILLIMETERS) OF *Cyclites costatus* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	H.A.	W.A.	Locality
Holotype	9.7	10.7	110°	6.1	5.1	728
Figured paratype	10.0	11.1	112°	5.8	5.0	728
Figured paratype	4.2	5.1	112°	3.1	2.6	512
	7.4	8.7	122°	5.2	—	728
	7.2	9.2	114°	—	—	728
	6.1	8.3	114°	5.3	4.4	728
	6.2	7.8	125°	—	—	728
	6.3	7.4	115°	4.3	3.7	728
	6.5	7.6	121°	4.6	3.7	728
	5.0	6.3	110°	3.0	—	728
	12.0	13.0	104°	7.7	6.2	512
	8.7	9.3	116°	5.6	4.7	512
	7.4	7.8	113°	4.6	4.0	512
	7.7	8.7	117°	5.2	4.1	512
	8.2	9.7	118°	5.5	4.6	512
	5.6	6.4	120°	3.9	3.4	512

Total height-total width, A.M.N.H. 512 and U.S.N.M. 728

$N=16$	$Sy=1.89$ mm.
$Mx=$ 7.47 mm.	$r=0.92$
$My=$ 8.72 mm.	$ORx=4.2$ mm.–12.0 mm.
$Sx=$ 1.85 mm.	$ORy=5.1$ mm.–13.0 mm.

SUPERFAMILY PSEUDOPHORACEA MILLER, 1889

FAMILY PSEUDOPHORIDAE MILLER, 1889

SALLYA YOCHELSON, NEW GENUS

Sallya bicincta Yochelson, new species

Plate 21, figures 28, 31–34

DESCRIPTION: Conical gastropods with fine revolving ornamentation on base and an extremely short, nearly horizontal frill; protoconch not certainly known, shell seemingly with a blunt apex; sutures distinct, just overhung by whorl above; upper whorl surface from suture commonly flattened for most of its width, turning abruptly outward for a very short distance before the rounded periphery so that a short frill or cape is formed projecting over suture below; inward from frill, the basal whorl surface very gently arched upward, becoming more strongly convex abruptly near the umbilicus; narrowly phaneromphalous; upper lip prosocline, forming a 30-degree angle with tangent to suture, sweeping backward strongly to periphery following a curve gently convex forward; basal lip unknown crossing inner edge of frill, seemingly prosocline along basal surface into the umbilicus; ornamentation consisting of fine, nearly invisible, revolving lirae on side of whorl, and seven or more coarser lirae on base.

DISCUSSION: This species differs from others referred to the genus in having an extremely narrow frill and in having the frill abruptly turning nearly horizontal, rather than gradually flaring. The fine lirae on the base and the virtual absence of recognizable ornamentation on the side are also distinctive. *Sallya bicincta* is similar to *S. lirata* (H. P. Chronic) in gross shape, but the ornamentation of the latter species is much coarser on the base and on the sides. The ornamentation of *S. bicincta* is so fine that it is shown on only the best-preserved specimens. Worn specimens from which the frill and outer shell layer have been removed show what may best be described as a stair-step whorl profile. This is probably owing to the abrupt bend of the frill.

The three Wolfcamp specimens listed below are much larger than the Hueco specimens, but otherwise appear similar.

HYPODIGM: Eighteen specimens as listed below. All specimens are silicified, but only six are well enough preserved to show ornamentation.

OCCURRENCE. *Hueco limestone:* U.S.N.M. 712a, nine; A.M.N.H. 51, four; A.M.N.H. 53, two. *Wolfcamp formation:* U.S.N.M. 707d, three.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119167; figured paratypes, U.S.N.M. Nos. 119170, 119171a, 119172a; unfigured paratypes, U.S.N.M. Nos. 119171b–119171g, 119172b–119172c.

Sallya linsa Yochelson, new species

Plate 22, figures 1–7

DESCRIPTION: Conical, finely ornamented gastropods with projecting frill on body whorl; protoconch not certainly known but believed to be discoidal or even depressed; sutures distinct, but not impressed; upper whorl surface flattened for most of its width, near periphery turning and following a curve concave outward to periphery, there forming a frill concealing base, the frill rarely having the same inclination as the side of the whorl

TABLE 27

MEASUREMENTS (IN MILLIMETERS) OF *Sallya bicincta* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	Locality
Holotype	4.2	6.8	68°	712a
Figured paratype	10[a]	14.7	62°	707d
Figured paratype	5.5	7.3	—	712a
	2.5	5.0	77°	712a
	4.2	5.5	68°	712a
	5.4	7[a]	70°	712a

[a] Estimated.

but turning towards horizontal; basal whorl surface beyond juncture with frill flattened, becoming strongly arched rather abruptly but smoothly near umbilicus; narrowly phaneromphalous; upper lip prosocline, forming a 30-degree angle with tangent to suture and sweeping backward to edge of frill, following a curve very gently convex forward; basal lip unknown crossing inner margin of frill, but prosocline across basal whorl surface, gradually sweeping backward as the umbilicus is approached; columellar lip not reflexed or thickened; ornamentation consisting of numerous fine revolving lirae on upper whorl surface which are cut by growth lines so that short revolving ridges are formed, and five or more faint revolving lirae on base.

DISCUSSION: The ornamentation on the upper whorl surface is quite distinctive of this species. Because of the interruption of the revolving lirae by growth lines into short segments, at first glance specimens seem to have obliquely arranged ridges sweeping forward down the shell. The ornamentation on the base is even finer than in *Sallya bicincta* and can be seen on only exceptional specimens. This nearly smooth base readily distinguishes *S. linsa* from *S. lirata* (H. P. Chronic).

Worn specimens can usually be distinguished from those of *S. bicincta*, as the upper whorl surface is almost straight rather than "stair-step," but some poor specimens of the two species cannot be certainly identified except when associated with better material in one population sample.

HYPODIGM: Forty-eight specimens, as listed below. All are silicified, and many are broken. A few, however, are excellently preserved.

OCCURRENCE: *Bone Spring limestone:* P.U. 3, seven; A.M.N.H. 433, 26; U.S.N.M. 716, four. *Word formation:* U.S.N.M. 703, seven; A.M.N.H. 503, three. *Cherry Canyon formation:* A.M.N.H. 512, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119172; figured paratypes, U.S.N.M. Nos. 119173a, 119173b, 119174a; unfigured paratypes, U.S.N.M. Nos. 119173c–119173h, 119174b–119174h.

Sallya striata Yochelson, new species

Plate 22, figures 8–12

DESCRIPTION: Conical gastropods with prominent transverse ribs; protoconch and apex unknown; sutures shallow, very indistinct; upper whorl surface flattened or gently arched outward, inclined downward and outward except on mature body whorl, the lower half of the body whorl following a curve concave outward so that there is a slight flaring of the shell forming a short

TABLE 28

MEASUREMENTS (IN MILLIMETERS) OF *Sallya linsa* YOCHELSON, NEW SPECIES

	Height	Width	Pleural Angle	Locality
Holotype	8.4	12.1	74°	3
Figured paratype	—	8.4	—	3
Figured paratype	6.9	10.9	74°	3
Figured paratype	6.2	8.0	71°	703
Unfigured paratype	10.2	12.8	71°	703
Unfigured paratype	10.0	13.7	76°	703
Unfigured paratype	3.9	7.4	81°	3
Unfigured paratype	6.2	9.7	76°	3
Unfigured paratype	13.2	15.3	61°	3
	4.5	6.4	74°	433
	4.5	6.4	77°	433
	5.2	7.7	77°	433
	6.0	8.4	68°	433
	18.8	11.5	70°	433
	10.9	14.4	68°	433

frill projecting over the base; basal whorl surface inclined upward at the juncture of the lower edge of frill and base, gently arched, becoming more strongly arched near the umbilicus; very narrowly phaneromphalous; outer lip not known in detail, but strongly prosocline from suture; basal lip prosocline, straight from periphery to suture; ornamentation consisting of coarse transverse ribs on mature whorls, commonly 16 to 18 in number, either straight or curving forward from suture to edge of frill, these ribs becoming stronger and more prominent downward, and causing portions of the frill to project outward as short spines, the base seemingly without ornamentation.

TABLE 29

MEASUREMENTS (IN MILLIMETERS) OF *Sallya striata* YOCHELSON, NEW SPECIES

	Height	Width[a]	Pleural Angle[a]	Locality
Holotype	9.0	10.1	71°	369
Figured paratype	4.9	7.4	76°	703
Figured paratype	8.9	11.0	74°	512
Unfigured paratype	5.0	9.4	78°	703
	4.8	7.8	57°	678
	5.3	7.0	71°	678

[a] Measurements of width and pleural angle do not include extension of spines at side.

DISCUSSION: The development of strong transverse ribs make *Sallya striata* the most distinctive of all species referred to the genus. Except for these ribs, the profile of the species is similar to that of *S. linsa*. In addition, this species is more narrowly phaneromphalous than other species of the genus.

HYPODIGM: Fifteen specimens, as listed below. All specimens are silicified, and, though some are broken, most are well preserved.

OCCURRENCE: *Bone Spring limestone:* A.M.N.H. 369, one; A.M.N.H. 678, two. *Word formation:* U.S.N.M. 703, two. *Cherry Canyon formation:* A.M.N.H. 512, seven; U.S.N.M. 728, two.

NUMBERED SPECIMENS: Holotype, A.M.N.H. No. 27947:1; figured paratype, A.M.N.H. No. 27947:2, U.S.N.M. No. 119175a; unfigured paratypes, U.S.N.M. Nos. 119175b, 119175c.

SUPERFAMILY **ANOMPHALACEA** WENZ, 1938

FAMILY **ANOMPHALIDAE** WENZ, 1938

GENUS **ANOMPHALUS** MEEK AND WORTHEN

Anomphalus verruculiferus (White)

Plate 22, figures 13–18

Rotella verruculifera WHITE, 1881, p. xxxii, pl. 4, figs. 7a–d.

DESCRIPTION: Very low-spired cryptomphalous gastropods with large callus in mature stage; protoconch simple, smooth; very low spired, the body whorl embracing high on penultimate whorl; sutures distinct, not impressed; upper whorl surface in mature stage nearly horizontal from suture for a very short distance, then bending downward and proceeding outward nearly straight, inclined 45 degrees, bending more strongly downward rather abruptly as periphery is approached, so that the periphery is well rounded; outer and basal whorl surfaces curved from below mid-whorl, the basal surface being slightly flattened but curving inward near the umbilical region; cryptomphalous in mature stage, with a prominent callus protruding, the character of the umbilicus in earlier stages unknown; outer lip prosocline, forming a 70-degree angle with tangent to suture; other parts of aperture not certainly known, but probably prosocline at nearly the same angle; ornamentation wanting.

DISCUSSION: *Anomphalus verruculiferus* (White) differs from *A. umbilicatus* Knight and *A. vanescens* in being cryptomphalous rather than hemiomphalous. It is most closely related to *A. rotulus* Meek and

Worthen, but differs from that species in being higher spired and, most important, in having the umbilical filling expanding markedly in the mature stage.

Topotype specimens of *A. rotulus* Meek and Worthen in the collections of the United States National Museum are less than half of the size of specimens of *A. verruculiferus* (White).

Because of the small number of specimens of White's species and because of their status as types, it is not feasible to section specimens to observe the character of the juvenile umbilicus. Nevertheless, it is most probable that the mature specimens examined are cryptomphalous rather than anomphalous. The original of White's figure 7d on plate 4 is here designated lectotype.

In a strict sense, this species should not be treated in a work on Permian gastropods. However, it is one of the few American Pennsylvanian non-pleurotomarians not treated by Knight, and it seems best to rectify this omission for the benefit of future workers. Knight should be given full credit for noting the generic placement of the species, because it was his designation of *Anomphalus* on the label that led the present writer to investigate it.

TABLE 30

MEASUREMENTS (IN MILLIMETERS) OF *Anomphalus verruculiferus* (WHITE)

	Height	Width
Lectotype	3.8	6.6
Figured lectoparatype	4.0	6.4
Figured lectoparatype	4.0	6.5
Unfigured lectoparatype	—	6.6
Unfigured lectoparatype	—	6.9

HYPODIGM: Five specimens, as listed below. Most show the gross shape well; several retain patches of a thin outer shell layer.

OCCURRENCE: *Carboniferous (probably middle Pennsylvanian):* U.S.N.M., from near Taos, New Mexico, five.

NUMBERED SPECIMENS: Lectotype, U.S.N.M. No. 119176; figured lectoparatypes, U.S.N.M. Nos. 8929a, 8929b; unfigured lectoparatypes, U.S.N.M. Nos. 8929c, 8929d.

Anomphalus vanescens Yochelson, new species

Plate 22, figures 19–22

DESCRIPTION: Rotelliform gastropods with umbilicus slightly restricted in mature stage; shell low spired; body whorl embracing high on penultimate whorl; sutures indistinct; upper whorl surface sloping downward and strongly outward approximately 10 degrees below horizontal, gently arched upward, there being a gradual but distinct change to a curve of smaller radius as the periphery is approached; outer whorl surface following a curve nearly the radius of a circle, downward and outward to mid-whorl, then inward to basal whorl surface, this surface being flattened, almost horizontal near the umbilicus; phaneromphalous, the umbilical walls in the mature stage inclined outward and upward so that the umbilicus becomes proportionally narrower with increasing maturity; aperture not certainly known, but judged to be prosocline, essentially straight from suture to umbilicus; juncture of basal and columellar lips thickened; ornamentation lacking.

TABLE 31

MEASUREMENTS (IN MILLIMETERS) OF *Anomphalus vanescens* YOCHELSON, NEW SPECIES

	Height	Width	Locality
Holotype	2.8	4.9	712b
Figured paratype	2.5	4.4	712
Unfigured paratype	2.5	4.9	712
Unfigured paratype	2.4	4.0	712b
Unfigured paratype	2.8	4.7	712b

DISCUSSION: *Anomphalus rotulus* Meek and Worthen and *A. verruculiferus* (White) differ from this species in being cryptomphalous in the mature stage. *Anomphalus umbilicatus* Knight and *A. vanescens* are similar in that they are both hemiomphalous. The former species appears to have the umbilicus more restricted and to have the upper and basal surfaces more abruptly flattened than *A. vanescens,* this abrupt flattening setting off the outer whorl more distinctly. In most other respects, the two species are quite similar.

HYPODIGM: Nineteen specimens, as listed below. All are silicified and preservation is fair, although none shows the aperture.

OCCURRENCE: *Hueco limestone:* U.S.N.M. 712, 10; U.S.N.M. 712b, nine.

NUMBERED SPECIMENS: Holotype U.S.N.M. No. 119177; figured paratype, U.S.N.M. No. 119178a; unfigured paratypes, U.S.N.M. Nos. 119178b–119178j, 119179a–119179i.

Anomphalus studiosus Yochelson, new species

Plate 22, figures 25–28

DESCRIPTION: Small rotelliform, phaneromphalous gastropods with opisthocline upper lip; protoconch discoidal or very slightly depressed; sutures not impressed, more distinct in mature stage; upper whorl surface almost straight, inclined 10 degrees below horizontal for nearly one-half of its width, curving gradually downward and merging into outer whorl face; outer whorl face curving downward steeply to periphery at midwhorl, below which point curving inward, following the arc of a circle to basal whorl surface where there is a distinct flattening, the basal whorl surface being very gently arched, bending more steeply inward near the umbilicus; phaneromphalous throughout all growth stages, the umbilicus narrow but not set off by a circumumbilical ridge and with nearly vertical walls; outer lip opisthocline, forming 70-degree angle with tangent to suture, for most of its length, then gradually curving to orthocline; outer portion of upper lip and upper portion of outer lip prosocline 5 degrees to 10 degrees from vertical, the lower portion of outer lip prosocline 5 degrees to 10 degrees from vertical; basal lip gently prosocline; columellar lip gently arcuate; ornamentation lacking.

DISCUSSION: This species is most similar to *Anomphalus vanescens* in general size and shape. In addition to differences in the shape of the aperture, the two species are readily separated in that the base of *Anomphalus studiosus* is more flattened than that of *A. vanescens,* and the umbilicus of the former species is wider than that of the latter.

A single incomplete juvenile specimen, possibly referable to *Anomphalus,* has been found at A.M.N.H. 512, Cherry Canyon formation. In the absence of more specimens it seems best not to include the specimen definitely within this genus as this would considerably extend the geographic range of the genus and suggest much more than the evidence warrants.

HYPODIGM: Forty-five specimens, as listed below. All are silicified, and most are well preserved, although most do not show growth lines and seem to lack a thin outer whell layer.

OCCURRENCE: *Leonard formation:* U.S.N.M. 702c, one; U.S.N.M. 702, 13; U.S.N.M. 707b, two; U.S.N.M. 703a, 25; A.M.N.H. 504, one. *Word formation:* A.M.N.H. 503, two; U.S.N.M. 703, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119181; figured paratype, U.S.N.M. No. 119182a; unfigured paratypes, U.S.N.M. Nos. 119182b–119182h.

Anomphalus species

Plate 22, figures 23, 24

DISCUSSION: Two specimens of *Anomphalus* from the Wolfcamp formation differ from specimens of *Anomphalus vanescens* in being almost twice as large as typical forms of that species. They also appear to be higher spired and may represent a new species, but are too poorly preserved to warrant being described.

MEASUREMENTS: The measurements of the two figured specimens, both from U.S.N.M. 701g, are: height, 7.5 mm., 8.5 mm. (estimated); width, 4.5 mm. (estimated), 5.3 mm.

HYPODIGM: Two poorly silicified specimens as listed below.

OCCURRENCE: *Wolfcamp formation:* U.S.N.M. 701g, two.

NUMBERED SPECIMENS: Figured specimens, U.S.N.M. Nos. 119180a–119180b.

TABLE 32

MEASUREMENTS (IN MILLIMETERS) OF *Anomphalus studiosus* YOCHELSON, NEW SPECIES

	Height	Width	Locality
Holotype	2.6	5.0	702
Figured paratype	3.1	5.7	702
Unfigured paratype	2.7	5.0	702
Unfigured paratype	2.7	4.8	702
Unfigured paratype	2.7	4.8	702
	2.0	3.0	702
	1.9	3.1	702
	2.6	4.7	702
	2.9	5.6	702
	3.0	5.7	702
	2.5	4.9	702
	2.3	4.7	703
	2.7	4.9	503
	2.5	5.0	703a
	2.5	4.8	703a
	2.1	4.4	703a
	2.1	4.4	703a
	2.5	4.9	703a
	2.6	4.7	703a
	2.1	4.3	703a

Total height-total width, U.S.N.M. 702

$N=11$	$Sy=0.83$ mm.
$Mx=$ 2.56 mm.	$r=0.87$
$My=$ 4.75 mm.	$ORx=1.9$ mm.–3.0 mm.
$Sx=$ 0.44 mm.	$ORy=3.0$ mm.–5.7 mm.

SUPERFAMILY **CRASPEDOSTOMATACEA** WENZ, 1938

FAMILY **CRASPEDOSTOMATIDAE** WENZ, 1938

SUBFAMILY **CRASPEDOSTOMATINAE** WENZ, 1938

GENUS **BROCHIDIUM** KOKEN, 1889

Brochidium morrisi Yochelson, new species

Plate 23, figures 1–4

DESCRIPTION: Small, low-spired gastropods with numerous narrow, nearly vertical ribs or varices; protoconch discoidal, smooth; shell extremely low spired, nearly flat on upper whorl surface except in mature stage, where body whorl slips downward; sutures distinct, becoming more strongly impressed with age; upper whorl surface rising upward and outward from suture, following a convex curve, becoming flattened, nearly horizontal near center, then turning downward; outer and basal whorl surfaces well rounded, nearly following the arc of a circle; narrowly phaneromphalous in all growth stages, without a circumumbilical ridge; upper lip orthocline across upper whorl surface; outer and basal lips prosocline 5 degrees to 10 degrees behind vertical; aperture periodically flaring, so that distinct ridges having the same inclination as the growth lines protrude from the general surface of the shell, these varices beginning at about the second whorl and increasing in size towards the aperture, closely spaced, but seemingly following a logarithmic pattern so that the older the shell the farther apart are the variçes, there being approximately the same number of varices on each whorl, other ornamentation lacking.

DISCUSSION: This species appears most similar to *Brochidium cingulatum* Münster, from the upper Triassic of the Alpine region. *Brochidium morrisi* differs in being low spired, whereas *B. cingulatum* is almost bilaterally symmetrical. The original figures of the latter species are reproduced in plate

TABLE 33

MEASUREMENTS (IN MILLIMETERS) OF *Brochidium morrisi* YOCHELSON, NEW SPECIES

	Height	Width	H.A.	W.A.	V.	Locality
Holotype	2.6	4.4	2.0	2.0	79°54′	702
Figured paratype	2.0	3.4	1.6	1.6	82° 0′	703a
Unfigured paratype	3.3	5.5	2.8	2.8	76°34′	703a
Unfigured paratype	2.1	3.8	—	—	81°29′	703a
Unfigured paratype	2.5	4.7	2.0	2.1	77°41′	703a
Unfigured paratype	—	5.2	—	—	76°49′	703a
Unfigured paratype	2.2	4.2	1.9	2.0	—	703a
Unfigured paratype	2.5	4.5	—	—	81°17′	703a
Unfigured paratype	2.3	4.3	1.8	1.8	80°25′	703a
Unfigured paratype	1.8	3.9	1.6	1.7	82° 0′	703a
Unfigured paratype	1.6	3.4	—	—	—	703a
Unfigured paratype	2.6	4.1	2.0	2.0	81°55′	702
Unfigured paratype	2.3	4.4	2.2	2.0	79°54′	702
Unfigured paratype	2.1	4.2	2.1	2.0	81°14′	702
Unfigured paratype	2.2	4.3	2.2	2.2	—	702
Unfigured paratype	2.3	4.2	2.2	2.0	—	702
Unfigured paratype	2.3	4.2	2.3	2.3	81°14′	702
Unfigured paratype	2.3	4.5	2.3	2.2	79°17′	702
Unfigured paratype	2.2	4.4	2.2	2.2	79°54′	702
Unfigured paratype	1.9	4.0	1.9	1.9	76°54′	702
Unfigured paratype	2.5	4.4	—	—	79°54′	702
	—	4.8	—	—	78°20′	703a
	—	4.3	—	—	79°20′	703a
	—	4.9	—	—	81°45′	703a
	—	4.2	—	—	79°47′	703a
	—	2.5	—	—	79° 5′	703a

Total height-total width, U.S.N.M. 702

$N=11$ $Sy=0.20$ mm.
$Mx=2.27$ mm. $r=0.28$
$My=4.22$ mm. $ORx=1.9$ mm.–2.6 mm.
$Sx=0.23$ mm. $ORy=4.0$ mm.–4.5 mm.

Total height-total width, U.S.N.M. 703a

$N=9$ $Sy=0.68$ mm.
$Mx=2.23$ mm. $r=0.85$
$My=4.13$ mm. $ORx=1.6$ mm.–3.3 mm.
$Sx=0.46$ mm. $ORy=3.4$ mm.–5.5 mm.

23, figures 5 and 6, for comparison. Other Triassic species of this genus seem to be either much higher spired or to have the varices not developed in the late mature stage.

HYPODIGM: Eighty specimens, as listed below. All are silicified, and most are incomplete, although there are many excellent specimens.

OCCURRENCE: *Leonard formation:* U.S.N.M. 703a, 19; U.S.N.M. 703b, one; U.S.N.M. 702, 35; U.S.N.M. 702d, one; U.S.N.M. 702c, nine; A.M.N.H. 504, seven; Y.P.M. 2, one. *Word formation:* U.S.N.M. 703, two; U.S.N.M. 706c, one; A.M.N.H. 501, one; A.M.N.H. 503, one. *Cherry Canyon formation:* A.M.N.H. 512, three.

NUMBERED SPECIMENS: Holotype U.S.N.M. No. 119183; figured paratype, U.S.N.M. No. 119184a; unfigured paratypes, U.S.N.M. Nos. 119184b–119184k, 119185a–119185dd.

DICHOSTASINAE Yochelson, new subfamily

DICHOSTASIA Yochelson, new genus

Dichostasia simplex Yochelson, new species

Plate 23, figures 7–11

Description: Small gastropods with coarse transverse ridges on upper whorl surface, but without ornamentation on base; protoconch slightly depressed, smooth; shell low-spired; sutures distinct, faintly impressed; upper whorl surface rising from suture sharply, well arched along most of width, but still set off from outer whorl face; outer whorl face nearly vertical in upper part, turning abruptly horizontal for a short distance and then proceeding downward, inclined inward 15 degrees from vertical, bending strongly inward near base; basal whorl surface flattened for a short distance, with inner half of whorl surface nearly the arc of a circle curving into umbilicus; moderately phaneromphalous in all growth stages; upper lip prosocline, forming a 60-degree angle with tangent to suture sweeping back gently to edge of upper whorl surface; outer lip prosocline, 10 degrees from vertical; basal lip prosocline; juvenile whorls without ornamentation, mature whorls bearing numerous, strong, rounded ridges parallel to growth lines and extending almost from suture to near outer edge of upper whorl surface, these ridges becoming larger and more widely spaced with increasing age so that there are approximately the same number of ridges on each whorl.

Discussion: The absence of strong revolving costae on the side readily separates *Dichostasia simplex* from *D. complex*. Specimens of *D. simplex* from the Leonard formation appear to be slightly higher spired than those from the Hueco limestone which are nearly horizontal on upper surface. Some of the Leonard specimens also seem to show coarser ridges of ornamentation. These differences are slight and based on observations of few specimens from the Hueco limestone; they are not considered to be significant.

Hypodigm: Fourteen specimens, as listed below. All are silicified, and preservation is fairly good, although many specimens are broken.

Occurrence: *Hueco limestone:* U.S.N.M. 712, one; U.S.N.M. 712b, four. *Leonard formation:* U.S.N.M. 703b, four; U.S.N.M. 702d, five.

Numbered Specimens: Holotype, U.S.N.M. No. 119186; figured paratype, U.S.N.M. No. 119187; unfigured paratypes, U.S.N.M. Nos. 119188a–119188f.

Dichostasia complex Yochelson, new species

Plate 23, figures 12–15

Description: Small, low-spired gastropods with three or four revolving costae on side; protoconch slightly depressed, smooth; sutures distinct, faintly impressed; upper whorl surface very slightly convex, almost horizontal for most of width, then bending more abruptly downward to a revolving costa at periphery; outer whorl face below this costa proceeding outward and downward to another at mid-whorl, crossing second costa and proceeding downward and inward to a third costa at juncture with basal whorl surface, basal whorl surface nearly horizontal for a short distance to circumumbilical ridge, which in some specimens protrudes upward so that it appears as a fourth costa; moderately narrowly phaneromphalous in all growth stages; upper lip prosocline, forming a 70-degree angle with tangent to suture, sweeping gently backward, forming a 60-degree angle with upper costa; outer whorl

TABLE 34

Measurements (in Millimeters) of *Dichostasia simplex* Yochelson, New Species

	Height	Width	Locality
Holotype	5.9	8.3	702d
Figured paratype	3.4	6.5	712
Unfigured paratype	5.2	8.1	702d
	4.2	7.4	712b

face prosocline 10 degrees to 15 degrees from vertical; basal lip nearly orthocline; mature aperture nearly entire, developing a thick, wide ring or varix, which has all edges reflexed; juvenile whorls unornamented; ornamentation of mature whorls consisting of strong transverse ridges, running from near suture almost to outer edge of upper whorl surface, normal to periphery rather than parallel to growth lines, the ridges becoming higher and spaced farther apart with age, and the three revolving costae on side of whorl.

TABLE 35

MEASUREMENTS (IN MILLIMETERS) OF *Dichostasia complex* YOCHELSON, NEW SPECIES

	Height[a]	Width	Locality
Holotype	2.7	4.8	702c
Unfigured paratype	3.0	5.1	703a
Unfigured paratype	2.6	4.8	703a
Unfigured paratype	2.0	4.1	703a
	2.4	4.8	703
	2.8	4.9	2

[a] Excludes thickened margin of aperture.

DISCUSSION: The prominent revolving costae on the outer whorl face readily differentiate *D. complex* from *D. simplex*.There is also a difference in the ornamentation of the upper surface, the ridges in *D. complex* ending abruptly rather than gradually dying out as in *D. simplex*.

It is not known whether or not the mature aperture of *D. simplex* has the same type of varix development as does this species. It seems probable that the thickened aperture marked terminated growth of the animal. When more specimens of *D. complex* and *D. simplex* are available, study may indicate that these two species are not congeneric.

HYPODIGM: Eight specimens, as listed below. All are silicified, and preservation varies from good to excellent.

OCCURRENCE: *Leonard formation:* U.S.N.M. 703a, four; U.S.N.M. 702c, one; Y.P.M. 2, two. *Word formation:* U.S.N.M. 703, one.

NUMBERED SPECIMENS: Holotype, U.S.N.M. No. 119189; figured paratype, U.S.N.M. No. 119190; unfigured paratypes, U.S.N.M. Nos. 119191a–119191d.

SUPERFAMILY **PLATYCERATACEA** HALL, 1856

FAMILY **PLATYCERATIDAE** HALL, 1859

GENUS **PLATYCERAS** CONRAD, 1840

SUBGENUS **ORTHONYCHIA** HALL, 1843

Platyceras (Orthonychia) bowsheri Yochelson, new species

Plate 24, figures 5–36

DESCRIPTION: Nearly straight to partially coiled, thick-shelled, smooth platyceratids; shape exceedingly irregular, but commonly with at least the earlier portion of the shell curved to hook-shaped; those specimens exhibiting coiling seldom completing more than three-quarters of an open whorl; aperture varying from nearly smooth to irregularly sinuate, in plan varying from irregularly compressed through oval to nearly circular; thick shell; some specimens retaining a pattern of stripes generally normal to plane of aperture.

DISCUSSION: All platyceratids from the upper part of the Word formation and equivalents are here placed within one species. The species is characterized by being unornamented and almost completely uncoiled, features that refer it to the subgenus *Orthonychia*. Beyond this, it is exceedingly difficult to classify the taxon because of the tremendous amount of individual variation. However, inasmuch as no platycerid species are known to have been named from the North American Permian, it seems justifiable to name a new species rather than carry a previously named species a long distance either geographically or stratigraphically.

Most specimens are well preserved and have a relatively thick shell, which may have been calcitic in life. As noted in the ecological section of this paper, many of the shells have been bored or overgrown by other organisms. These shells are most common in the upper Word localities in the Glass Mountains.

Occasional shells preserve a color pattern, which consists of light and dark stripes running from the juvenile shell to the aperture. Too few specimens show this feature for one to determine whether or not the stripes have a regular arrangement as to width and spacing. At least two specimens show nonuniform spacing of the stripes.

Although many of the specimens appear

to have a blunt apex, some exceptionally well-preserved juveniles, particularly those from older beds, show a tiny vermiform protoconch (pl. 23, figs. 27–29). Almost certainly a similar protoconch was originally present on all specimens studied. Loss of such a feature could not be readily detected on a silicified shell. The relatively rapid expansion of the shell beyond the protoconch suggests a marked change in habit. It may be that the vermiform protoconch represents a free living stage, and as soon as the specimen became attached to a crinoid calyx it expanded rapidly to increase the area of attachment.

In spite of the pronounced individual variation, it is possible to recognize three general growth forms within the upper Word formation and its equivalents. Forms 1 and 2 occur at the same localities in the Glass Mountains, but form 3 is restricted to the Cherry Canyon formation of the Guadalupe Mountains. They are here termed variants with the reservation that this action is not to be construed as establishing a formal nomenclatural taxon.

Variant 1, the most common of the three types, is nearly uncoiled in most specimens. A short, blunt, juvenile shell expands with a slight curve so that the form approaches that of a funnel on which the stem has been bent. The aperture is commonly subcircular in plan but may be strongly compressed. In side view it is serrated by five or more distinct sinuses in the lip. Further, this variant shows more individual variation than do the other two; it is the most irregular of the irregulars.

In contrast to the preceding type, variant 2 is relatively regular, although still exceedingly irregular when compared to free-living gastropods. The juvenile shell is hooked, so that the mature shell develops about three-quarters of an open coil. The aperture in plan is most commonly elongate-oval but may range to subcircular. Few specimens are known with the aperture strongly compressed and elongate. In side view the aperture most commonly has two shallow sinuses anteriorly and one sinus on the "columellar lip." About half of the specimens examined have the sinus or sinuses shallow, so that the apertural margin is relatively smooth.

Variant 3 can best be described as intermediate between variants 1 and 2. It has a hook-shaped juvenile shell and completes about three-fourths of a whorl but is more openly coiled than is variant 2. The aperture is subcircular in plan and is not so irregular as in variant 1. As in variant 1, the aperture of variant 3 is irregularly serrated, commonly by five or more adventitious sinuses.

Hypodigm: Five hundred and thirty-four specimens, as listed below. All are silicified, and most are fairly well preserved. Most large samples contain many juveniles and many adults but few specimens of intermediate size.

Occurrence: *Variant 1: Word formation:* U.S.N.M. 706c, 117; U.S.N.M. 706b, 198; U.S.N.M. 706, 24; U.S.N.M. 706e, 10; K.U. 18, 18; K.U. 27, five. *Variant 2: Word formation:* U.S.N.M. 706b, 21; U.S.N.M. 760c, 46; U.S.N.M. 706e, three; K.U. 18, three; K.U. 27, two; A.M.N.H. 505, two. *Variant 3: Cherry Canyon formation:* A.M.N.H. 512, 38; U.S.N.M. 728, 47.

Numbered Specimens: Holotype, U.S.N.M. No. 119211; figured paratypes, U.S.N.M. Nos. 119212a, 119213a–119213m, 119214a–119214d, 119215, A.M.N.H. No. 27952; unfigured paratypes, U.S.N.M. Nos. 119212b–119212z, 119213n–119213nnnnnnnn, 119214e–119214rrr.

Platyceras (Orthonychia) species 1

Plate 24, figures 1–3

Discussion: A single platyceratid from the Leonard is considerably different from the three variants of *Platyceras* (*Orthonychia*) *bowsheri*. The specimen is only slightly twisted and expands rapidly from the protoconch to a hemisphere. The aperture is indented by two large notches located 180 degrees apart. In addition to the vertical color stripes, the specimen also exhibits narrow dark and light alternations following the growth lines. Because the extreme variability of platyceratids demands that species be based on larger samples than is customary, the species to which this specimen belongs is not formally named.

Hypodigm: A single well-preserved silicified specimen, as listed below.

Occurrence: *Leonard formation:* U.S.N.M. 702ent., one.

NUMBERED SPECIMEN: Figured specimen, U.S.N.M. No. 119216.

Platyceras (Orthonychia) species 2

Plate 24, figure 4

DISCUSSION: In addition to the species complex described above, there may be an additional species of *Orthonychia* present in the west Texas fauna. The only known representative of this species has a thick blunt apex expanding rapidly but quite smoothly. The shell is very slightly twisted and in outline superficially resembles *Metoptoma* Phillips. The aperture is smoothly oval in plan and has only two exceedingly shallow sinuses. In most respects this species is quite similar to *Platyceras* (*Orthonychia*) *bowsheri*, variant 2. It seems to differ from this and all other described American Pennsylvanian and Permian species of *Platyceras* in bearing prominent rounded growth lamellae on the shell. Post-Devonian ornamented platyceratids are exceedingly rare, and it is considered that this difference is such as to warrant consideration as a separate species. The shell itself is thin, and there is some possibility that the lamellae shown may actually be lines of another sort within the shell, part of which was dissolved away during the etching process. Although this is a remote possibility, until more specimens are obtained to test this alternative suggestion, formal naming of the species does not seem justified.

HYPODIGM: One specimen, as listed below, well preserved except at the margin.

OCCURRENCE: *Word formation:* U.S.N.M. 703, one.

NUMBERED SPECIMEN: Figured specimen, U.S.N.M. No. 119217.

OTHER PERMIAN PLATYCERATIDS

Plate 23, figures 21, 22, 27–29

DISCUSSION: Collections of platyceratids from the older Permian strata are much smaller than those from the upper Word formation and equivalents and in many cases contain fewer than half a dozen specimens. As a consequence they are exceedingly difficult to distinguish. Nevertheless one gains the impression that one or more of the three variants of *Platyceras* (*Orthonychia*) *bowsheri* outlined above are present in most collections. The other collections contain shells intermediate between the three variants and are noted below simply as occurrences of the subgenus. It should be noted that the assignment of specimens from pre-upper Word strata is provisional, as larger collections may result in either the clearer recognition of more growth forms or integration of those tentatively assigned.

Five hundred and fifty-five specimens are included in this category, distributed as follows:

Tentatively *Platyceras* (*Orthonychia*) *bowsheri*, variant 2
- Leonard formation: U.S.N.M. 702, 11; U.S.N.M. 702, low, eight; U.S.N.M. 702ent, two; U.S.N.M. 702un, 15; Y.P.M. 128, one
- Hess limestone member of Leonard formation: U.S.N.M. 702d, 10, U.S.N.M. 702e, two
- Bone Spring limestone: A.M.N.H. 628, two

Tentatively *Platyceras* (*Orthonychia*) *bowsheri*, variant 3
- Bone Spring limestone: U.S.N.M. 716, one; A.M.N.H. 46, 16; A.M.N.H. 625, 96; A.M.N.H. 629, 58; A.M.N.H. 631, 62
- Leonard formation: U.S.N.M. 707q, three
- Word formation: U.S.N.M. 707e, 10

Not assigned as to species
- Wolfcamp formation: U.S.N.M. 701a$_2$, one; U.S.N.M. 701, 14; U.S.N.M. 701c, 10; U.S.N.M. 701-l, two; U.S.N.M. 706x, one; U.S.N.M. 707d, seven; Y.P.M. 93, two
- Hueco limestone: U.S.N.M. 712b, one
- Bone Spring limestone: A.M.N.H. 46, 12; A.M.N.H. 369, six
- Leonard formation: U.S.N.M. 702, 114; U.S.N.M. 702a, 12; U.S.N.M. 702c, 22; U.S.N.M. 703a, 52; U.S.N.M. 703b, six; U.S.N.M. 707b, two; Y.P.M. 2, three; Y.P.M. 126, three; A.M.N.H. 500, four
- Word formation: U.S.N.M. 702d, two; U.S.N.M. 703, four; Y.P.M. 4, two

NUMBERED SPECIMENS: Figured specimens, U.S.N.M. Nos. 119209, 119210a–119210c.

THE EFFECT OF THE CRINOID HOST ON THE VARIABILITY OF PERMIAN PLATYCERATIDS

ARTHUR L. BOWSHER

INTRODUCTION

THE EXTREME VARIATION in size and shape of the platyceratid gastropod shells makes them at best a very difficult group to identify at the species level. The fossil record clearly indicates that because of a sedentary habit this variation is a reflection of the irregular surfaces to which they attached. The irregularities of the apertural margin of these gastropod shells, also reflected in growth lines, indicate to a certain extent the type of host with which they were symbiotic (Bowsher, 1955, p. 4). The sedentary habit of most late Paleozoic platyceratids was such a stable one that even general shape was modified greatly. This resulted in extreme variation in shape and coiling. External control of shell growth must be considered in taxonomic study of platyceratid shells.

The platyceratids are thought to have been coprophagous on crinoids and cystoids (Bowsher, 1955, p. 6) because of their common occurrence on calyxes over the anal vent and the close conformation of the aperture to the shape of the calyx. The construction of blastoids is such that they do not appear to have been suitable hosts for these gastropods. Because only crinoids and blastoids are known from Permian rocks, the Permian platyceratids probably were restricted to crinoids in their symbiotic habit.

During recent years the United States National Museum, the American Museum of Natural History, and the University of Kansas have obtained large collections of fossils from the Permian rocks of western Texas. Because the crinoids in these collections have not been studied, one cannot at this time point out specifically all crinoids known to occur with these Permian platyceratids.

The objectives of this paper are to indicate a few possible host crinoids for some of the platyceratids and to suggest an explanation for some of the extreme variation in shape and coiling in this group of gastropods.

Three variants of *Platyceras* (*Orthonychia*) *bowsheri* are recognized by Yochelson. From these one can select specimens with distinctive types of apertures. Some have more or less round apertures (pl. 24, figs. 5–13, 17–26), others have broadly elliptical apertures (pl. 24, figs. 29–36), and others have highly compressed elliptical apertures (pl. 24, figs. 14–16). Other shells with irregular apertures do not fall into any of the above types.

I describe in the following pages three distinct types of aperture and suggest possible crinoid hosts for the platycerids with these apertures. Other types could also be discussed, but these examples explain some of the great variation within and among the three growth forms of *Platyceras* (*Orthonychia*) *bowsheri* from the Permian rocks of western Texas.

TYPES OF APERTURE

MORE OR LESS ROUND APERTURES

One conspicuous type of aperture is more or less round, with five or more salients and reëntrants. The large amount of variation in these shells indicates that there were several different crinoid hosts. Some shells of *Platyceras bowsheri*, variant 1, from the upper part of the Word formation of the Glass Mountains and variant 3 from the Cherry Canyon formation of the Guadalupe Mountains have this type of aperture. The irregularities of the aperture are more distinct and narrower on the anterior than on the posterior (pl. 24, fig. 19). The character of this aperture suggests that the gastropod was attached to a pavement of rounded plates. Tegmens of this type are found on *Platycrinites*. Although *Platycrinites* is not known from the Cherry Canyon formation, Wanner has illustrated *Platycrinites wachsmuthi* (1922, pl. 152, figs. 12a–b) from Permian rocks of Timor with a platyceratid attached to the tegmen. A specimen of *P. wachsmuthi* from Timor with a scar where a platyceratid lived on its tegmen is shown in figure 16 of plate 23. Text figure 4A is a reconstruction of the platyceratid that lived on this crinoid. The apertural characters of some of the west Texas platyceratids suggest that they may have been coprophagous on *Platycrinites*.

A single platyceratid from the Leonard formation of the Glass Mountains, *Platyceras* (*Orthonychia*) species 1, has a deep, rounded reëntrant on each side of the round aperture and square salients on the anterior and posterior margins (pl. 24, figs. 1–3). This type of aperture suggests that the host was either an inadunate crinoid like *Calceolispongia* (Teichert, 1949), which has strong, laterally directed spines and an anal opening near the top of the cups, or a small camerate crinoid such as *Eutelocrinus* (Wanner, 1937, pl. 6, fig. 40) with rounded ray ridges, a sunken

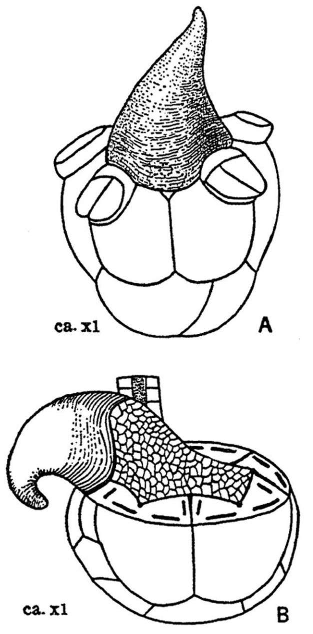

FIG. 4. A. Reconstruction of *Platyceras* on *Platycrinites* based on character of the scar shown in plate 23, figure 16. Compare with *Platyceras* (*Orthonychia*) *bowsheri* Yochelson, variant 1, especially plate 24, figures 19 and 20. B. Reconstruction of *Platyceras* on *Ulocrinus*. Drawing made with arms removed to show shape of gastropod aperture and position over anal tube. Broad reëntrant of aperture fitted around right posterior arm, and broad salient fitted around constricted primibrachials similar to those shown for *Cromyocrinus* (pl. 23, figure 18). Compare with *Platyceras* (*Orthonychia*) *bowsheri* Yochelson, variant 2, especially plate 24, figures 29 and 30. Both reconstructions approximately natural size.

anal area, and with the lower part of the tegmen overhanging the posterior interradial area. If the anal opening of *Calceolispongia* is anterior, as described by Teichert (1949, p. 55), this gastropod was not likely coprophagous on this crinoid. On the other hand, if the anal opening of *Calceolispongia* is on the flat disk as shown by Teichert (1949, pl. 10, fig. 3) but located on the posterior, as is anatomically more probable, *Calceolispongia* is as likely a host as *Eutelocrinus*.

COMPRESSED APERTURES

A few of the platyceratid shells referred to *Platyceras* (*Orthonychia*) *bowsheri*, variant 1, from the upper part of the Word formation of the Glass Mountains have a much compressed, elliptical aperture (pl. 24, figs. 14–16). The shape of the shells is quite variable. The margin of some is relatively smooth, but on others it is quite irregular. The apertural shape suggests that the platyceratid may have been attached to a long, cylindrical anal tube of a crinoid between the arms of right and left posterior rays which pressed against the gastropod shell, producing the elongate aperture. The erisocrinids, zeacrinids, scytalocrinids, and pirasocrinids of the Permian have anal tubes of this type (Moore and Laudon, 1943, figs. 7 and 8). The ornamentation of the anal tubes ranges from smooth to very rugose. Some of the platyceratid apertures are relatively smooth, suggesting they lived on crinoids with unornamented anal tubes. Others have irregular apertural margins, suggesting they lived on crinoids with rugose anal tubes. Several types of crinoids may have served as hosts, resulting in the observed variety of apertural types.

The expanding arm groups of the pirasocrinids and the zeacrinids close over the anal tube a very short distance above the cup. This structure makes them very unlikely hosts. The scytalocrinids and erisocrinids, on the other hand, have only 10 arms, and the posterior area along the anal tube is more or less open on some species. The abundance of *Delocrinus*, an erisocrinid with suitable anal and arm structures, in the Permian rocks of western Texas suggests that this genus was the primary host for this group of platyceratids.

Broadly Elliptical Apertures

A group of platyceratids from the upper part of the Word formation in the Glass Mountains has broadly ellipitical apertures, rather smooth apertural margins and growth lines, a broad salient on each side, and a narrower one on the anterior (pl. 24, figs. 29–36). The surface of these shells is smooth and lacks folds of any kind. The majority of shells included in *Platyceras* (*Orthonychia*) *bowsheri*, variant 2, by Yochelson have this type of aperture. These platyceratids appear to have been associated with a crinoid having a short anal tube, from five to 10 massive, closely grouped arms, and from one to three anal plates in the cup. The lateral salients of the gastropod shell probably extended over the sides of the relatively smooth primibrachials and cup, with the anterior margin projected upward over the anal opening at the top of the short anal tube. The broad lateral salients suggest that the crinoid crown was sharply constricted at the primibrachial level and had greatest diameter high on the radials (text fig. 4B). The two sharp, rounded reëntrants would have fitted around the massive arms of the crinoid. Crinoids of the Cromyocrinidae, Sundicrinidae, Cadocrinidae, and Timerocrinidae, which have this type of cup, are known from Permian rocks (Moore and Laudon, 1943, figs. 7 and 8). The hosts for this group of platyceratids probably belong to one or more of these families. The anal structure of the cadocrinids, the timerocrinids, and the sundicrinids is little known, although Wanner (1916) suggested that certain associated mushroom-shaped ventral sacs belonged to *Cadocrinus variabilis*. If this is so, the cadocrinids were unlikely hosts. The anal structure of *Cromyocrinus* is shown in plate 23, figure 17. The association of *Cromyocrinus* with a *Platyceras* having a broadly elliptical aperture is known from the Carboniferous of Russia (Troutschold, 1867). Specimens from the Springer collection (United States National Museum) showing this relationship are illustrated in plate 23, figures 18 to 20. *Ulocrinus*, a cromyocrinid, is known from Permian rocks of western Texas (Weller, 1909). If it be assumed that it has the same anal structure as *Cromyocrinus*, it was a suitable host. *Platyceras* (*Orthonychia*) *bowsheri*, variant 2, from the upper part of the Word formation in the Glass Mountains was probably coprophagous on *Ulocrinus* or a related crinoid. A suggested restoration is shown in text figure 4B.

CONCLUSION

The type and number of reëntrants and salients of the platyceratid aperture are related directly to the shape and ornamentation of the crinoid host. When more is known about the Permian crinoids of western Texas one will probably be able to relate more closely apertural shapes to specific crinoid types. Such a detailed analysis will lead to a better understanding of the variability of Permian platyceratids.

The variability of the aperture and shell shape of Pennsylvanian and Permian platyceratids is more prounced than in Devonian and Mississippian platyceratids. This is probably because the camerate crinoid, with a well-developed tegmen which furnished a suitable place of attachment for platyceratids, largely disappeared at the end of the Mississippian. The coprophagous platyceratids were forced to restrict their symbiotic habit to the less suitable inadunate crinoids of the Pennsylvanian and Permian. The greater variability of the late Paleozoic platyceratid shells is a reflection of the diversified anal structures of the inadunates and the ways in which the arms of these crinoids restrict the space available for attachment in the anal area.

REGISTER OF LOCALITIES

THE AMERICAN MUSEUM OF NATURAL HISTORY

46. Bone Spring limestone, fossiliferous dark gray limestone about 300 feet above base: 1 mile northwest of mouth of Apache Canyon, Sierra Diablo area, Texas.
51. Hueco limestone: Same as U.S.N.M. 712d.
53. Hueco limestone: Same as U.S.N.M. 712f.
55. Hueco limestone: Same as U.S.N.M. 712g.
369. Bone Spring limestone: Top of Shirtail Canyon, above the drilling well (now abandoned), Humble Oil and Refining Co., E. P. Crowden A. No. 14E, Peere Oil Co. (Rig. No. 17), Guadalupe Mountains, Texas.
391. Hueco limestone: 1.1 miles northwest of Ruddy Tanks, Aldwell Ranch, about 5 miles southeast of the Hueco Inn, Hueco Mountains, El Paso and Hudspeth counties, Texas.
397. Bell Canyon formation, Hegler through Rader limestone members: On the promontory of the spur approximately 0.2 mile east of the Hegler ranch house on the north side of the road, Guadalupe Mountains, Texas.
410. Bell Canyon formation, Rader limestone member: On small hill due west of Hegler ranch house and southwest of Hegler Spring.
433. Lower part of Bone Spring limestone (molluscan ledge, about 100 feet above base): On south side of mouth of Apache Canyon on county line, Sierra Diablo area, Texas.
500. Leonard formation: Same as U.S.N.M. 702.
501. Word formation, near top of limestone no. 1: Same as U.S.N.M. 703, but from a different lens.
503. Word formation, near top of limestone no. 1: Same as U.S.N.M. 703c, but from a different lens.
504. Uppermost part of Leonard formation: Same as U.S.N.M. 703a.
505. Word formation, limestone no. 3: Same as U.S.N.M. 706c.
512. Cherry Canyon formation, Getaway limestone member: Near break in the slope on middle leader on the west side of the airway station road, between the highway and the pipeline road, on the crest of the ridge, Guadalupe Mountains, Texas.
519. Cherry Canyon formation, Getaway limestone member: On west slope of outlier due northeast of BM 5315 in right-angle bend in Highway 62, approximately 0.5 mile east of airway station, Guadalupe Mountains, Texas.
537. Bell Canyon formation, Pinery limestone member: Up slope behind Lower Pine Spring, Guadalupe Mountains, Texas.
592. Bone Spring limestone (molluscan ledge): Between the north and middle branches of Black John Canyon, Van Horn quadrangle, Texas.
600. Cherry Canyon formation, Getaway limestone member: In small gully immediately south of the first cattle guard at junction of Highway 62 and road to airway beacon, east of Guadalupe Pass approximately 0.25 mile, Guadalupe Mountains, Texas.
625. Lower part of Bone Spring limestone: South side of the mouth of Victorio Canyon, 220 feet above the top of the clastic beds, Van Horn quadrangle, Texas.
628. Lower part of Bone Spring limestone: South side of the mouth of Victorio Canyon, Van Horn quadrangle, Texas.
629. Bone Spring limestone, 30 feet above massive bed at top of Hueco limestone: 0.25 mile south of the mouth of Victorio Canyon.
631. Bone Spring limestone, immediately above bioherm in Hueco behind Figure 2 ranch house: 2 miles south of Victorio Canyon, Sierra Diablo area, Texas.
655. Bone Spring limestone: 80 feet above the base on the northernmost of the Baylor Hills on west side of Highway 54.
678. Bone Spring limestone, Cutoff shaly member: On slope 1 mile southwest of point 6910 and 0.2 mile west of fault in front of Cutoff Mountain, Guadalupe Mountains, New Mexico.
700. Hueco limestone: Near top of hill on east side of the last gully to drain west at divide on the red tank road, Baylor Mountains, Van Horn quadrangle, Texas.

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11. Word formation, limestone no. 3: Same locality as U.S.N.M. 706e.
18. Word formation, limestone no. 3: Same locality as U.S.N.M. 706b.
27. Word formation, limestone no. 2: Same locality as U.S.N.M. 706c.

31. Cherry Canyon formation, Getaway limestone member: South of highway, near El Capitan, Guadalupe Mountains, Texas.

7419. Wolfcamp formation, bed 13: Wolfcamp Hills, north of Marathon, Hess Canyon quadrangle, Texas.

F. B. PLUMMER COLLECTION

(Stratigraphic data corrected by Raymond C. Moore)

22-T-11. Word formation: 0.2 mile south of junction of Road and Gillian canyons, Glass Mountains, Texas.

42-T-18. Admiral formation, Wildcat Creek shale member: South side of Gulf, Colorado, and Santa Fe Railway, 4.5 miles south of Coleman, Coleman County, Texas.

42-T-18-111.1. Admiral formation, Wildcat Creek shale member: 5 miles south-southwest of Coleman, Coleman County, Texas.

PRINCETON UNIVERSITY

3. Bone Spring limestone (molluscan ledge about 100 feet above base): Northwest wall of Apache Canyon near mouth, just north of Van Horn quadrangle, Texas.

5. Bone Spring limestone: At approximately 4600-foot contour on ridge due northwest of Apache Peak, on southeast wall of Apache Canyon, Van Horn quadrangle, Texas.

20g. Bone Spring limestone: Shoulder from downfaulted hills at northwest wall of Apache Canyon, Van Horn quadrangle, Texas.

24. Hueco limestone: South side of Apache Spring Canyon directly under the "n" in Spring, Van Horn quadrangle, Texas, approximately longitude 104°53′15″ W., latitude 31°53′ N.

37. Hueco limestone (just above conglomerate): On Eagle Butte, north side of Texas and Pacific Railway just west of Van Horn quadrangle, Texas.

37r. Hueco limestone (just above conglomerate): Ranch house west of Eagle Butte, just west of Van Horn quadrangle, Texas.

47. Hueco limestone: Slope of thin-bedded limestone and shale above conglomerate and below upper cliffs, southwest slope of Threemile Mountain, Van Horn quadrangle, Texas.

53. Hueco limestone: Northwest wall of Apache Canyon at 4500-foot contour, just north of "C" in Canyon, Van Horn quadrangle, Texas, approximately longitude 104°56′37″ W., latitude 31°55′ N.

57a. Hueco limestone: Southwest Wylie Mountains about 1 mile south of "W" in Wylie, Van Horn quadrangle, Texas, approximately longitude 104°46′15″ W., latitude 30°59′ N.

61a. Hueco limestone (basal): 9 miles southwest of Hueco tanks, second hill north 35° east of Carlsbad highway, Hueco Mountains, Texas.

TEXAS BUREAU OF ECONOMIC GEOLOGY

(Stratigraphic data corrected by Raymond C. Moore)

4075. Clyde formation, Grape Creek limestone member: Little bluff on Colorado River, Runnels County, Texas.

4100. Clyde formation, Talpa limestone member: Big bluff on Colorado River, Runnels County, Texas.

8505. Clyde formation, Talpa limestone member: Herrings Bluff on Colorado River, Runnels County, Texas.

10874. Clyde formation, Grape Creek limestone member: 2.25 miles west of Deadman's Bluff, Runnels County, Texas.

10973. Admiral formation, Elm Creek limestone member or Jagger Bend limestone member: West of Leady and southwest of Colorado River, Coleman County, Texas.

UNITED STATES GEOLOGICAL SURVEY

The upper Paleozoic unit of the Paleontology and Stratigraphy Branch has two separate series of locality numbers. An earlier series of "green" numbers is no longer used, but a "blue" series has been used since the early 1900's. With the exception of the first three localities listed, all numbers refer to the blue catalogue.

2915 green. Hueco limestone (chiefly from upper one-third of brown limestone exposed): Spur south of Cerro Alto and south of road, this spur parallel to and just north of that of 2925 green, Hueco Mountains, probably Texas.

2925 green. Hueco limestone: Spur south of Cerro Alto and south of road, the spur extending northward towards Cerro Alto and terminating at road, Hueco Mountains, probably Texas.

2930 green: Chiefly float, supposed to be from the dark limestone immediately above the sandstones of the Delaware Mountain group (probably from Bell Canyon formation, possibly Pinery limestone member): Almost entirely from north side of Pine Spring Canyon, from two spurs embracing the spring, Guadalupe Mountains, Texas.

5314. Naco group (possibly Colina limestone): 0.9 mile north 80° east of the southwest corner of sect. 19, T. 23 S., R. 25 E., and at other points to the southeast, Cochise County, Arizona.

5315. Naco group (possibly Colina limestone): 2.25 miles north of the middle of the north boundary of sect. 6, T. 24 S., R. 23 E., Cochise County, Arizona.

6690. Upper part of Hess limestone member of the Leonard formation: 200 feet from top, 2 miles northwest of Wolfcamp, Hess Canyon quadrangle, Texas.

6721. Hueco limestone (about 1000 feet above base): Hueco Canyon, south of road, 300 yards south of Cerro Alto Peak, Cerro Alto quadrangle, Texas.

6937. Hueco limestone: Threemile Mountain, Diablo Plateau, south 30.1 miles, east 8.8 miles of northwest corner of Van Horn quadrangle, Texas.

7003a. Basal beds of Hueco limestone: Northeast slope of a small sharp crested mesa, the eastern of two, about 2 miles northwest of Eagle Flat section house, just west of Van Horn quadrangle, Texas.

7004. Basal beds of Hueco limestone: Diablo Plateau, Diablo scarp approximately 2 miles southwest of Figure 2 Ranch, south 3.74 miles and east 7.3 miles of northwest corner of Van Horn quadrangle, Texas.

7007. Hueco limestone: Diablo Plateau, south wall of Apache Canyon just west of longitude 105° W., south 2.4 miles and west 0.2 mile of northwest corner of Van Horn quadrangle, Texas.

7028. Hueco limestone: East end of butte about 1 mile northwest of Eagle Flat station (Texas and Pacific Railway), just west of Van Horn quadrangle, Texas.

7050. Basal beds of Hueco limestone: Foot of Diablo scarp, 2.5 miles southwest of Figure 2 Ranch on south spur of outer Marble Canyon intrusive, 4.5 miles south and 7.0 miles east of northwest corner of Van Horn quadrangle, Texas.

7055. Bone Spring limestone: Diablo Plateau, above lower cliffs, 3 miles west by north of Figure 2 Ranch, Van Horn quadrangle, Texas.

8188. Naco group (possibly Colina limestone): Tombstone district, 1.75 miles southeast of Military Hill, Cochise County, Arizona.

8488. Colina limestone: Top of Hill 5501, in the SW. ¼, sect. 23, T. 21 S., R. 23 E., Pearce quadrangle, Arizona.

8501. Colina limestone: 800 feet south-southwest of BM 5700, on steep cliff, T. 21 S., R. 23 E., Pearce quadrangle, Arizona.

8502. Colina limestone: Same as U.S.G.S. 8501, 100 feet stratigraphically higher.

8503. Colina limestone: From about 15 feet stratigraphically below BM 5700, in T. 21 S., R. 23 E., top of big butte, Benson quadrangle, Arizona.

8513. Colina limestone: Top of Hill 5320, on line between R. 22 and R. 23 E., T. 20 S., Benson quadrangle, Arizona.

8522. Colina limestone: North spur of the Three Brothers Peaks, just north of porphyry contact, Benson quadrangle, Arizona.

8529. Earp formation: From 1500 feet northeast of crest of Hill 5501 in sect. 23, T. 21 S., R. 23 E., Pearce quadrangle, Arizona.

8532. Colina limestone (float): From high cliff on south face of Hill 5501 in sect. 23, T. 21 S., R. 23 E., Pearce quadrangle, Arizona.

8539. Lower part of Bone Spring limestone: From south portal of Victorio Canyon, east face of Sierro Diablo Plateau, Van Horn quadrangle, Texas.

8971. Colina limestone: About 7 miles south and 2.5 miles east of Tombstone Hill on north side of Government Draw in the SE. ¼, sect. 5, T. 21 S., R. 23 E., Benson quadrangle, Arizona.

9802. Admiral formation, local soft shaly limestone in Wildcat Creek shale member, approximately 15 feet below base of Overall limestone member: 4.9 miles west of south from center of Coleman, 0.45 mile (240 feet) south of Gulf, Colorado, and Santa Fe Railway 0.55 mile east-northeast of road crossing of railway just south of point where U. S. Highway 67 turns west-southwest on approaching railway, Coleman County, Texas.

9842. Clyde formation, Talpa limestone member, about 70 feet above base: 11.4 miles south of east from center of Ballinger and 5.5 miles south-southwest of Talpa on east-southeast trending secondary road west of Grape Creek, Runnels County, Texas.

9844. Clyde formation, Grape Creek limestone member, about 60 to 80 feet above base: 14.2 miles southeast of center of Ballinger at Deadmans Bluff on north side of Colorado River, 1.8 miles north of Runnels-Concho county line and 3.1 miles west of Runnels-Coleman county line, Runnels County, Texas.

9847. Clyde formation, Grape Creek limestone member, about 170 feet below top: 12.1 miles southeast of center of Ballinger and 10.8 miles south-southwest of Talpa, on slope east of tributary of Colorado River which enters at Deadmans Bluff (locality is 2.5 miles above mouth of this stream, airline), Runnels County, Texas.

9848. Clyde formation, Talpa limestone member, 60 to 65 feet below top: 6.9 miles due east of center of Ballinger and 3.2 miles due south of Bunoit, just north of east-west secondary road crossing of Mustang Creek at point 3.8 miles (airline) above its mouth, Runnels County, Texas.

9854. Clyde formation, Talpa limestone member, about 90 feet below top: 8.25 miles southeast of center of Ballinger, north end of Herrings Bluff on east side of Colorado River, 1.0 mile southeast of mouth of Mustang Creek, Runnels County, Texas.

9858. Lueders limestone, about 100 feet above base: 10.5 miles east-northeast of center of Ballinger and 4.7 miles west-northwest of Talpa on south trending secondary road 0.25 mile south of U. S. Highway 67, on slope south of middle fork of Mustang Creek, Runnels County, Texas.

9859. Clyde formation, Grape Creek limestone member, about 125 feet above base: 14.2 miles southeast of center of Ballinger, 3.8 miles west of Runnels-Coleman county line and 1.1 miles north of Runnels-Concho county line, bluff on south side of Colorado River 1 mile above (southwest of) Deadmans Bluff, Runnels County, Texas.

9860. Clyde formation, Talpa limestone member, upper 14 feet: 7.05 miles southeast of center of Ballinger on east-west road 2 miles west of Herrings Bluff on Colorado River and 1.5 miles southwest of mouth of Mustang Creek, Runnels County, Texas.

9861. Clyde formation, Talpa limestone member, about 20 feet below top: 8.9 miles slightly north of east from center of Ballinger and 3 miles southeast of Bunoit, just east of point where south trending secondary road crosses tributary of Mustang Creek, Runnels County, Texas.

9863. Clyde formation, Grape Creek limestone member, topmost bed: 12.8 miles south of east of center of Ballinger, 4.4 miles south-southwest of Talpa on west side of Grape Creek, 1 mile west of Runnels-Coleman county line, Runnels County, Texas.

9880. Pueblo formation, Camp Creek shale member, about 50 feet below top: 10.25 miles nearly due south of Gouldbusk, on west side of Saddle Creek, 1.4 miles south and 0.6 mile west of its mouth, 0.7 mile south of east-west road crossing Saddle Creek, McCulloch County, Texas.

9884. Clyde formation, Talpa limestone member, about 50 feet below top: On Hog Creek just south of Paint Rock, 0.2 mile southwest of point where U. S. Highway 83 crosses Hog Creek, Concho County, Texas.

14424. Hueco limestone: 3 miles northwest of Sheep Peak, 1.8 miles west and 17.7 miles south of northeast corner of Sierra Blanca quadrangle, Texas.

14425. Hueco limestone: West side of road, 2.5 miles south-southwest of Matthews Place, 9.4 miles west and 9.1 miles south of northeast corner of Sierra Blanca quadrangle, Texas.

14426. Hueco limestone, 25 to 50 feet above basal clastics: Hill 5071, 5.5 miles northwest of Van Horn, Van Horn quadrangle, Texas.

14430. Hueco limestone, lower marls: North side of Threemile Mountain, 4.3 miles north and 8.3 miles east of southwest corner of Van Horn quadrangle, Texas.

14431. Hueco limestone: 2.8 miles northwest of Eagle Flat section house, north side of first butte northwest of "Eagle Butte," 9.4 miles west and 9.2 miles north of southeast corner of Sierra Blanca quadrangle, Texas.

14432. Hueco limestone, basal marls: East nose of small mesa 4 miles northwest of Eagle Flat section house, 10.9 miles north and 9.4 miles west of southeast corner of Sierra Blanca quadrangle, Texas.

14437. Hueco limestone: Limestone on southeast nose of Threemile Mountain, 4.0 miles north and 8.3 miles east of southwest corner of Van Horn quadrangle, Texas.

14438. Hueco limestone: About 5 miles west of Van Horn on south side of west end of a limestone ridge, 4.1 miles north and 4.8 miles east of southwest corner of Van Horn quadrangle, Texas.

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701. Wolfcamp (upper 15 feet of bed 2): Bed of stream and both banks, and dip slope to southeast, just northeast of small canyon, about 0.4 mile upstream from mouth, Wolfcamp Hills, about 15 miles by road northeast of Marathon, Hess Canyon quadrangle, Texas.

$701a_2$. Wolfcamp (upper part of bed 9): Head of canyon, just south of forks, Wolfcamp Hills, Hess Canyon quadrangle, Texas.

701c. Wolfcamp formation (beds 9–12): Crest of hill facing and forming north side of canyon, on west side of tributary arroyo 0.2 mile up canyon from entrance, Wolfcamp Hills, 15 miles (by road) northeast of Marathon, Hess Canyon quadrangle, Texas.

701d. Wolfcamp formation (beds 9–12): Two small hills 1 mile northwest of Wolfcamp, west end of Wolfcamp Hills, 15 miles (by road) northeast of Marathon, Hess Canyon quadrangle, Texas.

701g. Wolfcamp formation (bed 9): Patch of gray-brown limestone with numerous *Orthotichia* in south gully near its head, south branch canyon, Wolfcamp Hills, Hess Canyon quadrangle, Texas.

701h. Wolfcamp formation (beds 9–12): Crest of hill, 0.75 mile south 78° west of Hill 5060, Wolfcamp Hills, Hess Canyon quadrangle, Texas.

701-l. Wolfcamp formation (bed 2): About 4625 feet elevation on south side of hill, 0.87 mile south 69° west of Hill 5060, Wolfcamp Hills, Hess Canyon quadrangle, Texas.

702. Leonard formation, upper part (original Leonard of P. B. King): Slopes on south side of road 0.2 to 0.5 mile east of Split Tank, 1.5 miles northeast of road fork near old Word Ranch, about 19 miles north-northeast of Marathon, Hess Canyon quadrangle, Texas.

702a. Leonard formation, upper part (middle of King's original Leonard formation): 0.5 mile east of Split Tank, 19 miles north-northeast of Marathon, Hess Canyon quadrangle, Texas.

702b. Leonard formation, upper part (lower part of original Leonard of P. B. King): 0.5 mile east of Split Tank, 19 miles north-northeast of Marathon, Hess Canyon quadrangle, Texas.

702c. Leonard formation (upper part of original Leonard of P. B. King): Knob on south side of road at elbow just west of south branch of Hess Canyon, 4.5 miles by road northeast of Hess gate, 4.2 miles (airline) north 48° east of Hess Ranch, Hess Canyon quadrangle, Texas.

702d. Leonard formation (Hess limestone member, eastern facies): Crest of hill 3.8 miles (airline) north 67° east of Hess ranch house, 0.4 mile southwest of head of south branch of Hess Canyon, Hess Canyon quadrangle, Texas.

702e. Leonard formation, Hess limestone member: Point of hill about 5700 feet elevation, 3.6 miles (airline) north 67° east of Hess ranch house, Hess Canyon quadrangle, Texas.

702ent. Leonard formation: From smooth greenish gray limestone with abundant *Enteletes*, patch just west (50 yards) of gully 0.5 mile east of Split Tank, about 100 feet above the conglomerate at base of King's Leonard, Hess Canyon quadrangle, Texas.

702f. Leonard formation, Hess limestone member (fossil bed): 0.5 mile southwest of Hill 5821, 4.4 miles north 66.5° east of Hess ranch house, Hess Canyon quadrangle, Texas.

702un. Upper part of Leonard formation: *Institella* beds of original Leonard formation of King at U.S.N.M. 702.

702x. Wolfcamp formation: Small hill 150 yards north 50° east of Gaptank, west side of Stockton Gap, Texas.

703. Word formation (limestone no. 1): Lens with goniatites in platy limestone near top of slope 0.5 mile southwest of road forks just northeast of old Word Ranch, Hess Canyon quadrangle, Texas.

703a. Uppermost part of Leonard formation (*Aulosteges* beds): On northwest side of road between road fork and sheep tank near old Word Ranch, about 17 to 18 miles north-northeast of Marathon, Hess Canyon quadrangle, Texas.

703b. Leonard formation, upper part (lower part of original Leonard of King): On southeast side of road between road fork and sheep tank at old Word Ranch, Hess Canyon quadrangle, Texas.

703c. Word formation (limestone no. 1): Crest of slope 0.25 to 0.5 mile southwest of road fork near old Word Ranch, 17 to 18 miles north-northeast of Marathon, Hess quadrangle, Texas. Sponge bed. Basal portion, dark platy, is called Word no. 1 by P. B. King, just above reefy beds on crest of slope on north side of road, 0.25 mile southwest of road fork near old Word Ranch, Hess Canyon quadrangle, Texas.

703d. Word formation (limestone no. 1): In elbow of road at turn to Thomas Ranch, head of canyon near Word Ranch, Hess Canyon quadrangle, Texas.

706. Word formation (lower part of limestone no. 3): North slope of hill on south side of Hess Canyon, 4 miles north 35° east of Hess Ranch, 14 miles north-northeast of Marathon, Hess Canyon quadrangle, Texas.

706b. Word formation (limestone between limestone no. 3 and limestone no. 4): 0.2 mile west of junction of Hess Canyon with south branch of Hess Canyon, Hess Canyon quadrangle, Texas.

706c. Word formation (about middle of limestone no. 2): Southwest slope and crest of low hill 3.7 miles north 36° east (airline) of Hess ranch house, Hess Canyon quadrangle, Texas.

706e. Word formation (top of limestone no. 3).: East side of small arroyo 4.1 miles (airline) north 34° east of Hess ranch house, Hess Canyon quadrangle, Texas.
706x. Wolfcamp formation (bed 12 to top): Just west of canyon just above sharp elbow, 0.5 mile north 76° west of Hill 5060, Wolfcamp Hills, Hess Canyon, Texas.
707a. Hess member of Leonard formation (*Scacchinella* bed) of King: 0.5 mile south of Hill 5300 and for 0.75 mile to northeast along Hess scarp, 2.75 miles north 23° west of Decie Ranch, west-northwest of Marathon, Altuda quadrangle, Texas.
707b. Leonard formation (top of limestone no. 1): North side of arroyo 4.1 miles (airline) due north of Decie ranch house, 1 mile northwest of entrance to Sullivan Ranch Canyon, Altuda quadrangle, Texas.
707c. Leonard formation (top bed of limestone no. 1): Dip slope of hill 3.85 miles (airline) due north of Decie ranch house, Altuda quadrangle, Texas.
707d. Wolfcamp formation (top): Knob on west side of entrance to Sullivan Ranch Canyon 3.5 miles north 7° east of Decie ranch house, Altuda quadrangle, Texas.
707e. Word formation (lower): 5.3 miles (airline) north 5° west of Decie ranch house, 0.9 mile (airline) south 25° east of Sullivan Peak, on nose of foothill southeast of Sullivan Peak, Altuda quadrangle, Texas.
707o. Wolfcamp formation (lower 30 feet of shale below Hess limestone member of Leonard formation): 100 yards south 81° east of Hill 4902, 3 miles north of Decie Ranch, 1.3 mile southwest of Hill 5300, Altuda quadrangle, Texas.
707q. Leonard formation: Base of hill just east of Clay Slide, Altuda quadrangle, Texas.
708r. Wolfcamp formation (beds 4–8): On slope just north of *Uddenites* knob, Wolfcamp Hills, Hess Canyon quadrangle, Texas.
708s. Wolfcamp formation (bed 5): West end of Wolfcamp Hills, Hess Canyon quadrangle, Texas.
708t. Wolfcamp formation (beds 5–8): Wolfcamp Hills, Hess Canyon quadrangle, Texas.
712. Hueco limestone: From an isolated hill 0.7 mile south of railway station at Orogrande, near the center of sect. 25, T. 22 S., R. 8 E., from bed just below top of hill; just south of small hill of trachyte-porphyry, Orogrande quadrangle, New Mexico.
712a. Hueco limestone (25 feet below siltstone, 200 feet below "cephalopod bed"): North center of section 24 near crest of hill in southeast and south of monument and pin at quarter corner at sect. 13 and sect. 24, T. 23 S., R. 8 E., Orogrande quadrangle, New Mexico.
712b. Hueco limestone (about 700 feet above Powwow conglomerate and probably below "cephalopod bed"): In the NE.¼ SW. ¼, sect. 25, T. 22 S., R. 8 E., near Orogrande, Otero County, New Mexico.
712c. Hueco limestone (about 200 feet below "cephalopod bed"): In the SE. ¼, sect. 8, T. 22 S., R. 10 E., Otero County, New Mexico.
712d. Basal middle Hueco limestone: 0.5 mile north-northeast of Hueco Inn, east of highway, Hueco Mountains, Texas.
712f. Middle part of Hueco limestone: Hill 1 mile north of Ruddy Tank, west of road, 4.5 miles southeast of Hueco Inn, Hueco Mountains, Texas.
712g. Lower part of Hueco limestone (near base, above Powwow conglomerate): Head of Powwow Canyon about 0.25 mile due west of BM 5067, Hueco Mountains, Texas.
712h. Hueco limestone ("cephalopod bed"): In the SW. ¼, sect. 20, T. 22 S., R. 10 E., Otero County, New Mexico.
712i. Hueco limestone ("cephalopod bed"): McGregor Ranch, south line of SW. ¼, sect. 20, T. 22 S., R. 10 E., Otero County, New Mexico.
712j. Hueco limestone: Center of sect. 9, T. 22 S., R. 10 E., Otero County, New Mexico.
716. Bone Spring limestone (lower 100 feet): Nose of Victorio Peak above Figure 2 Ranch headquarters, Van Horn quadrangle, Texas.
719. Lower part of Hueco limestone: Threemile Mountain northwest of Van Horn, Van Horn quadrangle, Texas.
720. Hueco limestone (basal marly beds): Southeast slope of Hill 5039 at entrance to Marble Quarry Canyon, Van Horn quadrangle, Texas.
721. Hueco limestone (lower beds): East end of Eagle Butte, a butte directly west of Eagle Flat station on Texas and Pacific Railway, just west of Van Horn quadrangle, Texas.
722. Gym limestone (bed 34 of Bogart): Florida Mountains, south 22° east of Gym Peak in the N. ½, sect. 18, and NW. ¼, sect. 17, T. 26 S., R. 7 W., New Mexico.
723. Gym limestone (bed 27 of Bogart): Florida Mountains south 22° east of Gym Peak in the N. ½, sect. 18, and NW. ¼, sect. 17, T. 26 S., R. 7 W., New Mexico.

724. Gym limestone (bed 30 of Bogart): Florida Mountains, south 22° east of Gym Peak in the N. ½, sect. 18, and NW. ¼, sect. 17, T. 26 S., R. 7 W., New Mexico.
726. Gym limestone (bed 32 of Bogart): Florida Mountains, south 22° east of Gym Peak, in the N. ½, sect. 18, and NW. ¼, sect. 17, T. 26 S., R. 7 W., New Mexico.
728. Cherry Canyon formation, Getaway limestone member: Same as A.M.N.H. 512.
3358. Leonard formation, Hess limestone member(?): Elevation 4930, on scarp facing southeast, 0.65 mile north 83° west of Hill 4815, 3.95 miles west of Montgomery ranch house, Hess Canyon quadrangle, Texas.
3360. Wolfcamp formation: 22 yards south 45° east of Gaptank, east side of Stockton Gap, Texas.

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2. Leonard formation: Same as U.S.N.M. 702.
4. Word formation (limestone no. 3): Same as U.S.N.M. 706e.
7. Leonard formation (middle): About 1.25 miles northeast of Hill 5021 to a little east of Clay Slide, Altuda quadrangle, Texas.
91. Wolfcamp formation (bed 12): Same as U.S.N.M. 701c.
93. Wolfcamp formation (bed 9 and float from next few higher beds): On side of the arroyo northeast of Wolfcamp, Hess Canyon quadrangle, Texas.
126. Leonard formation: Above conglomerate near the Word Ranch, Hess Canyon quadrangle, Texas.
128. Leonard formation: Same as U.S.N.M. 702.
142. Word formation (limestone no. 4): About 0.5 mile northeast of Willis Ranch, Hess Canyon quadrangle, Texas.
174. Leonard formation (upper): 4.5 miles northeast of the Word Ranch near the Pecos-Brewster county line, 0.25 mile east of Hill 5157, in arroyo, Hess Canyon quadrangle, Texas.
242. Word formation (limestone no. 3): From bed below uppermost white limestone at east end of range north of Leonard Mountain, on the north slope of Hill 5453, Hess Canyon quadrangle, Texas.
252. Word formation (limestone no. 4): Approximately 1.25 miles north-northeast of Word ranch house, on north slope of Hill 5575, Hess Canyon quadrangle, Texas.

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PLATES 9–24

PLATE 9

1, 2. *Straparollus* (*Euomphalus*) *pernodosus* Meek and Worthen. 1. Top view, holotype, from Coal Measures, Alton, Illinois, I.G.S. No. 2867. 2. Umbilical view, same specimen.

3–8. *Straparollus* (*Euomphalus*) *cornudanus* (Shumard). 3. Umbilical view, hypotype, from U.S.G.S. 9863, Clyde formation, U.S.N.M. No. 119100a. 4. Top view, same specimen. 5. Side view, same specimen. 6. Oblique top view, hypotype, from U.S.G.S. 9863, Clyde formation, U.S.N.M. No. 119100b. 7. Umbilical view, same specimen. 8. Top view, same specimen.

All figures natural size.


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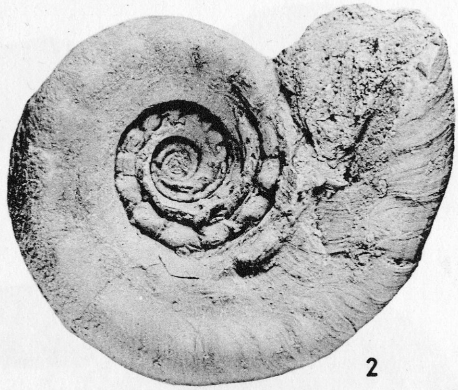
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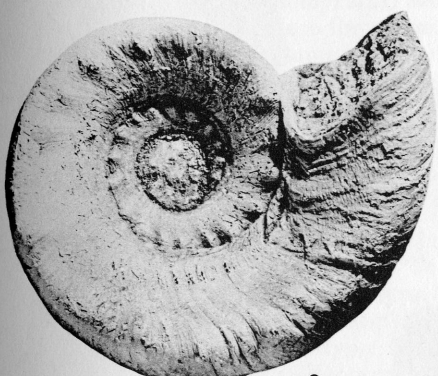
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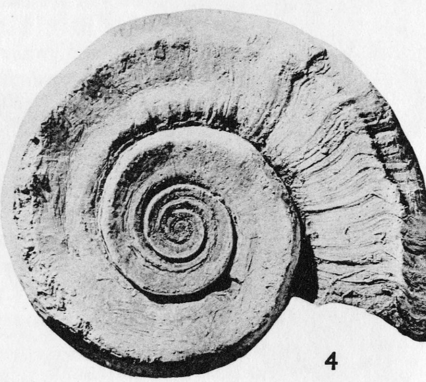
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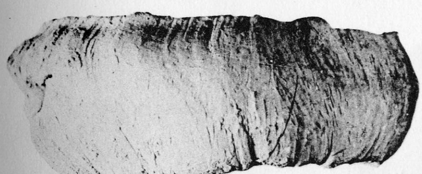
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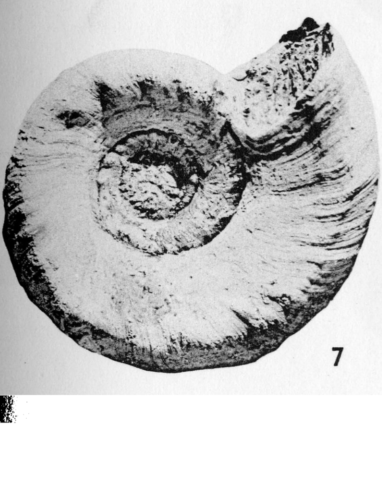
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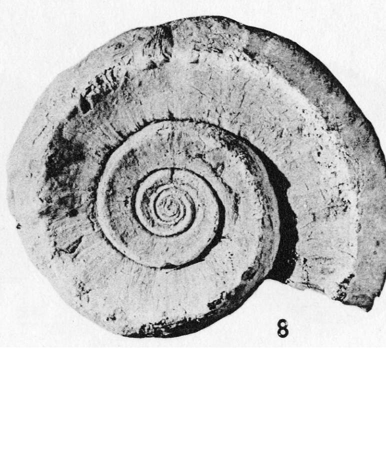
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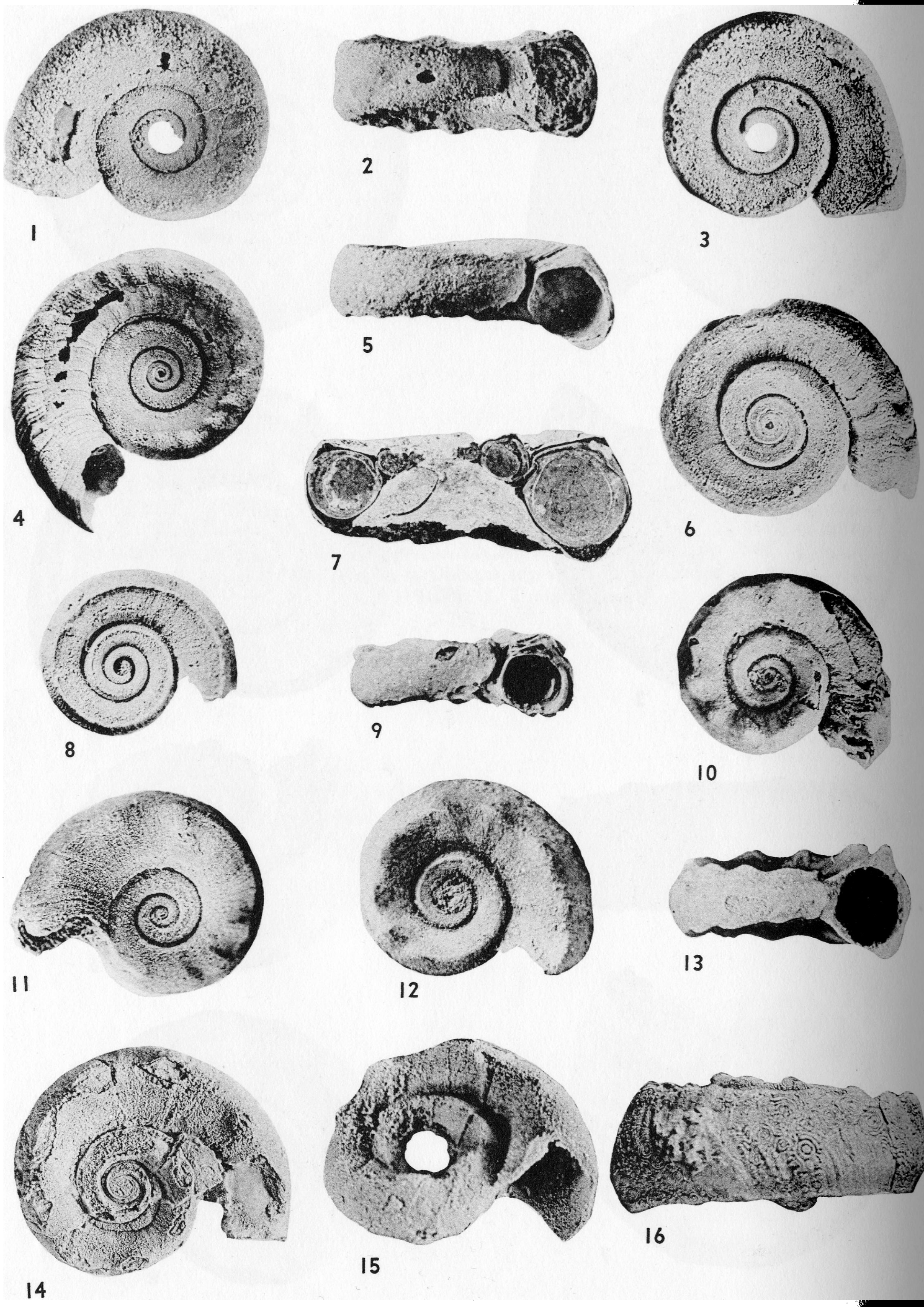
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PLATE 10

1–8. *Straparollus* (*Euomphalus*) *cornudanus* (Shumard). 1. Umbilical view, hypotype, from A.M.N.H. 51, Hueco limestone, U.S.N.M. No. 119101a. 2. Apertural view, same specimen. 3. Top view, same specimen. 4. Umbilical view, hypotype, from A.M.N.H. 55, Hueco limestone, U.S.N.M. No. 119102. 5. Apertural view, same specimen. 6. Top view, same specimen. 7. Polished section of hypotype, from U.S.G.S. 9863, Clyde formation, U.S.N.M. No. 119100c. 8. Top view of juvenile hypotype, from A.M.N.H. 51, Hueco limestone, U.S.N.M. No. 119101b.

9–16. *Straparollus* (*Euomphalus*) *kaibabensis* (H. P. Chronic). 9. Apertural view, hypotype, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119104a. 10. Top view, same specimen. 11. Umbilical view, juvenile hypotype, from U.S.N.M. 703, Word formasion, U.S.N.M. No. 119104b. 12. Top view, same specimen. 13. Apertural view, same specimen. 14. Top view of hypotype, from One Tree Peak, San Andres Mountains, sect. 29, T. 18 S., R. 16 E., New Mexico, San Andres formation, U.S.N.M. No. 119103. 15. Oblique top view of hypotype, from U.S.G.S. 8522, Colina limestone, U.S.N.M. No. 119106. 16. Side view of hypotype showing similarity of mature body whorl to that of *S.* (*E.*) *cornudanus* (Shumard), from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119105a.

1–7, 9, 10, 14, and 16 are natural size; 8, 11–13, and 15 are twice natural size.

PLATE 11

1–6. *Straparollus* (*Euomphalus*) *levicarinatus* Yochelson, new species. 1. Top view, paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27936:2. 2. Umbilical view, same specimen. 5. Apertural view, same specimen. 3. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27936:3. 4. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27936:4. 6. Top view, holotype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27936:1.

7. ?*Straparollus* (*Euomphalus*) species, umbilical view, from U.S.N.M. 707b, Leonard formation, U.S.N.M. No. 119108.

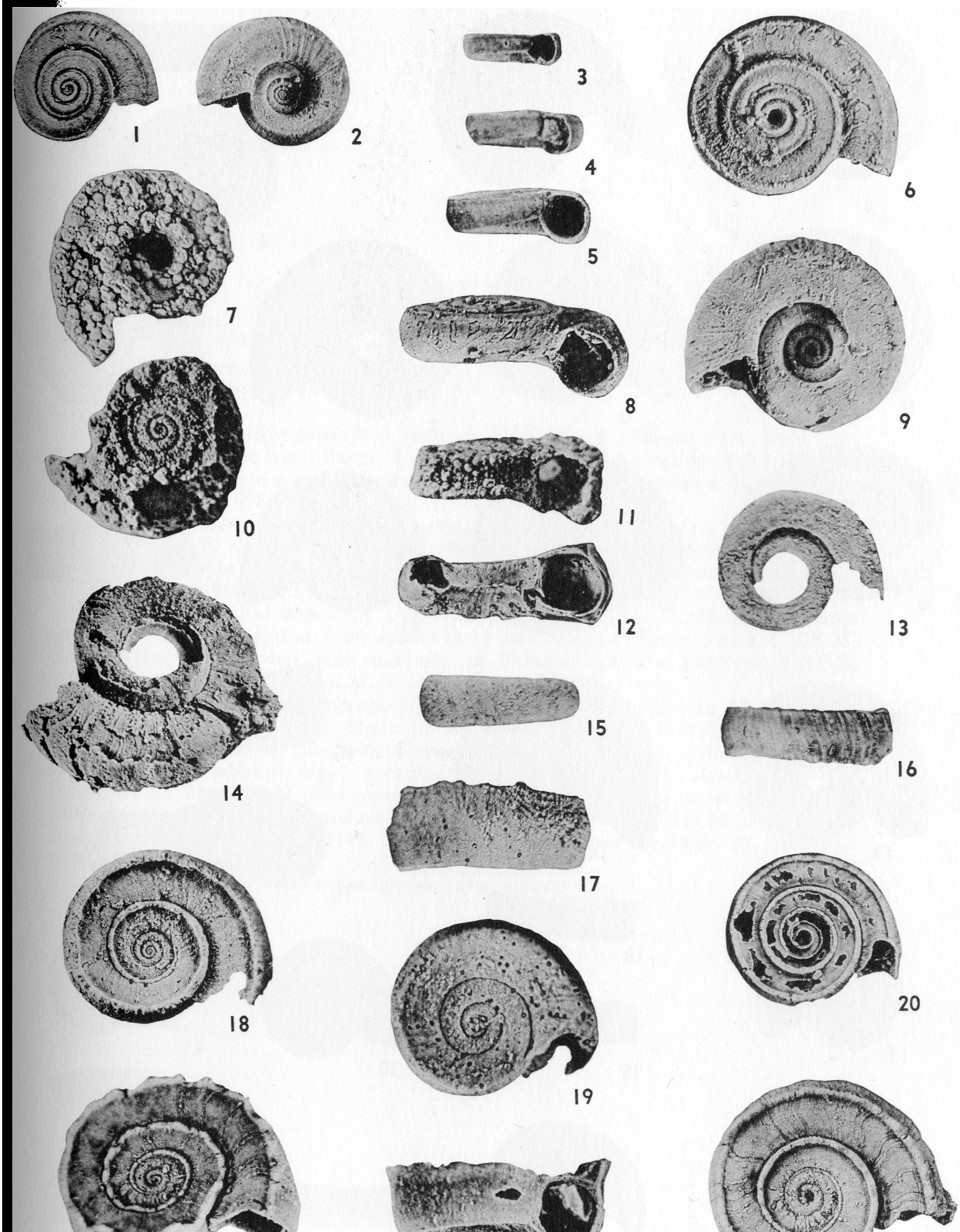
8, 9. *Straparollus* (*Euomphalus*) *levicarinatus* Yochelson, new species. 8. Apertural view, holotype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27936:1. 9. Umbilical view, same specimen.

10, 11. ?*Straparollus* (*Euomphalus*) species. 10. Top view, from U.S.N.M. 707b, Leonard formation, U.S.N.M. No. 119108. 11. Apertural view, same specimen.

12–15. *Straparollus* (*Euomphalus*) species indeterminate. 12. Natural cross section showing clearly two silicified shell layers, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119109d. 13. Top view of another specimen showing well-rounded whorls, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119109b. 14. Specimen, possibly *S.* (*E.*) *kaibabensis* (H. P. Chronic), showing silicification of inner shell layer, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119109a. 15. Side view showing rounded whorl of inner shell layer, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119109c.

16–23. *Straparollus* (*Euomphalus*) *glabribasis* Yochelson, new species. 16. Side view, largest paratype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27937:5. 20. Top view, same specimen. 17. Side view, holotype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27937:1. 18. Top view, same specimen. 19. Umbilical view, same specimen. 21. Oblique top view of paratype showing crenulated upper keel, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27937:4. 22. Apertural view of juvenile paratype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27937:2. 23. Top view of another paratype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27937:3.

12–15, 16, and 20 are natural size; 1–6, 8, 9, 17–19, 21, and 23 are twice natural size; 7, 10, 11, and 22 are three times natural size.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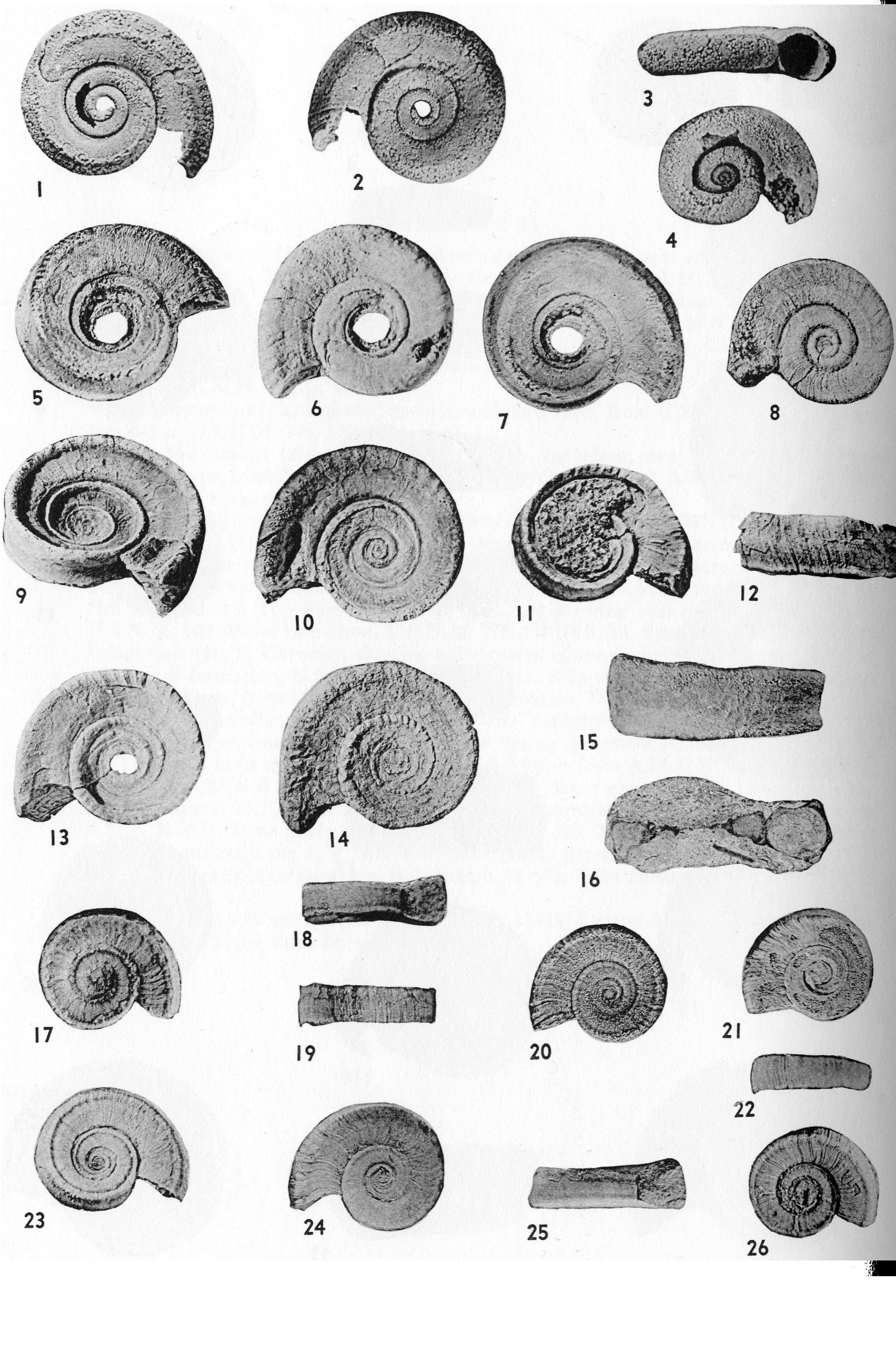
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PLATE 12

1–4. *Straparollus* (*Leptomphalus*) *micidus* Yochelson, new species. 1. Top view, holotype, A.M.N.H. 369, Bone Spring limestone, A.M.N.H. No. 27938:1. 2. Umbilical view, same specimen. 3. Apertural view, same specimen. 4. Oblique top view of juvenile paratype showing early whorls, A.M.N.H. 369, Bone Spring limestone, A.M.N.H. No. 27938:2.

5–8. *Amphiscapha* (*Amphiscapha*) *muricata* (Knight). 5. Oblique view, hypotype, showing characteristic basal flange, U.S.G.S. 9880, Pueblo formation, U.S.N.M. No. 119110a. 6. Basal view, same specimen. 7. Top view, same specimen. 8. Basal view of hypotype, U.S.G.S. 9880, Pueblo formation, U.S.N.M. No. 119110b.

9–16. *Amphiscapha* (*Amphiscapha*) *gigantea* Yochelson, new species. 9. Oblique top view, holotype, P. C. 42-T-18, Admiral formation, B. E. G. No. 13556. 10. Umbilical view, same specimen. 11. Oblique top view, paratype, U.S.G.S. 9802, Admiral formation, U.S.N.M. No. 119111a. 12. Side view, same specimen. 13. Umbilical view of paratype, U.S.G.S. 9802, Admiral formation, U.S.N.M. No. 119111b. 14. Umbilical view, large paratype, Admiral formation, 4 miles south and 1 mile west of Coleman, Texas, U.S.N.M. No. 119112a. 15. Side view, same specimen. 16. Polished section of paratype, U.S.G.S. 9802, Admiral formation, U.S.N.M. No. 119111c.

17–26. *Amphiscapha* (*Amphiscapha*) *proxima* Yochelson, new species. 17. Top view, holotype, from U.S.N.M. 712j, Hueco limestone, U.S.N.M. No. 119113. 18. Apertural view, same specimen. 19. Adapertural view, same specimen. 20. Umbilical view, same specimen. 21. Umbilical view, paratype, from U.S.N.M. 712j, Hueco limestone, U.S.N.M. No. 119114a. 22. Side view, same specimen. 26. Top view, same specimen. 23. Oblique top view of paratype showing pronounced keel, from U.S.N.M. 712j, Hueco limestone, U.S.N.M. No. 119114b. 24. Umbilical view, same specimen. 25. Apertural view, same specimen.

11–26 are natural size; all other figures, twice natural size.

PLATE 13

1, 2. *Amphiscapha (Amphiscapha) dextrata* Yochelson, new species. 1. Top view, holotype, from A.M.N.H. 51, Hueco limestone, U.S.N.M. No. 119116. 2. Umbilical view, same specimen.

3, 4. *Amphiscapha (Cylicioscapha) subquadrata* (Meek and Worthen). 3. Top view, paratype, upper Coal Measures, Montgomery County, Illinois, I.G.S. No. 2863. 4. Umbilical view, same specimen.

5. *Amphiscapha (Amphiscapha) dextrata* Yochelson, new species. Side view, holotype, from A.M.N.H. 51, Hueco limestone, U.S.N.M. No. 119116.

6. *Amphiscapha (Cylicioscapha) subquadrata* (Meek and Worthen). Side view, hypotype, from Montgomery County, Illinois, U.S.N.M. No. 47955.

7–11. *Amphiscapha (Cylicioscapha) texana* Yochelson, new species. 7. Top view, holotype, from 3 miles west of Perrin, Texas, Wolf Mountain formation, U.S.N.M. No. 119118. 8. Apertural view, same specimen. 9. Adapertural view, same specimen. 10. Umbilical view, same specimen. 11. Umbilical view of large paratype, from 3 miles west of Perrin, Texas, Wolf Mountain formation, U.S.N.M. No. 112119a.

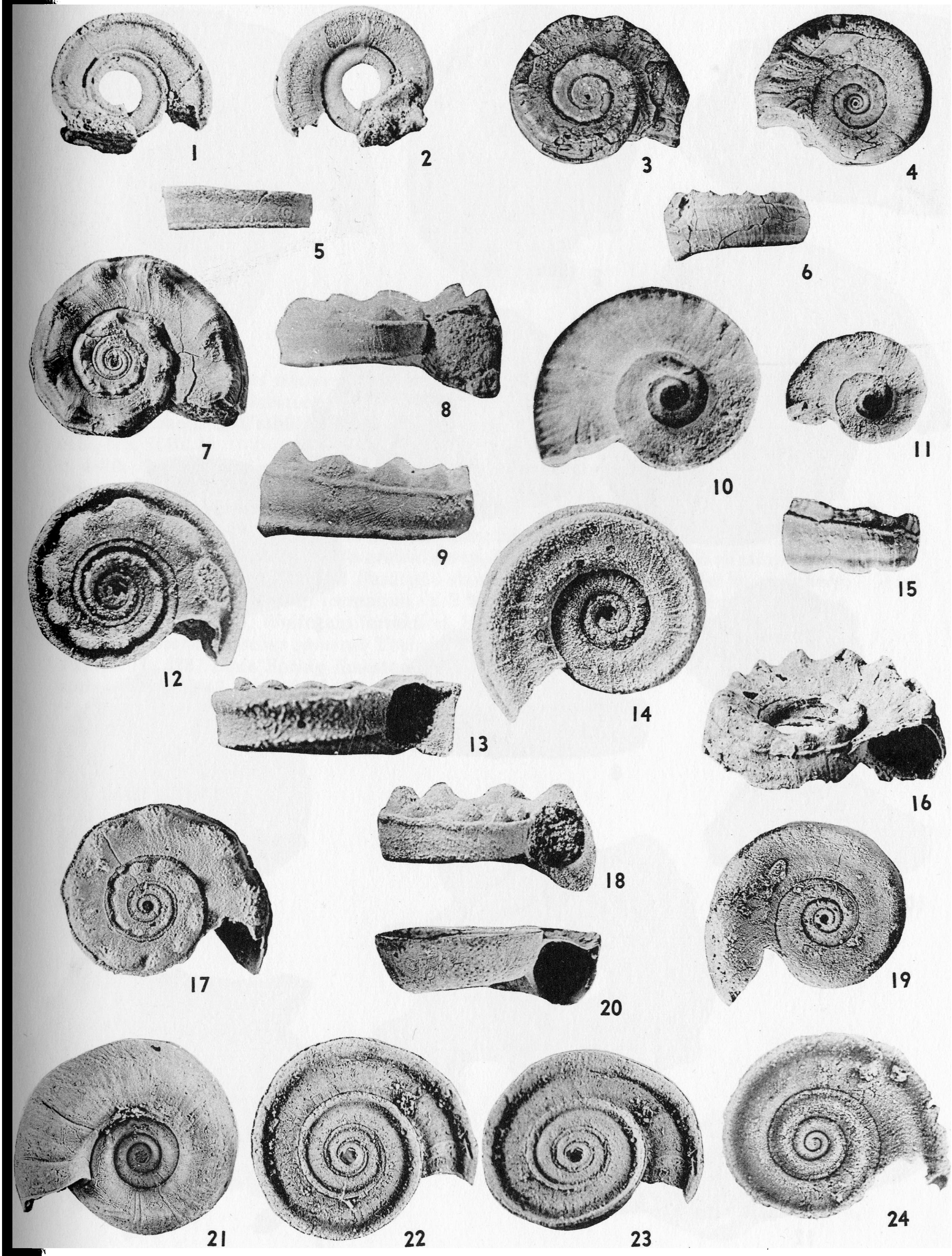
12–14. *Amphiscapha (Cylicioscapha) williamsi* Yochelson, new species. 12. Top view, small paratype, A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27939:2. 13. Apertural view, same specimen. 14. Umbilical view, same specimen.

15. *Amphiscapha (Cylicioscapha) texana* Yochelson, new species. Side view of broken paratype showing typical profile on left, from Military Crossing of Big Wichita River, Belle Plains formation, U.S.N.M. No. 119120a.

16–19. *Amphiscapha (Cylicioscapha) williamsi* Yochelson, new species. 16. Oblique top view of largest paratype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27939:3. 17. Top view, holotype, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27939:1. 18. Apertural view, same specimen. 19. Umbilical view, same specimen.

20–24. *Planotectus cymbellatus* Yochelson, new species. 20. Apertural view, holotype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119121. 21. Umbilical view, same specimen. 22. Top view, same specimen. 23. Oblique top view showing keel, same specimen. 24. Top view of paratype showing early whorls, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27940:1.

11, 15, and 16 are natural size; 1–10 and 17–23 are twice natural size; 12–14 and 24 are four times natural size.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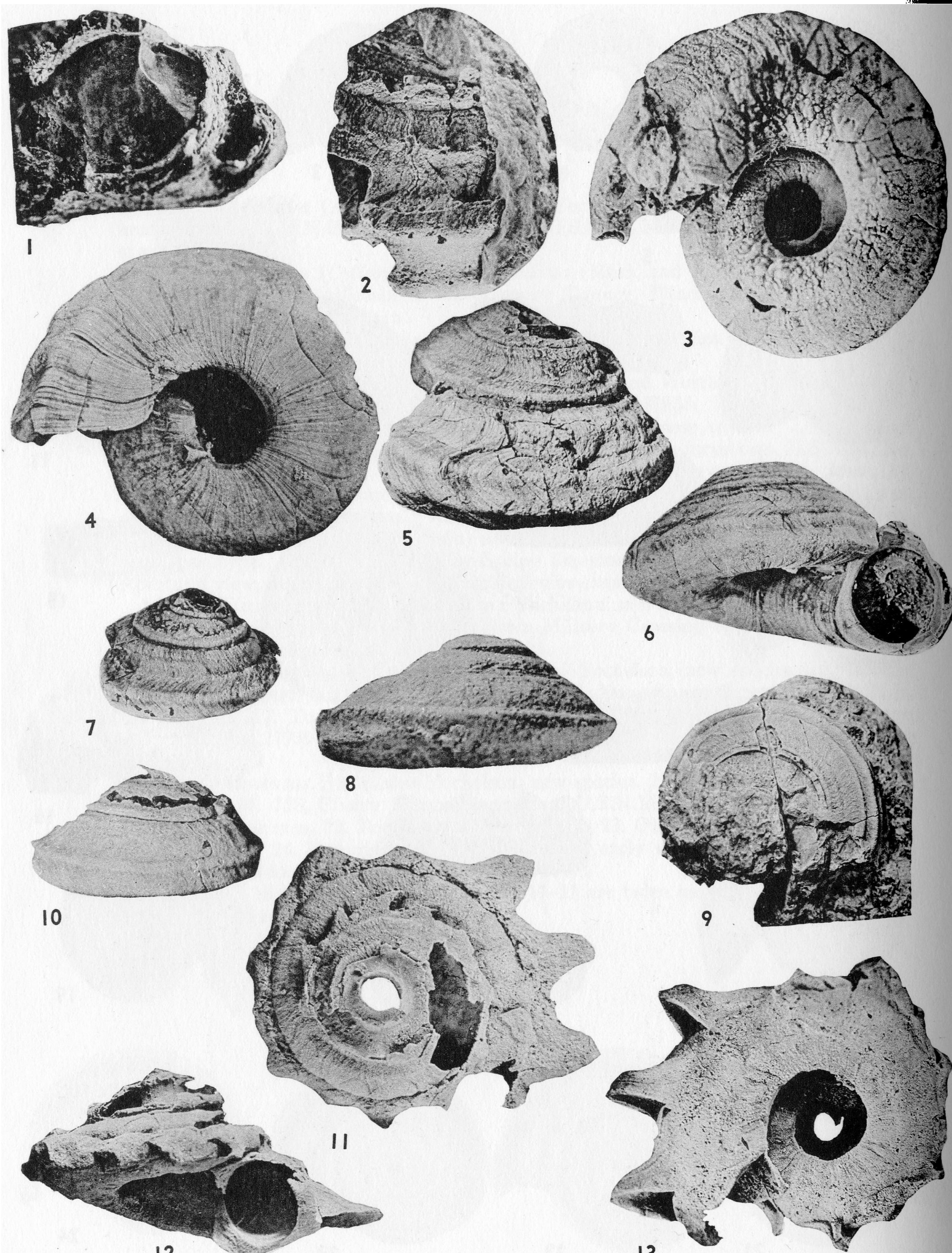
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PLATE 14

1–3. *Omphalotrochus whitneyi* (Meek). 1. Side view showing profile, hypotype, from S.U. 445, McCloud limestone, S.U. No. 6522. 2. Oblique side view showing growth lines, same specimen. 3. Umbilical view of hypotype, from S.U. 445, McCloud limestone, S.U. No. 5110.

4–10. *Omphalotrochus wolfcampensis* Yochelson, new species. 4. Umbilical view, holotype, from Y.P.M. 93, Wolfcamp formation, Y.P.M. No. 17113. 5. Side view, same specimen. 6. Oblique apertural view, same specimen. 7. Oblique side view of small paratype, from U.S.N.M. 708t, Wolfcamp formation, U.S.N.M. No. 119123a. 8. Juvenile paratype with the earliest whorls eroded away, from U.S.N.M. 3360, Wolfcamp formation, U.S.N.M. No. 119124. 9. Paratype showing a depression parallel to periphery, from Y.P.M. 91, Wolfcamp formation, Y.P.M. No. 17114. 10. Side view of paratype, from U.S.N.M. 701d, Wolfcamp formation, U.S.N.M. No. 119122.

11–13. *Omphalotrochus spinosus* Yochelson, new species. 11. Top view, holotype, from A.M.N.H. 628, Bone Spring limestone, A.M.N.H. No. 27941:1. 12. Apertural view, same specimen. 13. Umbilical view, same specimen.

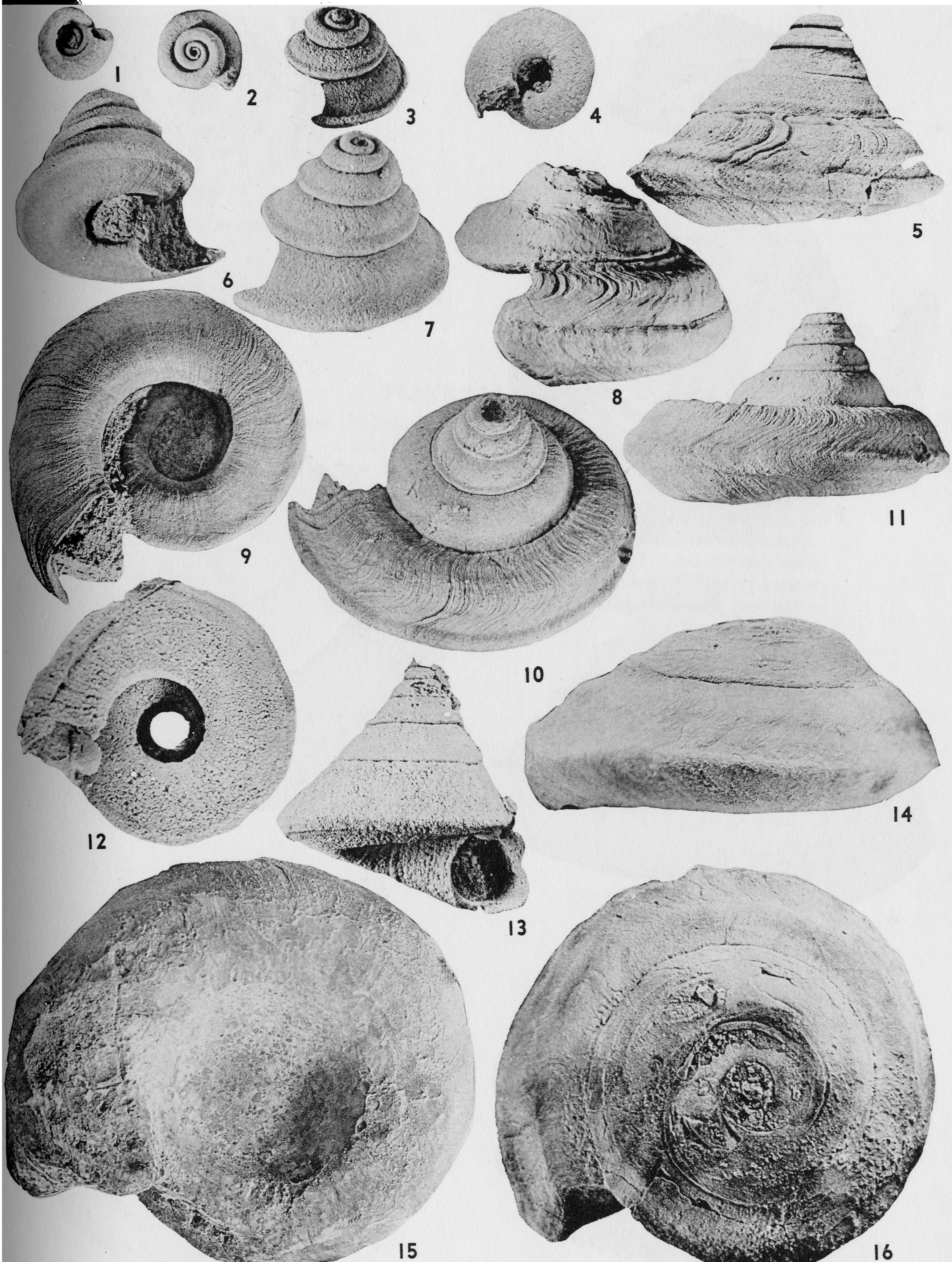
All figures natural size except 8, which is twice natural size.

PLATE 15

1–13. *Omphalotrochus obtusispira* (Shumard). 1. Umbilical view, juvenile hypotype, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119126a. 2. Top view, same specimen. 3. Oblique side view, juvenile hypotype, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119126b. 4. Umbilical view, same specimen. 5. Mature hypotype, broken but showing characteristic profile on left edge, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119126d. 6. Oblique basal view, late juvenile hypotype, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119126c. 7. Oblique top view, same specimen. 8. Mature hypotype showing shape of unbroken aperture, from B.E.G. 10874, Clyde formation, B.E.G. No. 13557. 9. Umbilical view, mature hypotype with body whorl embracing high on penultimate whorl, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119126e. 10. Oblique top view, same specimen. 11. Side view, same specimen. 12. Apertural view, mature hypotype, from A.M.N.H. 51, Hueco limestone, U.S.N.M. No. 119125. 13. Umbilical view, same specimen.

14–16. *Omphalotrochus alleni* Yochelson, new species. 14. Side view, holotype, from U.S.N.M. 707o, Wolfcamp formation, U.S.N.M. No. 119132. 15. Umbilical view, same specimen. 16. Top view, same specimen.

5 and 8–16 are natural size; 1–4, 6, and 7 are twice natural size.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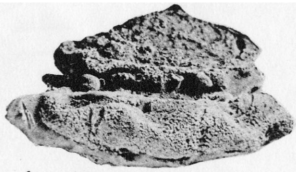

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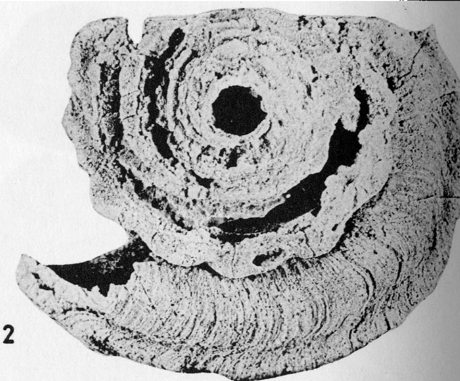

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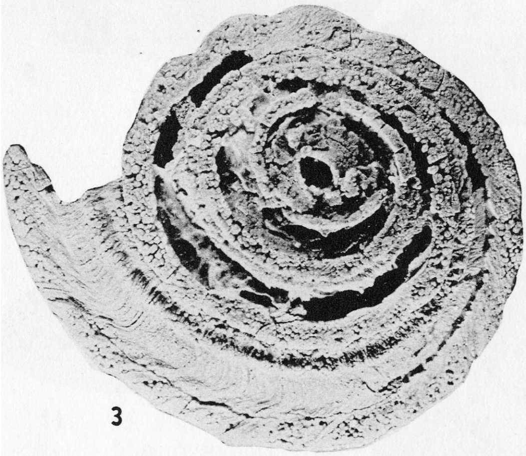

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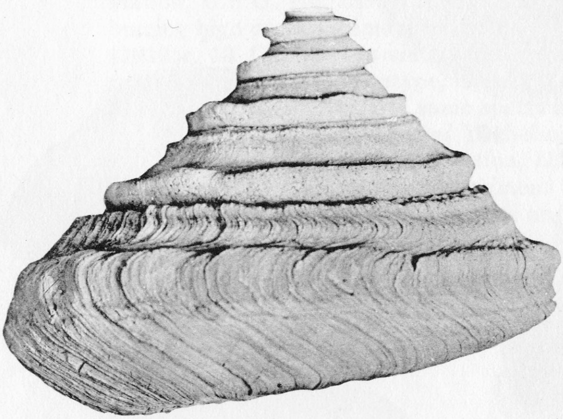

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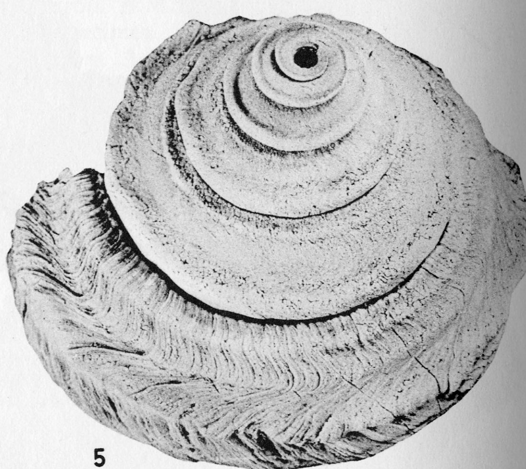

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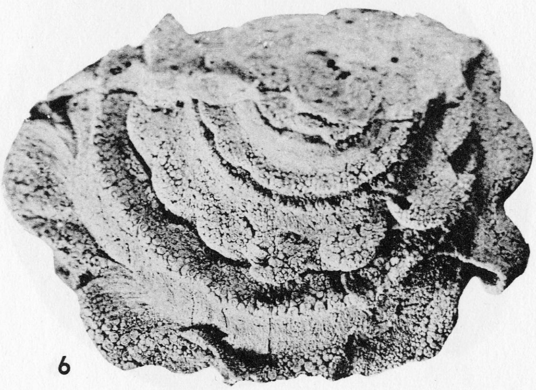

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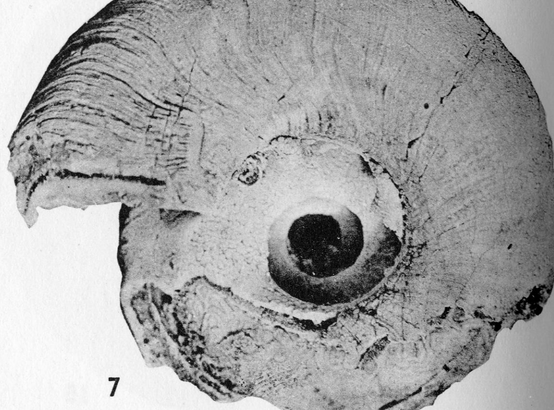

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PLATE 16

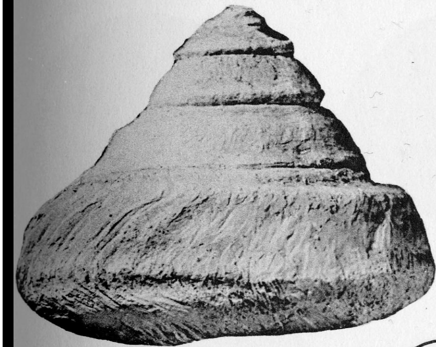
1–7. *Omphalotrochus hessensis* Yochelson, new species. 1. Side view of an incomplete paratype showing crenulated margin, from U.S.G.S. 5314, possibly Colina limestone, U.S.N.M. No. 119135a. 2. Top view of a paratype showing crenulations of periphery, from U.S.G.S. 5314, possibly Colina limestone, U.S.N.M. No. 119135b. 3. Slightly oblique top view of slightly crushed paratype showing crenulations of periphery, from U.S.N.M. 702d, Leonard formation, U.S.N.M. No. 119134b. 4. Side view, holotype, from U.S.N.M. 702f, Leonard formation. U.S.N.M. No. 119133. 5. Oblique top view, same specimen. 7. Umbilical view, same specimen. 6. Oblique top view of paratype showing crenulations of outer edge and spines, from U.S.N.M. 702d, Leonard formation, U.S.N.M. No. 119134a.

All figures natural size.

PLATE 17

1–6. *Omphalotrochus cochisensis* Yochelson, new species. 1. Adapertural view, holotype, from U.S.G.S. 8502, Clyde formation, U.S.N.M. No. 119127. 2. Apertural view, same specimen. 6. Top view, same specimen. 3. Apertural view of paratype, from U.S.G.S. 5314, probably Colina limestone, U.S.N.M. No. 119131. 4. Outline of largest individual known, from U.S.G.S. 8503, Colina limestone, U.S.N.M. No. 119129. 5. Incomplete paratype showing characteristic profile on left side, from U.S.G.S. 8532. Colina limestone, U.S.N.M. No. 119130.

All figures natural size.



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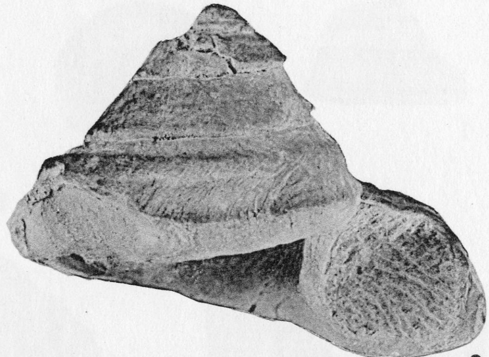

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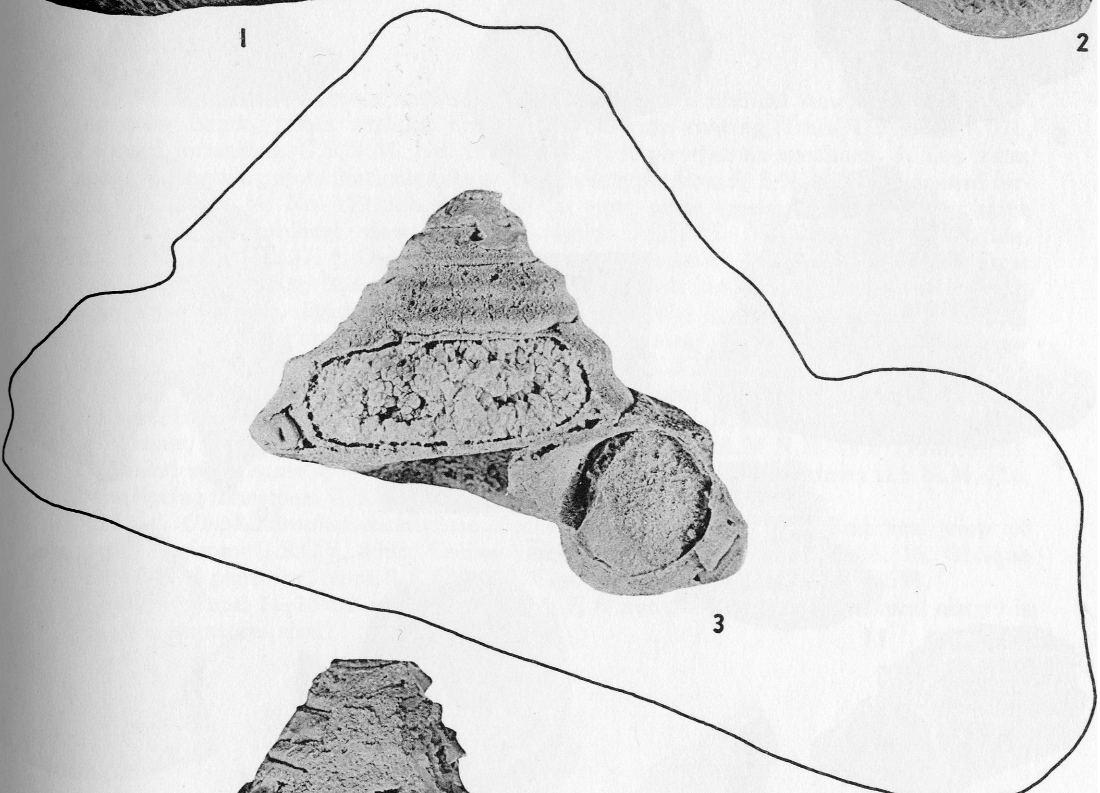

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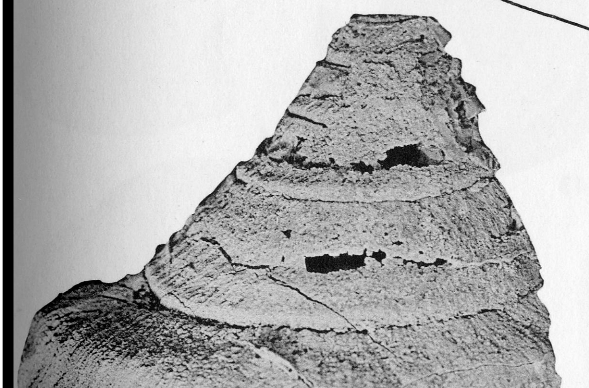

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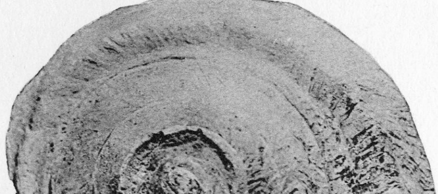

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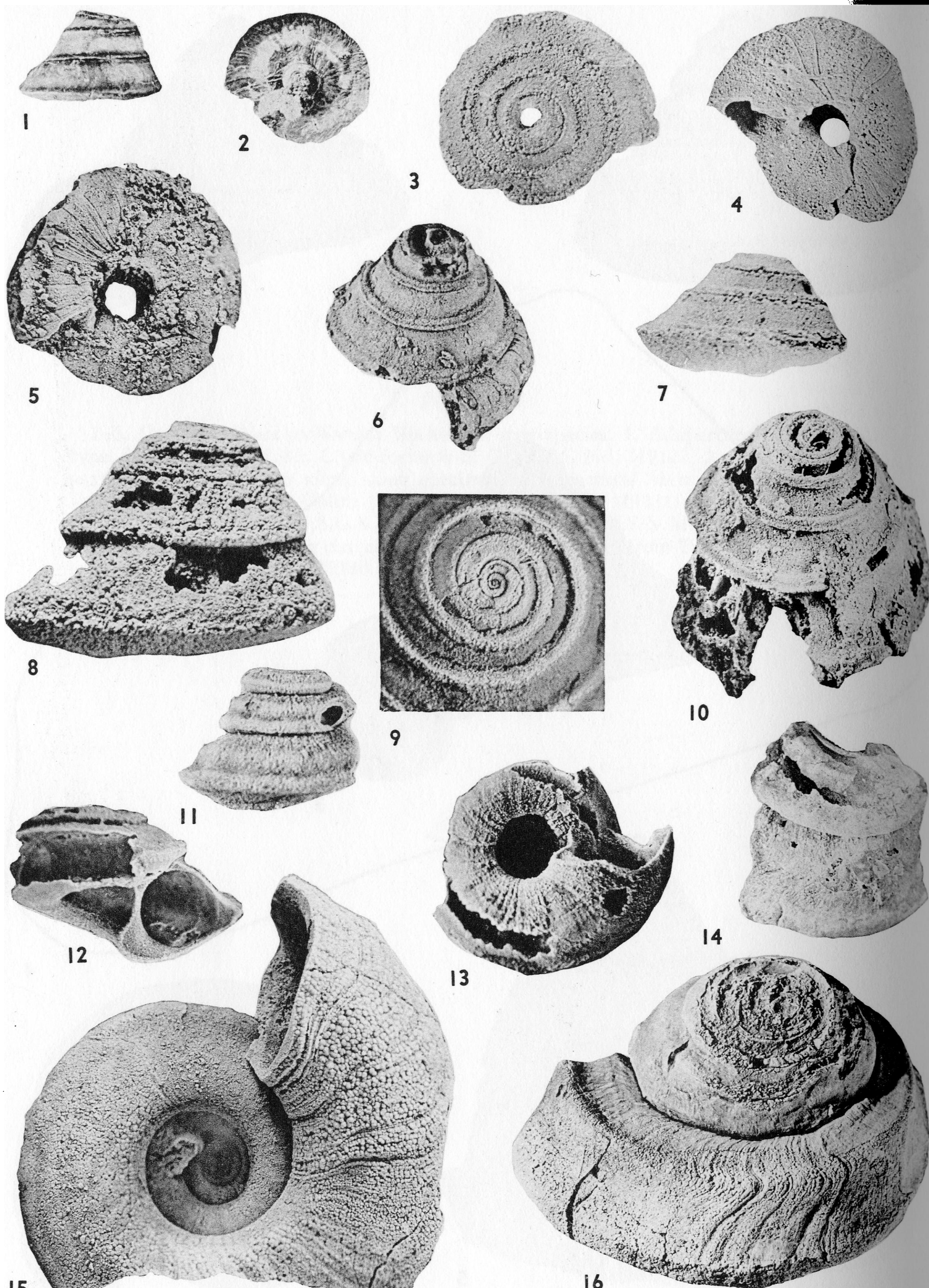
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PLATE 18

1–10. *Babylonites turritus* Yochelson, new species. 1. Umbilical view, paratype showing color bands, taken without ammonium chloride coating, from U.S.N.M. 707q, Leonard formation, U.S.N.M. No. 119139a. 2. Side view, same specimen. 3. Top view, paratype showing more lenticular shape than holotype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119138b. 4. Umbilical view, same specimen. 7. Side view, same specimen. 5. Umbilical view, holotype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119137. 6. Oblique side view, same specimen. 8. Paratype showing gross shape, from P.U. 20g, Bone Spring limestone, U.S.N.M. No. 119140. 9. Paratype showing juvenile whorls, slightly eroded, from U.S.N.M. 707q, Leonard formation, U.S.N.M. No. 119139b. 10. Paratype, oblique side view showing development of carina near periphery, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119138a.

11–14. *Omphalotrochus* species. 11. Specimen showing profile of juvenile stage on left side, from U.S.N.M. 716, Bone Spring limestone, U.S.N.M. No. 119136a. 12. Apertural view, from A.M.N.H. 625, Bone Spring limestone, A.M.N.H. No. 27942:1. 13. Umbilical view, same specimen. 14. Specimen showing growth lines, from U.S.N.M. 716, Bone Spring limestone, U.S.N.M. No. 119136b.

15, 16. *Omphalotrochus cochisensis* Yochelson, new species. 15. Umbilical view of paratype, from U.S.G.S. 8502, Colina limestone, U.S.N.M. No. 119128. 16. Oblique side view of paratype, from B.E.G. 4100, Clyde formation, B.E.G. No. 13558.

1, 2, 5, 6, and 14–16 are natural size; 3, 4, 7, 8, and 10–13 are twice natural size; 9 is four times natural size.

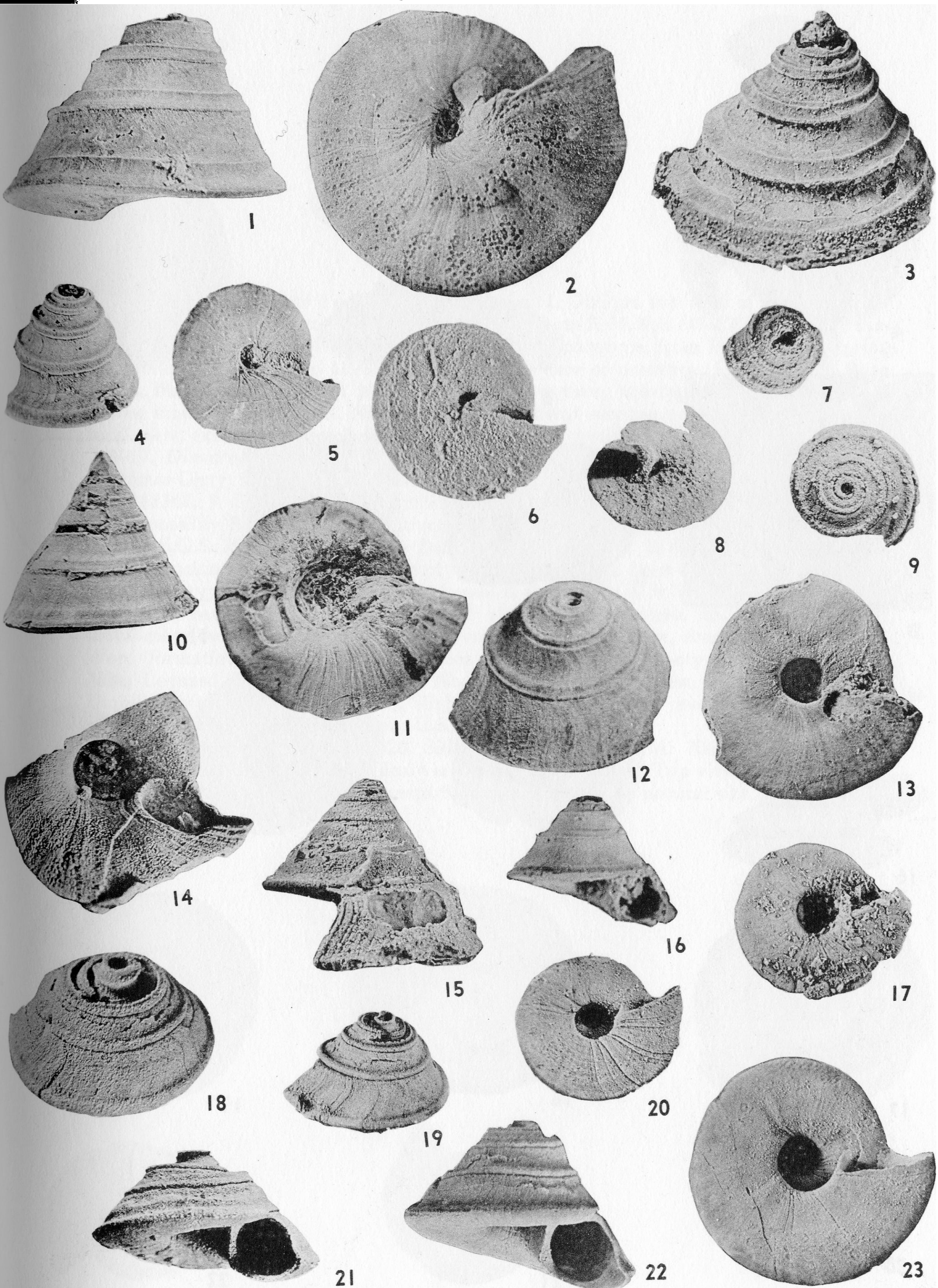
PLATE 19

1–9. *Babylonites carinatus* Yochelson, new species. 1. Side view, paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119141a. 2. Umbilical view, same specimen. 3. Oblique side view of paratype, from U.S.N.M. 706e, Word formation, U.S.N.M. No. 119143a. 4. Slightly oblique side view, holotype, from U.S.N.M. 706b, U.S.N.M. No. 119141. 5. Umbilical view, same specimen. 6. Paratype showing constriction of umbilicus, from U.S.N.M. 706e, Word formation, U.S.N.M. No. 119143b. 7. Slightly oblique top view of paratype, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119144a. 8. Paratype showing reflexed columellar lip, from K.U. 18, Word formation, U.S.N.M. No. 119142b. 9. Top view of paratype showing flattened early whorls, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119144b.

10–17. *Babylonites acutus* Yochelson, new species. 10. Side view, apex is covered with matrix, paratype, from 2 miles east of Puerto de las Sardinas, Coahuila, Mexico, U.S.N.M. No. 119148. 11. Umbilical view, same specimen. 12. Oblique side view, holotype, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119145. 13. Umbilical view, same specimen. 14. Slightly oblique basal view, paratype, from U.S.N.M. 707e, Word formation, U.S.N.M. No. 119147a. 15. Side view, same specimen. 16. Side view showing poor development of carina, paratype, from U.S.N.M. 706c, Word formation, U.S.N.M. No. 119146a. 17. Basal view, same specimen.

18–23. *Babylonites conicus* Yochelson, new species. 18. Oblique side view, paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119150a. 21. Apertural view, same specimen. 19. Very slightly oblique side view, holotype, from U.S.N.M. 706e, Word formation, U.S.N.M. No. 119149. 20. Basal view, same specimen. 22. Apertural view, paratype, from K.U. 18, Word formation, U.S.N.M. No. 119150b. 23. Umbilical view, same specimen.

1–5, 8, 10, 11, 14–17, 19, and 20 are natural size; 6, 7, 9, 12, 13, 18, and 21–23 are twice natural size.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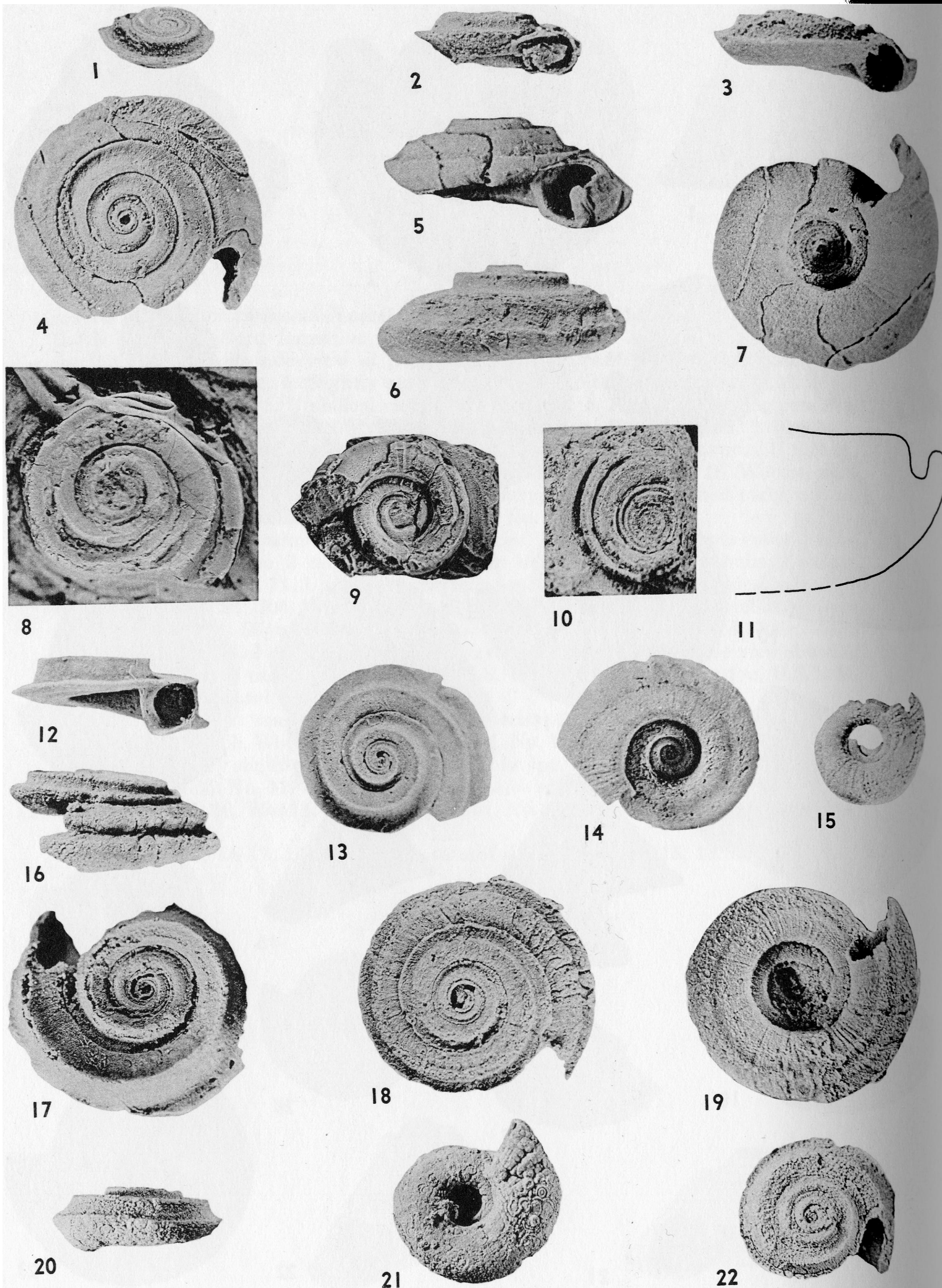
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PLATE 20

1–7. *Discotropis girtyi* Yochelson, new species. 1. Oblique top view of juvenile paratype showing similarity to juvenile of *D. publicus*, from A.M.N.H. 433, Bone Spring limestone, A.M.N.H. No. 27943:1. 2. Apertural view of paratype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 119152a. 3. Apertural view of paratype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 119152b. 4. Top view, holotype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 119151. 5. Apertural view, same specimen. 6. Adapertural view, same specimen. 7. Umbilical view, same specimen.

8–19. *Discotropis sulcifer* (Girty). 8. Top view, holotype of *Euomphalus sulcifer angulatus* Girty, from U.S.G.S. 2930 green, probably Bell Canyon formation, U.S.N.M. No. 118367. 9. Slightly oblique umbilical view of lectoparatype, from U.S.G.S. 2930 green, possibly Bell Canyon formation, U.S.N.M. No. 118366. 10. Top view, lectotype, from U.S.G.S. 2930 green, possibly Bell Canyon formation, U.S.N.M. No. 119153. 11. Camera lucida sketch of side of lectotype showing flange bent upward. 12. Apertural view, hypotype, from U.S.N.M. 703, Leonard formation, U.S.N.M. No. 119154a. 13. Top view, same specimen. 14. Umbilical view, same specimen. 15. Slightly oblique umbilical view of hypotype showing somewhat rounded base, from U.S.N.M. 707e, Word formation, U.S.N.M. No. 119156a. 16. Side view, hypotype, from U.S.N.M. 703a, Leonard formation, U.S.N.M. No. 119155a. 18. Top view, same specimen. 19. Umbilical view, same specimen. 17. Slightly oblique top view of juvenile hypotype, from U.S.N.M. 703, Leonard formation, U.S.N.M. No. 119154b.

20–22. *Discotropis* species 1. 20. Side view, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119158. 21. Umbilical view, same specimen. 22. Top view, same specimen.

All figures twice natural size except 8, which is five times natural size, and 11, which is 10 times natural size.

PLATE 21

1–11. *Discotropis publicus* Yochelson, new species. 1. Top view, holotype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:1. 2. Umbilical view, same specimen. 3. Adapertural view, same specimen. 8. Apertural view, same specimen. 4. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:2. 5. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:4. 6. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:5. 7. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:6. 9. Apertural view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:7. 10. Umbilical view of largest paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:8. 11. Slightly oblique top view of paratype showing earliest whorls, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27944:2.

12, 13. *Discotropis* species 2. 12. Umbilical view showing nodes, from U.S.N.M. 703a, Leonard formation, U.S.N.M. No. 119159. 13. Apertural view, same specimen.

14, 15. *?Discotropis* species 3. 14. Side view, from A.M.N.H. 410, Bell Canyon formation, A.M.N.H. No. 27945:1. 15. Top view, same specimen.

16–23. *Diploconula biconvexa* Yochelson, new species. 16. Side view of paratype showing strongly impressed sutures, from Y.P.M. 128, Leonard formation, Y.P.M. No. 17115. 17. Top view of paratype, showing unbroken upper lip, from P.C. 22-T-11, Word formation, B.E.G. No. 13559. 18. Umbilical view, holotype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119160. 19. Top view, same specimen. 20. Apertural view, same specimen. 21. Side view of a small paratype showing growth lines, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119162a. 22. Oblique top view, juvenile paratype, from U.S.N.M. 703. Word formation, U.S.N.M. No. 119162c. 23. Oblique umbilical view, same specimen.

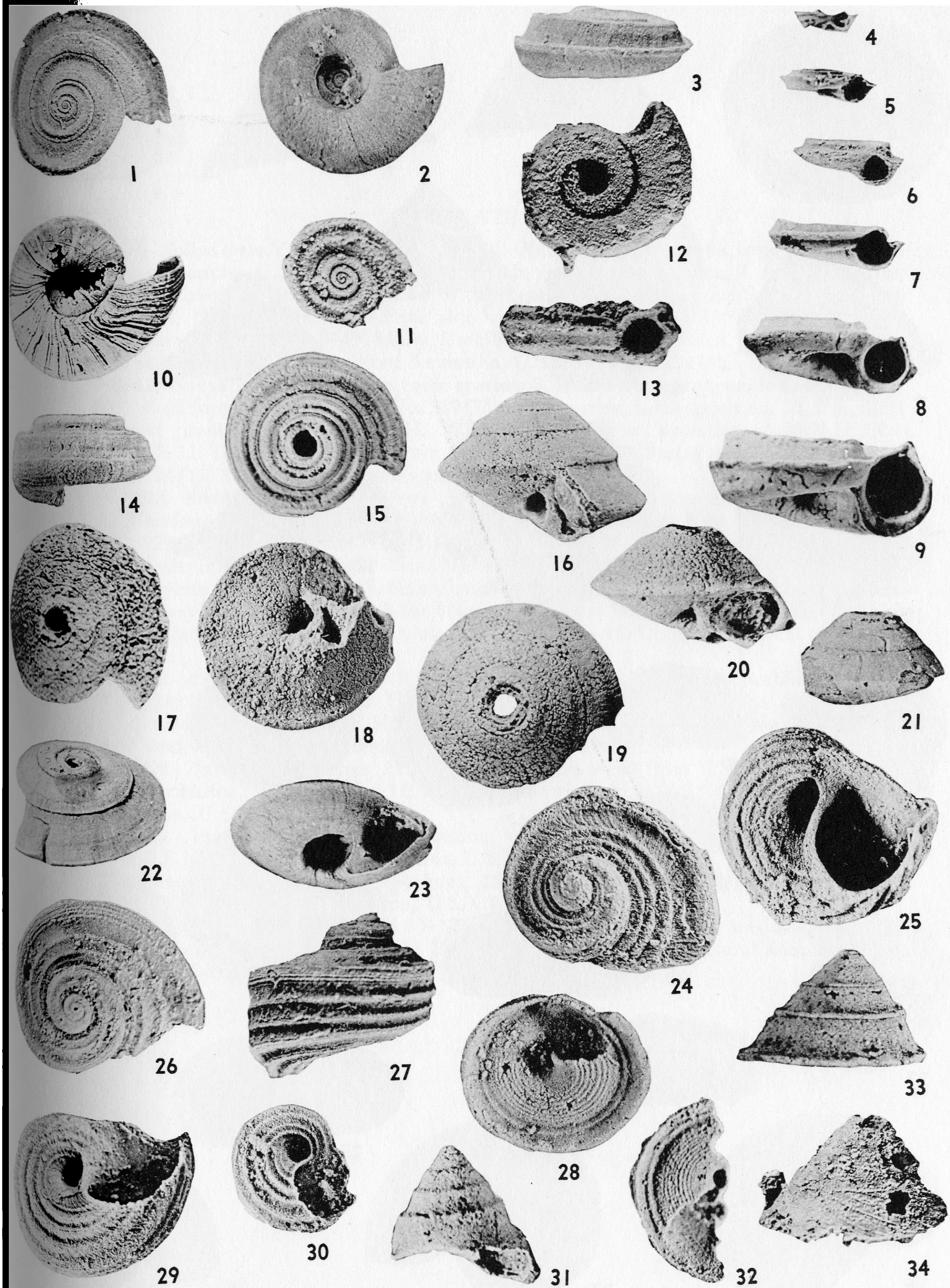
24–27. *Cyclites costatus* Yochelson, new species. 24. Top view, large paratype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119168a. 25. Oblique umbilical view, same specimen. 26. Top view, holotype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. 119167. 27. Side view, same specimen.

28. *Sallya bicincta* Yochelson, new species. Oblique umbilical view showing ornamentation, holotype, from U.S.N.M. 712a, Hueco limestone, U.S.N.M. No. 119169.

29, 30. *Cyclites costatus* Yochelson, new species. 29. Umbilical view, holotype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119167. 30. Umbilical view of small paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27946:1.

31–34. *Sallya bicincta* Yochelson, new species. 31. Side view of steinkern showing "stair-step" profile, from A.M.N.H. 53, Hueco limestone, U.S.N.M. No. 119170. 32. Umbilical view of an incomplete paratype, from U.S.N.M. 712a, Hueco limestone, U.S.N.M. No. 119171a. 34. Side view of large paratype showing growth lines, from U.S.N.M. 707d, Wolfcamp formation, U.S.N.M. No. 119172a.

10 is natural size; 1–9, 12–21, 31, and 34 are twice natural size; 24–29 and 33 are three times natural size; 11, 22, 23, 30, and 32 are four times natural size.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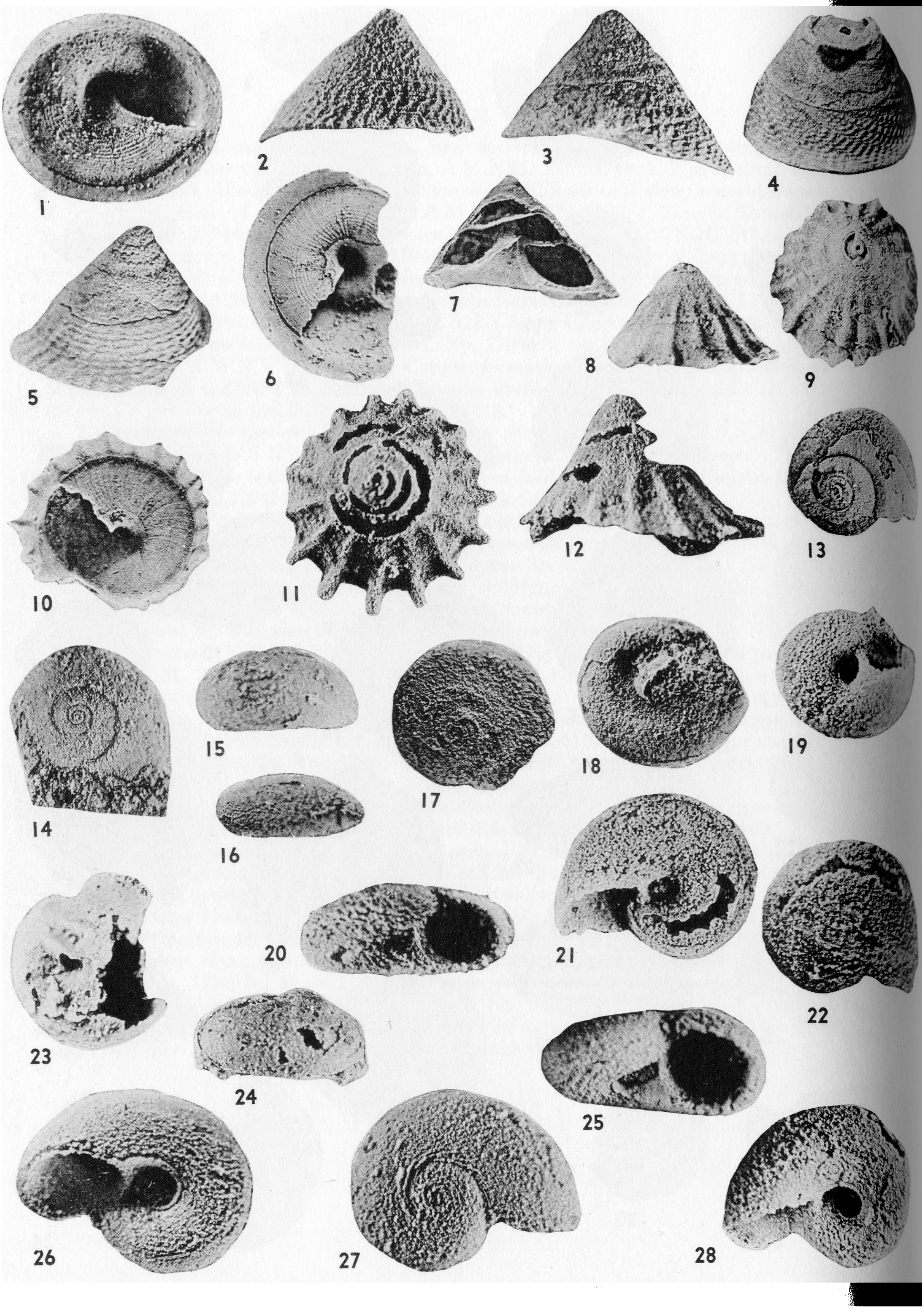
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PLATE 22

1–7. *Sallya linsa* Yochelson, new species. 1. Oblique view, holotype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 191172. 2. Side view, same specimen. 3. Apertural view, same specimen. 4. Oblique side view of paratype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 119173a, 5. Oblique side view, paratype, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119174a. 6. Umbilical view, same specimen. 7. Natural section of a paratype, from P.U. 3, Word formation, U.S.N.M. No. 119173b.

8–12. *Sallya striata* Yochelson, new species. 8. Side view, paratype, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119175a. 9. Top view, same specimen. 10. Umbilical view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27947:2. 11. Top view, holotype, from A.M.N.H. 369, Bone Spring limestone, A.M.N.H. No. 27947:1. 12. Side view, same specimen.

13–18. *Anomphalus verruculiferus* (White). 13. Lectoparatype showing growth lines on adhering shell particles, from the Pennsylvanian near Taos, New Mexico, U.S.N.M. No. 8929a. Original of White (1881), plate 4, figure 7c. 14. Top view, lectoparatype, from the Pennsylvanian near Taos, New Mexico, U.S.N.M. No. 8929b. Original of White (1881), plate 4, figures 7a–b. 15. Side view, same specimen. 16. Side view, lectotype, from the Pennsylvanian near Taos, New Mexico, U.S.N.M. No. 119176. Original of White (1881), plate 4, figure 7d. 17. Top view, same specimen. 18. Oblique umbilical view, same specimen.

19–22. *Anomphalus vanescens* Yochelson, new species. 19. Oblique umbilical view of paratype, from U.S.N.M. 712, Hueco limestone, U.S.N.M. No. 119178a. 20. Apertural view, holotype, from U.S.N.M. 712b, Hueco limestone, U.S.N.M. No. 119177. 21. Umbilical view, same specimen. 22. Top view, same specimen.

23, 24. *Anomphalus* species. 23. Oblique umbilical view, from U.S.N.M. 701g, Wolfcamp formation, U.S.N.M. No. 119180a. 24. Side view, from U.S.N.M. 701g, Wolfcamp formation, U.S.N.M. No. 119180b.

25–28. *Anomphalus studiosus* Yochelson, new species. 25. Apertural view, holotype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119181. 26. Umbilical view, same specimen. 27. Top view, same specimen. 28. Umbilical view of largest paratype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119182a.

7 is twice natural size; 1–3 and 10–12 are three times natural size; 4–6, 8, 9, 13–18, 23 and 24 are four times natural size; 19–22 and 28 are six times natural size; 25–27 are eight times natural size.

PLATE 23

1–4. *Brochidium morrisi* Yochelson, new species. 1. Top view of paratype, from U.S.N.M. 703a, Leonard formation, U.S.N.M. No. 119184a. 2. Slightly oblique umbilical view, holotype, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119183. 3. Top view, same specimen. 4. Side view, same specimen.

5, 6. *Brochidium cingulatum* (Münster). 5. Top view. Original illustration of the genotype from Münster (1841), plate 11, figure 4, reproduced for comparison. 6. Apertural view, same specimen.

7–11. *Dichostasia simplex* Yochelson, new species. 7. Umbilical view, paratype, from U.S.N.M. 712, Hueco limestone, U.S.N.M. No. 119187. 8. Top view, same specimen. 9. Top view, holotype, from U.S.N.M. 702d, Leonard formation, U.S.N.M. No. 119186. 10. Oblique umbilical view, same specimen. 11. Side view, same specimen.

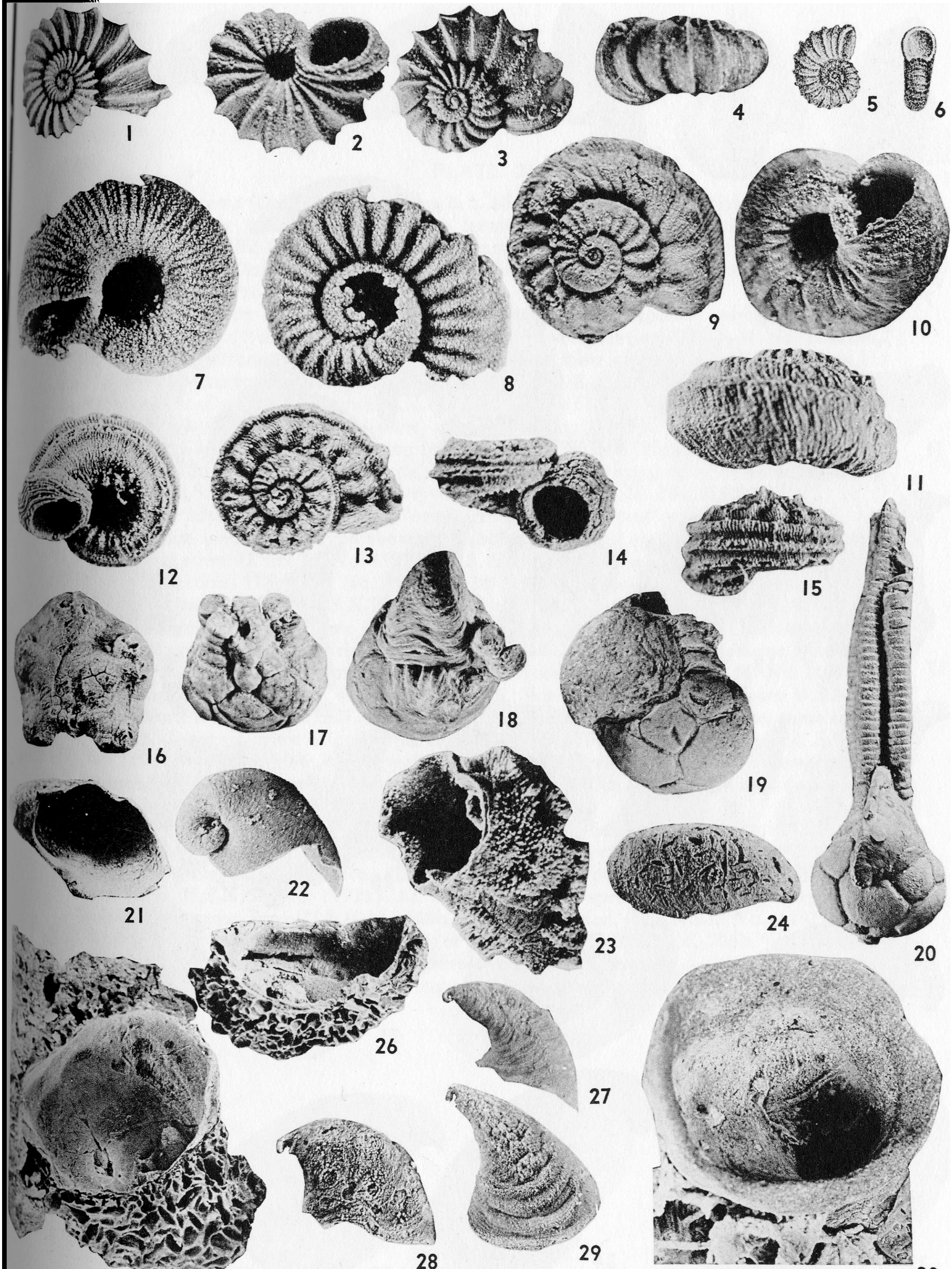
12–15. *Dichostasia complex* Yochelson, new species. 12. Umbilical view, holotype, from U.S.N.M. 702c, Leonard formation, U.S.N.M. No. 119189. 13. Top view, same specimen. 14. Apertural view, same specimen. 15. Adapertural view, same specimen.

16. *Platycrinites wachsmuthi* Wanner. Top view showing the scar of attachment of a platyceratid, from the Permian, Basleo Beds, Dutch Timor, U.S.N.M. Frank Springer collection No. S.4015.

17–20. *Cromyocrinus simplex* (Trautschold). 17. Oblique top view showing anal tube and scars of platyceratid attachment on side of cup, from the Carboniferous at Mjatschkowa, near Moscow, U.S.S.R., U.S.N.M. Frank Springer collection No. S.208. 18. Oblique top view showing a platyceratid over the anal tube, from the Carboniferous at Mjatschkowa, near Moscow, U.S.S.R., U.S.N.M. Frank Springer collection No. S.208. 19. Side view, same specimen. 20. Side view showing a platyceratid on cup; the platyceratid has been crushed slightly by the squeezing of the crinoid arms after death; from the Carboniferous at Mjatschkowa, near Moscow, U.S.S.R., U.S.N.M. Frank Springer collection No. S.208.

21–30. *Platyceras* (*Orthonychia*) species. 21. Apertural view of coiled specimen comparable to *Platyceras, sensu stricto*, from U.S.N.M. $701a_2$, Wolfcamp formation, U.S.N.M. No. 119209. 22. Top view, same specimen. 23. Oblique apertural view showing overgrowth of bryozoan colony on dead shell, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213c. 24. Side view showing borings in dead shell, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213j. 25. Apertural view of specimen showing muscle pits and muscle scar extending diagonally downward in the upper right-hand portion, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213a. 26. Apical portion of same specimen. The muscle scar extends from the narrow horizontal black area, where the shell has been bored away, horizontally to the right to where the exterior of the shell conceals it. The extreme upper right corner of this fragment attaches to the slightly projecting right-hand corner of aperture in 25. 27. Juvenile showing hooked protoconch, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119210a. 28. Juvenile showing hooked protoconch, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119210b. 29. Juvenile showing hooked protoconch, from U.S.N.M. 702, Leonard formation, U.S.N.M. No. 119210c. 30. Apertural view of specimen showing muscle scar. The scar may be seen faintly extending in a semicircle from near the black dot about half an inch below center of top of picture downward to the right. From U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213b.

16–20 and 24–26 are natural size; 21–23 and 30 are twice natural size; 9–11 and 27–29 are four times natural size; 2–4, 7, 8, and 12–15 are six times natural size; 1 is eight times natural size. Magnifications of 5 and 6 are unknown, but are presumably four times or smaller.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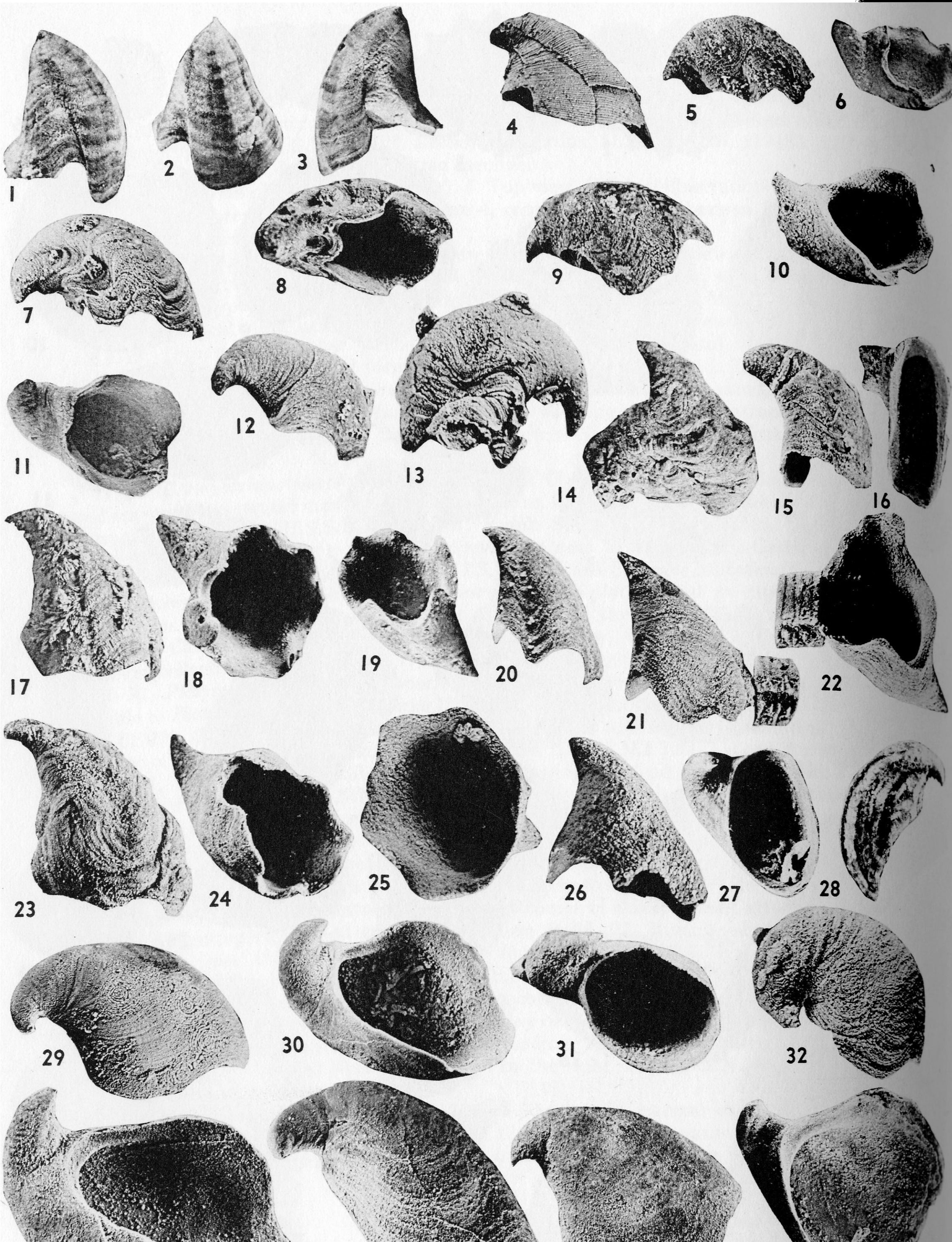
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PLATE 24

1–3. *Platyceras* (*Orthonychia*) species 1. 1. Right side view, taken without ammonium chloride coating to show color bands, from U.S.N.M. 702ent, Leonard formation, U.S.N.M. No. 119216. 2. "Front" view, same specimen. 3. Left side view, same specimen.

4. *Platyceras* (*Orthonychia*) species 2. Right side view showing lamellae, from U.S.N.M. 703, Word formation, U.S.N.M. No. 119217.

5–13. *Platyceras* (*Orthonychia*) *bowsheri* Yochelson, new species, variant 3. 5. Side view of paratype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119214a. 6. Oblique apertural view, same specimen. 7. Side view of paratype, from A.M.N.H. 512, Cherry Canyon formation, A.M.N.H. No. 27952. 8. Apertural view, same specimen. 9. Side view of paratype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119214b. 10. Oblique apertural view, same specimen. 11. Apertural view of paratype, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. 119214c. 12. Side view, same specimen. 13. Side view of paratype showing irregularity suggestive of damage during life, from U.S.N.M. 728, Cherry Canyon formation, U.S.N.M. No. 119214d.

14–28. *Platyceras* (*Orthonychia*) *bowsheri* Yochelson, new species, variant 1. 14. Oblique side view of paratype showing wrinkled surface of shell, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213d. 15. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213e. 16. Apertural view, same specimen. 17. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213f. 18. Oblique apertural view, same specimen. 19. Oblique apertural view of holotype, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119211. 20. Side view, same specimen. 21. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213g. 22. Oblique apertural view, same specimen. 23. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213h. 24. Oblique apertural view, same specimen. 25. Apertural view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213i. 26. Side view, same specimen. 27. Apertural view of paratype, taken without ammonium chloride coating to show color bands, from U.S.N.M. 706, Word formation, U.S.N.M. No. 119212a. 28. Side view, same specimen.

29–36. *Platyceras* (*Orthonychia*) *bowsheri* Yochelson, new species, variant 2. 29. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213k. 30. Apertural view, same specimen. 31. Apertural view of paratype, from K.U. 27, Word formation, U.S.N.M. No. 119215. 32. Side view, same specimen. 33. Oblique apertural view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213. 34. Side view, same specimen. 35. Side view of paratype, from U.S.N.M. 706b, Word formation, U.S.N.M. No. 119213m. 36. Apertural view, same specimen.

All figures are twice natural size, except 4 and 14, which are natural size.