

# PERMIAN GASTROPODA OF THE SOUTHWESTERN UNITED STATES

## 2. PLEUROTOMARIACEA: PORTLOCKIEL- LIDAE, PHYMATOPLEURIDAE, AND EOTOMARIIDAE

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## INTRODUCTION

### ABSTRACT

THE DEVELOPMENT OF A mass etching program for the recovery of silicified fossils from Permian limestone of west Texas has resulted in the accumulation of a large number of fossil gastropods and has made possible the present systematic study of the pleurotomarian gastropods. Most of the collections used herein were made by, or under the direction of, G. Arthur Cooper, Norman D. Newell, and J. Brookes Knight. These collections were obtained from the Wolfcamp, Leonard, and Word formations of the Glass Mountains of Texas and from the Hueco, Bone Spring, and Cherry Canyon formations of the Sierra Diablo and Guadalupe Mountain region.

Comments on stratigraphy are made for the orientation of the reader. Little original stratigraphic work has been done, except to verify or corroborate correlations based on other fossil groups. A few of the paleoecological relationships are discussed, with particular emphasis on molluscan assemblages in the Glass Mountains. An instance is cited of a relationship between a *Heliospongia* and *Glyptotomaria* (*Glyptotomaria*) *marginata*.

Statistical methods used include those based on univariate analysis and on allometric growth line comparisons. This latter type of analysis is based on the relative growth line, as estimated by the reduced major axis. Discrimination was based, in part, on a comparison of slope and position differences of the relative growth line between samples.

Studies of the logarithmic spiral show that it can be useful in the study of pleurotomarians and may be treated statistically. The value of the logarithmic spiral formula as a discriminatory

During the past 15 years, an intense program of zonal collecting in the Permian deposits of west Texas and New Mexico has yielded a tremendous invertebrate fauna represented by the largest collections of Permian fossils extant. The main part of these collections consists of a vast number of silicified fossils which have been etched by hydrochloric acid from some 60 tons of limestone blocks. This mass etching program (Newell, Rigby, *et al.*, 1953, p. 10), employed by G. Arthur Cooper, United States National Museum, and Norman D. Newell, the American Museum of Natural History, is a part of a general collaborative study of the Permian paleontology of west Texas. As a result of this

character must be weighed against the time and labor required in its derivation. Gross measurements of the spiral, such as the use of suture ratios, tend to reduce expenditure of time, but they also reduce accuracy.

Some of the directional and non-directional variations within species and genera are noted. This study attempts to show some aspects of pleurotomarian speciation during the Permian. These are particularly well illustrated in the genus *Tapinotomaria*. Studies of population structure made it possible to understand some of the changes thought to be responsible for most speciation in the families studied. Emphasis is placed on ontogenetic growth characters.

The bulk of this paper is devoted to an analysis and description of the rich and heretofore unknown Permian pleurotomarian faunules. The general increase in knowledge about Permian representatives of the superfamily Pleurotomaria-cea is briefly discussed. Two families, Portlockiellidae and Phymatopleuridae, are diagnosed and discussed. The family Eotomariidae Wenz, 1938, is redefined and expanded.

Thirteen genera are discussed herein: *Lamellospira* and *Lacunospira* are new; *Eirlysia*, *Tapinotomaria*, *Discotomaria*, *Callitomaria*, and *Shwedagonia* are discussed for the first time (see Batten, 1956). *Tapinotomaria* and *Shwedagonia* have been discussed at some length because of their interesting evolutionary developments. Five previously described genera are also included; *Euconospira*, *Spiroscala*, and *Glyptotomaria* are redefined; *Phymatopleura* and *Paragoniozona* are discussed. A total of 32 species are included, 28 of which are new and named.

program, it has been possible to accumulate what may be the world's largest and best collection of Permian pleurotomarian gastropods.

For the first time, suitable materials are assembled for studies on speciation, population characteristics, taxonomic diversity, development of higher categories, and paleoecologic relationships of Permian pleurotomarians. These fossil studies, along with studies of the Permian ecology (e.g., Newell, Rigby, *et al.*, 1953), will greatly aid in the understanding of this interesting geologic period and its life.

Until the past few years, taxonomic studies of gastropods were commonly conducted as

incidental to general faunal works. Well-preserved faunas containing pleurotomarians were relatively rare, even though they are a common gastropod element in the Permian. Recently, such faunal papers as Newell, Chronic, and Roberts (1953), Chronic (1952), and Newell (1940) have been of considerable aid to the understanding of Permian gastropods, but they have considered the gastropods from one particular area or another without regard to the over-all phylogenetic view. This present study is the second published part of a program of studies being conducted by J. Brookes Knight, Ellis Yochelson, and the writer, which, when completed, should result in contributions covering the taxonomy, paleoecology, and evolution of the known Permian gastropods of the southwestern United States.

The emphasis of this work is, first, on the description of the fauna, in as much as many species and genera are new, and, second, on the phylogenetic and paleoecologic interpretations of the faunas. The descriptions incorporate statistical analyses, where feasible. Both qualitative and quantitative characters were studied, with the view of discovering those most significant for the separation of taxonomic groups. The logarithmic spiral, not previously employed on Permian pleurotomarians, was found to be of significance in several species, particularly in noting changes in growth. The spiral formula for determining the vector angle was not used, however, because of the exorbitant length of time required to make necessary measurements. Instead, measurement was made of characters most influenced by spiral growth, such as

suture ratios.

The families Portlockiellidae, Phymatopleuridae, and Eotomariidae were selected for this analysis, because they well illustrate variation, speciation, and adaptive radiation. These families are particularly amenable to the development of research techniques used in population studies.

A continuation of this study is planned and will be concerned with families that are commonly found in large numbers throughout the Permian. The emphasis will be on population studies and the more complicated aspects of growth analysis.

As the present study progressed, it became apparent that the pleurotomarians were particularly well suited for allometric studies, more so perhaps than other gastropods, because many of their characters can be expressed quantitatively and measured on each whorl. Between 20 and 70 measurements can be made on each specimen for use in growth analyses, and these, combined with large samples, have aided tremendously in the understanding of the pleurotomarians.

The majority of the quantitative results of this present study have not been included under each species, but, rather, the statements made regarding variation are summaries of the quantitative work done. Thus most conclusions are not based solely on qualitative judgments. Ten to 50 scattergrams were made for each sample and between sample study charts would run into the hundreds; thus, to have included all the statistical data, raw data, charts, and scattergrams would have greatly enlarged this work.

#### ACKNOWLEDGMENTS

The initial part of this study was done at the United States National Museum, Washington, D. C., with the aid of a grant from the James F. Kemp Fund of Columbia University. Dr. Norman D. Newell of Columbia University and the American Museum of Natural History suggested this project as a subject for a doctoral dissertation. He joined the writer in many hours of stimulating discussion and arranged for the use of facilities and collections of the American Museum of Natural History under his care.

Dr. J. Brookes Knight not only supplied part of the collections for this study but was the principal source of inspiration and encouragement. Dr. Knight first hoped to complete a monographic study of the Permian gastropods himself, but, after the initial phase of his research, he was unable to continue the work. He generously made available his notes and experience to Dr. Ellis Yochelson and the present writer. He has given continuous guidance throughout the course of the study.

Dr. G. Arthur Cooper, head curator of geol-



ogy at the United States National Museum, made available to the writer facilities and collections of the museum during three summers and a full year, and enabled the writer to visit many of the Permian outcrops of west Texas and New Mexico. His advice and support have been of inestimable aid.

Dr. John Imbrie of Columbia University gave much of his time in counseling the writer in many phases of the research.

The writer wishes to acknowledge aid from Dr. Carl O. Dunbar of Yale University and Dr. B. F. Howell of Princeton University in the use of fossil gastropods from the collections under their care.

To Dr. Ellis Yochelson, my friend and fellow student, I owe much gratitude for his

patience and help. It has been a pleasure and source of stimulation to work with him on the Permian gastropods.

The writer gratefully thanks Mr. Robert Finks of Brooklyn College for his permission to use the remarkable photograph which he made of a *Heliospongia* cloacal wall growing about a specimen of *Glyptotomaria* (*Glyptotomaria*) *marginata*. It was he who first noticed this interesting relationship.

Finally, but no less gratefully, I want to thank the American Museum of Natural History in general, and the Publications Committee in particular, for their kindness in accepting this paper for publication in the Bulletin.

### SYMBOLS AND ABBREVIATIONS USED

The following symbols and abbreviations are used in the tabular material:

B, width of a basal trough located just under the lower edge of the outer whorl face, used in *Discotomaria*

CA, number of spiral cords above the selenizone

CB, number of spiral cords below the selenizone

CBS, width of area between the slit and the lower selenizone margin, used in the tribe Ptychomphalides

CS, distance between the top of the first major cord above the selenizone and that next above

CSS, width of the cord or area that forms the lower edge of the outer whorl face measured from the bottom of the cord or area to the first spiral element under the lower selenizone margin

H, height

Ha, distance between the top of the basal cord or lower edge of the outer whorl face to the top of a cord located midway between the lower selenizone margin and the lower edge, used in *Discotomaria*

HW, whorl height

N, frequency

S.D., standard deviation

S.E. (*m*), standard error of the mean

SR, suture ratios, a ratio of successive whorl heights

SS, the distance between the suture and the top

of the upper selenizone margin

SW, width of the selenizone measured from the inner edges of the selenizone margin

W, total width of shell

Wa, distance between the lower selenizone margin and the next spiral element under it, used in *Discotomaria*

WBC, width of basal cord, used only in *Lamellospira*

Wh, width of the trough under the selenizone measured from the first lira under the selenizone to the inner edge of the margin, used in the tribe Ptychomphalides

Wo, total number of whorls

WW, whorl width

$\bar{x}$ , arithmetic mean of a sample

The following abbreviations are used in connection with the numbers of localities and the numbers of catalogued specimens. The abbreviation "No." with the institutional abbreviation distinguishes specimen numbers from the numbers given to localities.

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

Plummer, F. B. Plummer Collection

U.K., University of Kansas

U.S.G.S., United States Geological Survey

U.S.N.M., United States National Museum

Y.U., Yale University

## STRATIGRAPHY

A DETAILED ACCOUNT or analysis of stratigraphic problems and correlations of the west Texas Permian is beyond the scope of the present paper, which is primarily concerned with a description of only a portion of the molluscan faunas. The majority of the fossils studied are from the Glass Mountains, and the greatest emphasis is placed on this area. The pleurotomarian gastropods tend to corroborate evidence of other fossil groups on stratigraphic correlations between the Permian of the Glass Mountains and other Permian sequences of the southwest. The pleurotomarians represent roughly one-half of the total number of species of gastropods, but the gastropod species as a whole probably compose not more than 10 per cent of the entire fauna. Accordingly the stratigraphic conclusions given here are based on admittedly slight evidence.

The west Texas Permian can be readily divided into two major outcrop provinces. The first extends eastward from the Hueco Mountains to the Diablo Plateau, thence northward to the Guadalupe Mountains and includes the Baylor Hills, the Delaware Mountains, and the Apache Mountains. The second major outcrop area is centered on the Glass Mountains and includes the Del Norte Mountains.

A basal conglomerate found in the western Glass Mountains initiated the deposition of the Permian. This conglomerate was deposited over folded and faulted Pennsylvanian rocks, and the unconformable relationship is more pronounced in the western than in the eastern Glass Mountains. The lowermost recognized fossiliferous Permian of the Glass Mountains is the *Uddenites* zone, a series of limestones and shales about 100 to 300 feet thick in the eastern area. This zone varies considerably in thickness along the outcrop belt. Faunally and lithologically the zone is similar to the underlying Pennsylvanian shales and the overlying Wolfcampian shales (King, 1930).

Brachiopods found in the limy phases of *Uddenites* zone suggest Hueco and Leonard affinities (Cooper, personal communication). Yochelson (1954, p. 233) reports *Omphalo-*

*trochus* from the zone, a gastropod genus generally considered to be restricted to the Permian. In so far as the pleurotomarians and brachiopods are concerned, the shale fauna closely resembles known Pennsylvanian faunas of other areas. These similarities may reflect similar environmental facies rather than a common age. The stratigraphic placement of the *Uddenites* zone has been in dispute, but in the latest statement of this problem, Cooper (1953) considers that it is probably Permian. Pleurotomarian gastropod species identified from the *Uddenites* zone are:

*Spiroscala pagoda* Knight

*Borestus* sp. Thomas

*Phymatopleura brazzoensis* (Shumard)

*Paragoniozona nodilirata* Nelson

The Wolfcamp formation at the type section lies immediately over the *Uddenites* zone, apparently without a break. The formation consists of a series of thin limestone beds separated by shale, the whole averaging about 600 feet in thickness. The base of the formation is defined by a gray limestone about 45 feet thick (limestone no. 2 of King, 1942, p. 647); within this unit a number of small reef masses are developed. The top of the formation is defined by a conglomerate which in turn is overlain by the Leonard formation.

Southwest along the Glass Mountains front, the Wolfcamp formation changes into conglomerates, sandstone, limestones, and limestone conglomerates. The formation is about 500 feet thick in the western exposures. A few small reefs are developed in the lower limestone units in the west, but mainly they occur east of Leonard Mountain (Cooper, oral communication). Most of the fossils were collected from the reef limestones.

The fauna of the Wolfcampian shales has close affinities with the underlying *Uddenites* zone and Gaptank (Pennsylvanian) shales but is quite different from that of associated Wolfcampian limestones. *Glyptotomaria* (*Glyptotomaria*) *marginata*, *Tapinotomaria globosa*, and *Euconospira pulchra* are the only additions to the long-ranging species of the underlying beds. It is possible that similar environ-



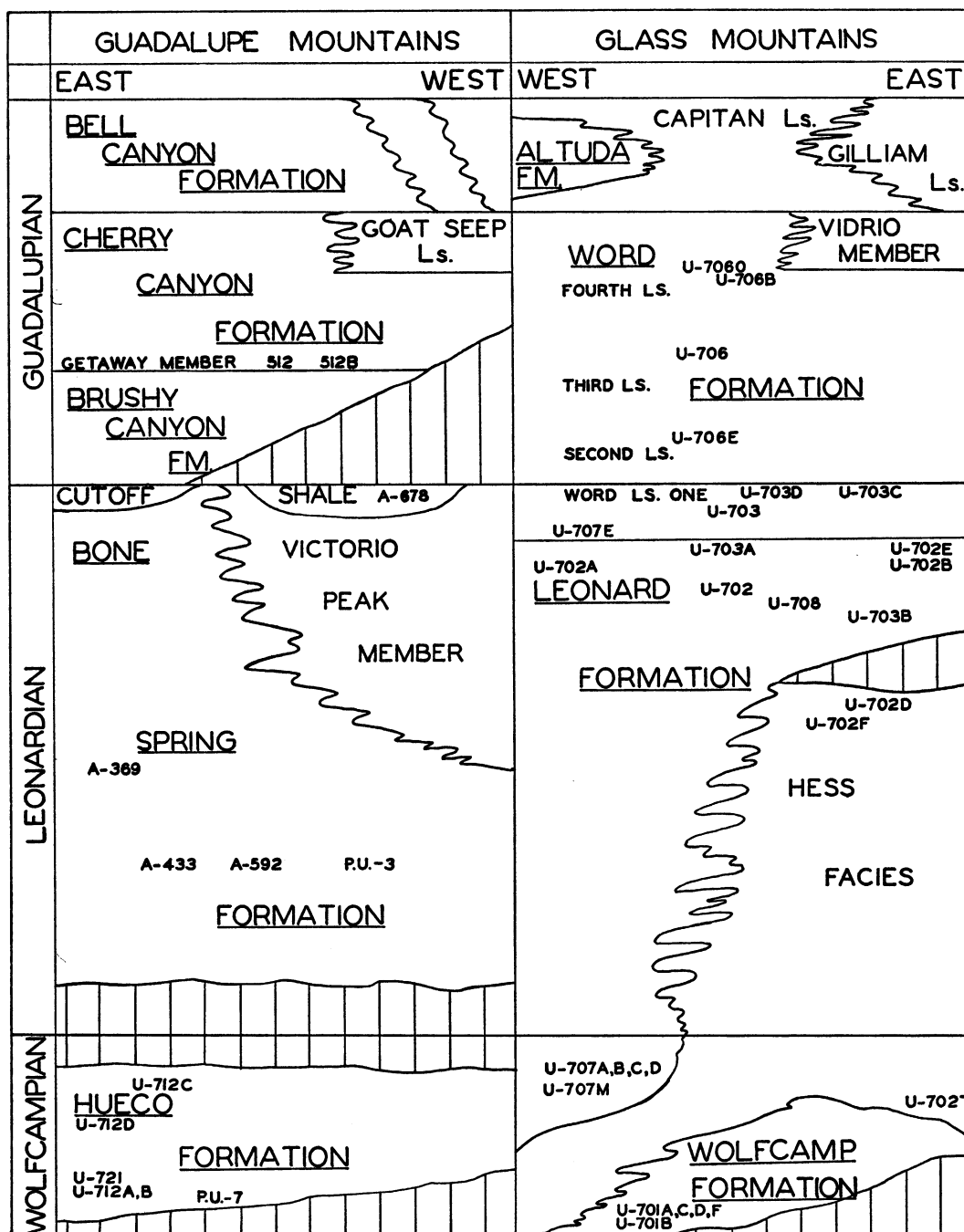


FIG. 1. Correlation chart showing some of the important pleurotomarian localities in their approximate positions in the Permian formations. *Abbreviations:* A., the American Museum of Natural History; P.U., Princeton University; U., United States National Museum. Modified after King, 1942, and Yochelson, 1956.

ments existed from the late Pennsylvanian onward through at least a part of the Wolfcampian.

The Wolfcamp shales exhibit faunal similarities to the shale members of the Admiral and Belle Plains formations of north central Texas, also usually classed as Wolfcampian. This is noted especially in the presence of the following pleurotomarians in both areas:

*Shansiella tabulata*  
*Euconospira spiroperforata*  
*Phymatopleura brazoensis*  
*Paragoniozona nodilirata*

The limestones at the type section of the Wolfcamp formation contain two species, *Glyptotomaria* (*Glyptotomaria*) *marginata* and *Shwedegonia elegans*. Both species are quite common in the post-Wolfcampian Permian of west Texas and in the lower part of the Hueco limestone (Wolfcampian) in the Hueco Mountains. *Euconospira pulchra* is found in small reef masses in the lower limestone units of the Wolfcamp in the western Glass Mountains. It is also found in the western facies of the Hess.

According to King (1930, p. 57), the base of the Leonard formation in the Glass Mountains is marked by a persistent basal conglomerate. The formation is about 2000 feet thick, consisting of limestone and shale. In the eastern Glass Mountains, 1800 feet of a thin-bedded dolomitic limestone has been named the Hess facies of the Leonard formation. This facies thins westward where it is replaced by calcarenites and massive limestone conglomerates. A thin limestone of the Leonard formation (Leonard limestone no. 1 of King) is separated from the Wolfcamp by 100 feet of yellow shale and from the western facies of the Hess by 100 feet of yellow shale. Faunally limestone number 1 has close affinities with the Wolfcamp formation. Above a sequence of basal limestone units including limestone number 1, there is a series of yellow, siliceous shales and sandstones which thicken westward and are equivalent to the Leonard of the eastern Glass Mountains.

Most of the pleurotomarians were collected from a sponge bed in the upper part of the Hess facies in Hess Canyon (U.S.N.M. 702d) and in the upper 200 feet of the formation above the Hess (U.S.N.M. 703a, 702, 708, 702un, 702b). A few specimens are

known from the western Glass Mountains where they occur rather low in the section.

Four species, *Tapinotomaria crassa*, *Tapinotomaria costata*, *Glyptotomaria* (*Glyptotomaria*) *marginata*, and *Shwedegonia elegans*, from the Leonard limestone number 1 (U.S.N.M. 707b) are also found in the lower Bone Spring formation in the Sierra Diablo. Stehli (1954, p. 276) states that "... in the Sierra Diablo the lower Bone Spring fauna contains a few forms which in the Glass Mountains are seemingly restricted to the Wolfcamp and a possibility exists that these rocks are somewhat older than the Leonardian of the Glass Mountains." The distribution of the species listed above tends to support Stehli's conclusion.

Precise faunal or lithologic correlation among the beds of the Leonardian in the eastern and western Glass Mountains is difficult. Several lithologic facies are represented, and collections from the two regions are not comparable. For example, pleurotomarians have been found at two localities in the western Glass Mountains in limestone number 1. The earliest known Leonardian pleurotomarians in the eastern Glass Mountains occur near the top of the Hess facies which is thought to be older than Leonard limestone number 1 in the west on the basis of brachiopods. The upper Hess occurrence is unique, the gastropods being found in association with sponges, which suggests unusual environmental conditions not found in the west.

The upper part of the Leonard formation is composed of a series of limestones and shales with a basal conglomerate (King, 1942, p. 653). It is best exposed and has been exhaustively collected at Split Tank. The brachiopods seem to indicate a similarity with the Leonard formation in the western part of the Glass Mountains, but the lack of pleurotomarians there prevents further comparison. The upper part of the formation in the east commonly contains the following pleurotomarians:

*Tapinotomaria globosa*  
*T. rugosa*  
*T. crassa*  
*T. costata*  
*T. duplicostata*  
*T. mirabilis*

*Glyptotomaria (Glyptotomaria) marginata*  
*Discotomaria nodosa*  
*D. dubia*  
*D. basisulcata*  
*Shwedegonia elegans*  
*Euconospira pulchra*

Above the Leonard formation, the base of the Word formation is defined by a persistent limestone which reaches a maximum development in the western Glass Mountains where it is about 300 feet thick. This first limestone bed thins eastward to about 50 feet near the old Word ranch (the type locality). In the western Glass Mountains the Word limestone number 1 is succeeded by about 1000 feet of shales, sandstones, and thin limestones (King, 1942, p. 654). In the east the formation above the first limestone ranges from 500 feet in thickness near the Word ranch to about 1000 feet on the west side of Hess Canyon (King, 1942, p. 72). This section contains the Vidrio member of the formation at the top, part of which is Capitanian in age (King, 1942, p. 656).

Pleurotomarians were found in the Word limestone number 1 in both the eastern and western Glass Mountains. In the east (at U.S.N.M. 703) the species identified are:

*Tapinotomaria globosa*  
*T. rugosa*  
*T. crassa*  
*T. costata*, groups 1 and 3  
*T. duplicostata*  
*T. submirabilis*  
*Callitomaria magna*  
*Discotomaria costata*  
*Euconospira pulchra*

Thus the pleurotomarians are quite similar to those found in the Leonardian.

Pleurotomarians are known from a single locality of Word number 1 (U.S.N.M. 707e), near Sullivan Peak in the western Glass Mountains. They are:

*Tapinotomaria costata*, group 2  
*T. duplicostata*  
*Spiroscala pulchra*

Northeast of the Hess ranch (U.S.N.M. 706c) three species of pleurotomarians were found near the top of Word limestone number 2. These are:

*Glyptotomaria (Glyptotomaria) pistra*  
*Discotomaria nodosa*  
*Spiroscala pulchra*

The top of limestone number 3 (U.S.N.M. 706e) has furnished a single species, *Shwedegonia elegans*. U.S.N.M. 706b between Word limestones numbers 3 and 4 yielded *Glyptotomaria (Glyptotomaria) marginata*. Pleurotomarians are not known from younger Permian beds in the Glass Mountains.

In the Hueco Mountains and the Guadalupe Mountains, the Permian is locally parallel with the underlying Pennsylvanian beds, and a hiatus must be inferred only from paleontologic evidence. In other places profound erosion occurred before the deposition of the Permian. In the type section about 1600 feet (King, 1942, fig. 5) of Hueco limestone, thought to be equivalent to the Wolfcamp, overlies the Pennsylvanian Magdalena formation. The Hueco limestone can be traced northward and westward into New Mexico, and several localities in the Orogrande region have yielded excellent gastropods. Eastward the formation is covered until it reappears in outcrops on the Diablo plateau.

In the Hueco Mountains the formation consists of a series of limestones similar to the underlying Magdalena formation. In the Sierra Diablos, the formation is about 500 to 700 feet thick and consists of a basal clastic section in the south of the mountains grading upward into sandstones, siltstones, and marls. Above the clastics there is a uniform sequence of carbonate rocks. The formation thins northward mostly by loss of the basal deposits (Stehli, 1954, p. 369). It was deposited unevenly on a deeply eroded surface. The Hueco limestone in the Sierra Diablos is overlain by the Bone Spring (Leonardian) formation.

The Hueco limestone and its characteristic fauna are widespread, in sharp contrast to the limestone faunas of the Wolfcamp formation, which are local in distribution. Because of the restricted distribution it has been suggested (Knight and Cooper, personal communication) that the lower series of the Permian might better be named after the Hueco limestone rather than the Wolfcamp formation.

At the Orogrande locality (U.S.N.M. 712) of lower Hueco age, *Tapinotomaria globosa* and *Discotomaria basisulcata* have been recognized.

Pleurotomarians from the Hueco lime-



stone in the Hueco Mountains and Orogrande, New Mexico, are unknown in the Sierra Diablo. The following species are identified from U.S.N.M. 712f, the middle part of the Hueco limestone:

*Shansiella conica*  
*Glyptotomaria (Glyptotomaria) marginata*  
*Discotomaria nodosa*

The Hueco gastropod faunas in a general way resemble those of the Magdalena limestone, which suggests environmental affinities. These are not, however, readily comparable to those of the Wolfcamp formation. *Tapinotomaria globosa* occurs in the lower and middle part of the Hueco limestone, but it is slightly different from the forms found in the Wolfcamp; this may be an effect of both geographic and stratigraphic separation.

*Glyptotomaria (Glyptotomaria) marginata* is found in Wolfcampian shales of north central Texas, in shales of the Wolfcamp formation at Gaptank, and in limestones of the middle and upper parts of the Hueco of the Hueco Mountains.

The Bone Spring formation in the Sierra Diablo lies unconformably on the Hueco and older rocks. It is characterized by extreme and rapid facies changes (Stehli, 1954, p. 271). A barrier reef with accompanying fore-reef and back-reef deposits in the formation marks the first of the great barrier reef deposits around the Delaware basin. The eastern edge of the Sierra Diablo apparently was the pivot area between shelf and basin. Essentially the formation is a dark, sandy limestone, but it is extremely variable, and equivalent basin deposits are said to be composed of dark shales. The formation in the Sierra Diablo reaches a maximum of about 2500 feet (Stehli, 1954, p. 271).

In the Sierra Diablo and the Guadalupe Mountains the Bone Spring limestone at the margin of the Delaware basin consists dominantly of dark to black limestone. Most of the pleurotomarians are found in the lower part of the formation in this facies. In the Sierra Diablo, a rich assemblage of pleurotomarians was found in Apache Canyon (King and Knight, 1944, O. and G. map). The "molluscan ledge" is in the lower Bone Spring formation, in black limestones of basin type. It is believed to be an accumulation of re-

worked muddy facies shells. Pleurotomarians identified, thus far, are:

*Tapinotomaria rugosa*  
*T. crassa*  
*T. costata*  
*Callitomaria magna*  
*Discotomaria costata*  
*Spiroscala pulchra*

The Cutoff shale member at the top of the Bone Spring formation in the Guadalupe Mountains contains *Tapinotomaria costata*, group 2, and *Shwedegonia elegans*. This member probably is slightly younger than Word limestone number 1 in the Glass Mountains (Newell and Knight, personal communication).

In the Sierra Diablo a series of sandstones and dolomites overlies the Bone Spring. This is correlated with the Cherry Canyon sandstone of the Guadalupe Mountains. This formation with the overlying dolomites of the Queen limestone are the only representatives of the Guadalupian on the Diablo plateau. In the Guadalupe Mountains, Guadalupian rocks reach a maximum of 4000 feet. Three formations comprise the Delaware Mountain group of Guadalupian age; in ascending order they are Brushy Canyon, Cherry Canyon, and Bell Canyon formations (Newell, Rigby, *et al.*, 1953, p. 25). The Brushy Canyon and Cherry Canyon formations are essentially composed of sandstones and siltstone with sporadic limestone units, particularly in the Cherry Canyon. During the Cherry Canyon and Bell Canyon deposition great barrier reefs were formed at the basin margins, the Goat Seep and Capitan reefs. The distribution of facies and paleoecological implications of these formations are fascinating aspects of the Permian of the area. They have been well described by Newell, Rigby, *et alii* (1953).

Only one horizon has yielded pleurotomarians from the Guadalupian series in this region. This is the lower part of the Getaway member of the Cherry Canyon formation deposited before the Goat Seep reef came into existence. This horizon is near the basin margin, apparently on the flank of a patch reef. The following species have been identified:

*Tapinotomaria globosa*  
*T. costata*, group 3

*T. pyramidalis*  
*T. coronata*  
*Callitomaria magna*  
*Glyptotomaria (Glyptotomaria) pistra*  
*Discotomaria nodosa*  
*D. costata*  
*Shwedegonia elegans*  
*Euconospira pulchra*

On the basis of the contained fossils, this member, the lower Getaway, may be correlated with Word number 2 or 3 in the Glass Mountains. There is, however, some uncertainty about the exact correlation. The pleurotomarians cannot contribute to a solution of the problem, because there is but a single species in common with Word number 3 (*Shwedegonia elegans*) and a single species in common with Word number 2 [*Glyptotomaria*

(*Glyptotomaria*) *pistra*], both of which are rather long-ranging species.

A single specimen of *Euconospira spiroperforata* is known from the back-reef deposits in the Carlsbad limestone.

In general, the pleurotomarians thus far studied tend to support correlations made with other fossil groups. However, it must be emphasized that only about one-half of the pleurotomarians of the west Texas Permian are considered in this study. A cursory survey of the unstudied forms indicates that more definite conclusions eventually can be made on correlations of the Wolfcampian and the Leonardian formations. The forms not studied are actually more widely distributed geographically and stratigraphically than those described herein.

## PALEOECOLOGY

PALEOECOLOGICAL STUDIES of the Permian rocks in the Guadalupe Mountains by Newell, Rigby, *et alii* (1953) form one of the more stimulating contributions among general studies of the west Texas Permian. Until the majority of the gastropod kinds are described from these deposits, it is not feasible to relate them to their environment. A brief outline is given here of some of the conditions thought to have existed at certain localities where gastropods have been found.

Before the beginning of Wolfcampian time in the Glass Mountains, erosion was acting on a near-by land mass to the south of the present Glass Mountains front. This resulted in the accumulation of late Pennsylvanian and Wolfcampian shales and conglomerates. The shore line and general facies trend of the deposits form an angle to the present mountain front, as evidenced by the distribution of the conglomerates. The only inference that can be made from this observation is that there was probably rather shallow water at some of the localities. Faunas of the Permian shales of north central Texas are like those of shales found in the Glass Mountains. This is interpreted as being a result of similar environments and approximate time equivalents in the two areas.

Fossils occur in several kinds of concentrations in the Permian rocks of the Glass Mountains. The first type of concentration is commonly found in the shales and limestones as patch reefs, and is in the form of lenticular mounds. Many of these are found in the Wolfcamp formation and also are topographic mounds, owing to the recent erosion of surrounding shales. Typically, the flanks of these lenticular bodies are composed of accumulations of organic debris, mainly brachiopods and bryozoans. The central portions of the lenses are generally recrystallized and massive. These small reefs are frequently encountered in all Permian rocks, up through deposits as young as Guadalupian. Associated conglomerates in the Wolfcamp formation indicate that they were almost certainly deposited in very shallow water close to shore.

The second type of fossil concentration in the Glass Mountains is represented by large accumulations of worn and broken brachio-

pod and mollusk shells, fragmented bryozoan colonies, and sponge debris. The bedding in and around these accumulations seems to indicate that fossil debris was concentrated in depressions beneath the general surface of the sea bottom, rather than in mounds. The water, when these accumulations were forming, was probably very shallow during much of the Wolfcampian, gradually deepening during the Leonardian, but the area was still probably above wave base even as late as late Leonardian.

A comparable accumulation is to be found in the shallow lagoons along the east coast of Florida. The writer has examined shell concentrates along the intertidal zone of Biscayne Bay. These are found in elongate depressions that may be several feet in depth, with the length being up to 10 feet and the width up to 5 feet. The accumulations consist of broken and wave-worn gastropod and pelecypod shells, echinoid plates and spines, asteroid plates, occasional loose chiton plates, and fragments of arthropod carapaces. Numerous scavengers are active in these depressions, including *Thais rusticus*, several species of crabs, and small fish. Many specimens of both living and dead *Cerithium* are found. The tide is mostly responsible for the currents which concentrate this debris, and storm activity quickly fills these depressions and forms others. This type of concentration is thought to be analogous to the conditions of accumulation at U.S.N.M. 702 in the upper Leonard formation and U.S.N.M. 703 in the Word formation, limestone number 1.

Another type of accumulation is seen at U.S.N.M. 702d in beds just below the upper Leonard. In contrast to patch reefs, the cores of which are massive and recrystallized, there is a large concentration of massive sponges which have been covered by sediments that can be traced into the surrounding beds. These concentrations are irregularly shaped and somewhat lenticular, but there is no sign that any portion of the included area is recrystallized. Mollusks are very common, along with crinoids and brachiopods. Large spiny nautiloids and neritaceans, with other forms having delicate ornament, seem to indicate that there was little current activity or

disturbance and that these areas of sponge growth were quickly buried. Cooper (personal communication) has suggested that these concentrations of sponges and the associated fauna were clustered on a relatively flat bottom and, because of the nature of the deposit and its disposition, could not be considered to fit the usual definition of a reef.

Sponges appear to be exceedingly important to an understanding of the ecology of many of the organic accumulations in this area. At the present time, a study is being conducted by Robert Finks on the sponges and sponge ecology, and we must wait until this study is completed before further interpretations can be made. Pleurotomarians are frequently found at localities where there are sponges; it is thought that this association may mean that the gastropods preferred a similar environmental situation, such as soft, muddy bottoms and fairly shallow water, with some tolerance for an occasional period of turbid water.

It is likely that most of the above gastropod-bearing deposits represent accumulations that, if moved at all, are at least in close proximity to the place where they lived. Even in the depression type of shell accumulation found at U.S.N.M. 702, it is thought that the fossils were washed in from the immediate surroundings. On the other hand, in the Sierra Diablo, Guadalupe Mountains, and Glass Mountains, where there were steep slopes off large reefs, many of the deposits near the foot of the slope represent a mixture of forms that in all probability have been moved for some distance. The rich molluscan assemblages from block limestone at A.M.N.H. 433 and P.U. 3, both in the lower Bone Spring limestone, are examples of mixed faunas transported some distance. Several miles away and topographically higher, a reef of fringing type of the same age was developed and grew on top of the sloping, eroded surface of the underlying Hueco limestone (Stehli, 1954, p. 272). Gastropods were very probably living along the reef front in shallow water. The forereef deposits in the form of limestone conglomerates interfinger with the black limestones which represent deposition in the basin in fairly quiet and deep water (King, 1942, p. 631). The evidence (King, 1942; Stehli, 1954) points to the

fact that the water is of considerable depth at these localities, and it is possible that much of the fauna may have been moved as much as 2 miles down the slope of the forereef into the basin. Examination of the material indicates that many specimens are water worn and broken, with few large forms present, which indicates that they probably were transported (see fig. 2).

Pleurotomarians are exceedingly rare in the reef and back-reef deposits. A single specimen of *Euconospira spiroperforata* is known from the immediate back-reef deposits in the Guadalupe Mountains.

In summary, it is probable that the Permian pleurotomarians lived in shallow water from the littoral zone to depths of perhaps 100 to 200 feet. Modern pleurotomarians are found in fairly cold water from about 20 fathoms to 500 fathoms. Paleozoic pleurotomarians were probably warm-water forms. Newell, Rigby, *et alii* (1953, p. 185) suggest that the temperatures of the Delaware basin region during the Permian were equivalent to semi-tropical conditions; "the climate was approximately what might be expected at the present time if the Gulf of Mexico extended as far as western Oklahoma and central New Mexico."

Conditions of recent sediments where pleurotomarians are found suggest that they live on mud or sand bottoms. It has been suggested that they live on firm bottoms, on the basis of scanty information obtained in the procuring of living specimens in the Indo-Pacific region (Knight, personal communication). Niino (personal communication) states that while dredging numerous living specimens in submarine canyons off the coast of Japan he was able to observe, from retrieved water samples and cores, that the bottom is composed of rather soft blue muds frequently stirred by heavy current action. Living pleurotomarians, with their aspidobranch gills, may only with difficulty free silt particles from the filaments.

There is one specific association between a species of *Glyptotomaria* (*Glyptotomaria marginata*) and *Heliospongia* that should be included here. An undescribed species of *G. (Glyptotomaria)* in the Pennsylvanian is generally found associated with sponges having a cloaca similar to that of *Heliospongia*. At



U.S.N.M. 702d *G. (Glyptotomaria) marginata* has been found by Robert Finks within the cloaca of *Heliospongia*, and the repeated occurrence suggests the possibility of an ecologic relationship (see pl. 42, fig. 9). This may be an example of commensalism or some similar relationship between the two organisms. It must be remembered that the pleurotomarians are not organized for filter-feeding. If filter-feeding were the case, one could postulate that the gastropod could have filtered food from the currents swept into

freely moved about and were not sedentary. One specimen from the same locality has a portion of the cloacal wall growing about the lower portion of the shell, which indicates that the specimen must have been within the cloaca during the time when the sponge was still alive. The writer wishes to thank Robert Finks for the discovery of this interesting and important relationship; it was he who observed and identified the cloacal wall growing about the specimen of *G. (Glyptotomaria) marginata*.

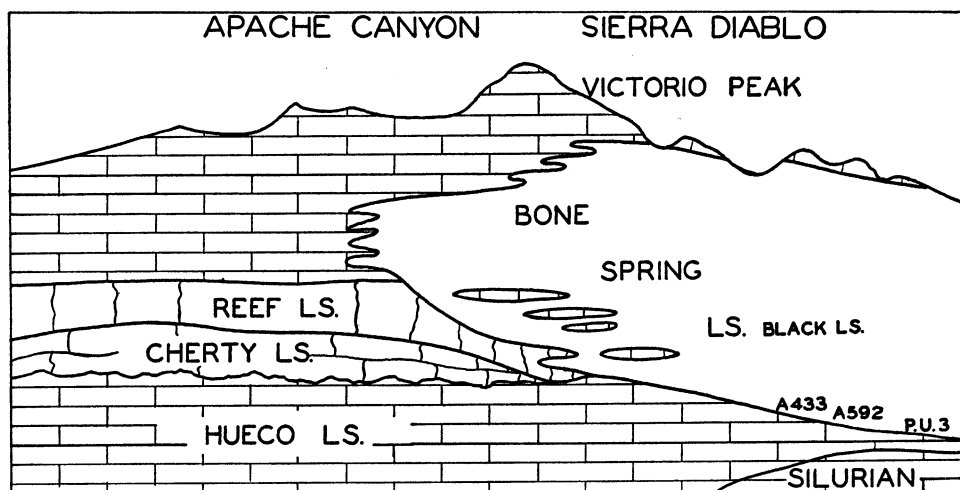


FIG. 2. A stratigraphic diagram of Apache Canyon, Sierra Diablo, Texas. The diagram indicates an approximate distance of 1 mile and height of about 800 feet through which gastropods have been moved from the top of the Bone Spring reef limestone (just left of center) eastward to the indicated localities (A 433, A 592, and P.U. 3). From King, 1942.

the cloaca through the canal system. Most living archeogastropods, including the pleurotomarians, are almost without exception herbivorous. Another possibility is that this species could have lived on algal material collected on the cloacal walls.

Known Paleozoic commensal gastropods, *Platyceras*, for example, that are coprophagous on crinoids, have irregular growth lines and highly variable shapes, depending on the type of substrate organism. *Glyptotomaria (Glyptotomaria) marginata* is characterized by having regular growth lines with a rather elaborate ornament and a fairly stable shape. There is a broad sinus on the base which is characteristic of the genus. From these characters, it seems obvious that the specimens

Representatives of other phyla and different gastropods of about the same size as *G. (Glyptotomaria) marginata* are found at this locality. These are among other debris found within the cloaca of *Heliospongia*, but species of other groups are not found so consistently as is *G. (Glyptotomaria) marginata*. This suggests that the association is not fortuitous.

It is not thought that a specific commensalism is the case here, because it is most probable that neither the Pennsylvanian sponges nor the gastropods are the same as the Permian species. More material must be obtained before a proper interpretation is possible and before other basic questions regarding this possible association can be answered.

## STATISTICAL CONSIDERATIONS

THE USE OF STATISTICS has become increasingly important in paleontology with refinement of methods of collection and preparation. Adequate samples of fossil populations can be statistically treated, with a resulting increase in knowledge of variation and taxonomic relationships. Many students have been discouraged from applying statistics because of apparently formidable difficulties imposed by biased samples (mostly sorting and collecting bias), by small samples, and by lack of accuracy in measurement. Kermack (1954, pp. 384-391) has discussed some of the problems that involve bias and measurement and has emphasized the importance of the use of shape parameters rather than size parameters. The use of shape parameters tends to lessen the effect of bias.

Some difficulty is found in obtaining precise measurements and in arriving at a standard orientation of specimens. Gastropod shells offer the greatest challenge to standard orientation because, with the exception of those forms that exhibit pronounced gerontic characters such as apertural thickening, they lack reference points of relative time and measurement. In this paper all measurements are regarded as approximations. Several samples were measured on different days, and slightly different measurements were recorded on each day which were not significant when tested. However, the important point is that the statistical results have been consistent. Each sample was measured at one sitting, using the same orientation of specimens so that the maximum amount of consistency could be obtained.

Most of the measurements made were without a point of reference on the shell and were made as close to the oldest portion of the shell as possible. An attempt was made to orient the specimen in such a manner that the axis of coiling was approximately perpendicular to the line of vision. This was done by placing the specimen in a box of magnetite sand with the aperture resting against the granules. The specimen was adjusted until the axis was approximately perpendicular to the line of vision and then placed on the stage of a low-powered microscope. All measurements were made with the aid of a microm-

eter eyepiece. Sloan (1951) developed a method which would aid in placing the axis vertically by the use of a special measuring device, but this cannot be used for fragile silicified specimens.

The methods of measurement adopted in this study do not require a high order of precision, as it was not necessary to measure equivalent growth stages. With the above method of orientation, results were checked by the calculation of the correlation coefficient for two well-correlated characters. In a single sample the correlation coefficient was 0.995, which suggests that the orientation is accurate enough for most statistical treatments.

Bias can be reduced by the use of growth comparisons, rather than univariate analysis for any given stage of development. In fossil gastropods, the aperture is usually missing or broken, so that there is little opportunity of recognizing adults. Most statistical devices that are based on univariate analysis assume that forms are from a single age group. When a number of growth stages are involved, a time factor must be introduced, and the simple methods based on frequency distribution are no longer applicable.

Statistics have been used in the present work as an aid for obtaining such population characteristics as variability, amount of overlap between various populations of a species, and, most important of all, for determining related quantitative characters that can be a measure of qualitative characters. Discrimination is therefore not a primary function of quantitative analysis used here. In relatively few species or populations was discrimination needed and used; in those cases in which it was needed, there was also some qualitative overlap. Qualitative overlap is most commonly found where there is a wealth of material and where populations occur in close geographic or stratigraphic association.

The pleurotomarians as compared with gastropods in general have many characters that can be measured; in some groups, these measurements can be made on fragments, in such cases increasing the useful size of the measurable sample. Height and width are dimensions which are easily measured, and

they represent the summation of many characters that are individually not so readily reduced to quantitative data. Height and width, like any other characters or sets of characters, are not necessarily the most reliable or most significant in every species. It is usually desirable to examine a number of readily measurable and easily calculated characters and then test to see which are most distinctive in the group under consideration.

After the measurements were made on a sample, characters were plotted against one another to determine which pairs had the highest correlation coefficients. Each of these sets of characters was, in turn, matched with the qualitative characters used to distinguish species within the genus. Pairs of quantitative characters with the highest correlation, matching qualitative characters, were then taken as the best for statistical treatment. They were used both for characterizing the population or species and for discrimination, if necessary. These quantitative characters may significantly change from species to species, or may be consistent for all species of a genus.

If most of the sample contained mature shells, then an expression of difference in sample means can be done graphically by the use of the "Dice Line" (Dice, 1937; Simpson and Roe, 1938, p. 317). The statistics were determined for a particular character, such as height or width. After the mean, standard deviation, and standard error of the mean were calculated they were plotted on a line representing the observed range of the sample. The standard error of the mean was plotted on each side of the mean. Two samples plotted in this manner were compared, and, if there was little or no overlap between the two areas delimited by the standard errors, then it was usually assumed that there was a significant difference between the two samples.

To compare variability between two samples (each of a single growth stage) the Pearson coefficient of variability,

$$V = \frac{(100 \text{ S.D.})}{\bar{x}},$$

was used as a standard of comparison.

To test the probability that a difference

between the means of two samples was due to chance sampling of a single population, the *t* test was employed; *t* is a value dependent on the size of the sample and is the measure of deviation between the two samples. This formula is given in Simpson and Roe (1939, pp. 210-211). The *t* determined was then compared in a table of probability (Simpson and Roe, 1939, p. 206), and, if the value of *t* was greater than the probability expected between the 5 per cent and 1 per cent levels of significance, then a significant difference existed.

In most samples of populations in this paper, many growth stages were present, and it was necessary to employ statistical methods utilizing allometric growth relationships. In these cases a set of two characters that were related, having particularly high correlation coefficients, were estimated by the use of a simple scattergram. Then, by means of a prepared correlation form (see Imbrie, 1956, p. 244) the standard deviations, means, and correlation coefficients were determined for each of the sets of characters.

The general growth formula, as determined by Huxley (1932), is  $y = bx^a$ . Growth of most organisms assumes a straight-line relationship, except in early and late stages of life, so that the formula  $y = ax + b$  can be used for most samples. Here *a* is the growth ratio and *b* is the initial growth index. These coefficients, *a* and *b*, may be estimated by regression methods, providing that there is a high degree of linear correlation between the variates. If a character *Y* is a dependent variable and character *X* is the independent variable, and if the sample has a high correlation coefficient (*r*), a line will be formed. If character *Y* is the independent variable and if the correlation coefficient is low, another regression line different from the other will be formed. Kermack and Haldane (1950) constructed a line which is a more conservative line between the regression lines and was called by them the reduced major axis. Here,

$$a = \frac{S.D.y}{S.D.x}.$$

The correlation coefficient (*r*) can easily be determined by the use of any standard formula in statistics textbooks, or may conveniently be determined by means of a corre-

lation form such as the one developed by the Yale University Student Appointment Bureau (Imbrie, 1956).

After the correlation coefficient has been determined for the two characters of a population, if discrimination is desired, the sample may be readily compared to a second sample. One test, here called the "correlation coefficient discrimination test" (after Imbrie), is for the significance of the difference between the two correlation coefficients. This formula is given in Simpson and Roe (1939, p. 279).

A method for testing for the difference between two samples is that of testing the differences between shape and position of the two relative growth lines based on the reduced major axis. Variance must be determined by use of the following formula:

$$\text{Var. } (y_1 - y_2) = \frac{(S.D.y_2)^2 (1 - r_2)^2 (\bar{x}_1 - \bar{x}_2)^2}{(N_2) (S.D.x_2)^2} = (S.D.a_2)^2 (\bar{x} - \bar{x}_2)^2.$$

The formula for the test of significance between the slope of two growth lines used here is:

$$t = \frac{a_1 - a_2}{\sqrt{S.D.a_1^2 + S.D.a_2^2}}.$$

The formula for the test of position of two growth lines is:

$$t = \frac{y_1 - y}{\sqrt{\text{Var. } (y_1 - y_2)}} \text{ at point } \bar{x}_0 - \bar{x}_1.$$

These formulas have been developed by Kermack (1954) and by Imbrie (1956).

In a number of species it was possible to use both the relative growth and univariate types of analysis, because samples of adult forms and mixed forms were available. In those species in which discrimination was not needed, the statistics for each measured character was made, providing the sample was large enough to make this practical.

Most of the samples in this portion of the study were small, and there was only an occasional series of overlapping samples.

## THE LOGARITHMIC SPIRAL

COMPARED TO some other fossil organisms, most gastropod shells have relatively few characters that can be studied and measured; but the spiral pattern of shell growth, a dominant and obvious character of gastropods, has not been given much attention in the past. There are a great many difficulties involved in the use of this feature. A common belief is that gastropods do not follow a sufficiently fixed growth pattern to make the logarithmic spiral of the shell taxonomically significant. The chief difficulty lies in making accurate measurements for calculation of a reliable spiral formula. As an alternative, an approximation of the growth pattern of the shell, with the use of some gross measurement influenced by the forces that result in the spiral, can be used. If measurements can be made within the range of accuracy needed for statistical treatment, then consistent results can be obtained. Because this study is concerned with the growth and population characteristics, we are more interested in the ontogenetic changes that occur in spiral growth than in a precise formula for each shell.

There are several ways of determining the formula for the logarithmic spiral of a given shell. A formula based on the determination of the radius vector is used here as an illustration. The formula for this vector is

$$R = e^{w \cot V}$$

with  $e$  a constant based on naperien logs,  $w$  the angle subtended by two radius vectors extending out to the spiral from the point of origin, and  $V$  the vector angle, formed by a radius vector and a tangent at the point of intersection of that vector with the spiral (see fig. 3).

The vector angle of most gastropods ranges from 80 degrees to a little less than 90 degrees. If the angle  $V$  is 90 degrees, a circle would be described by the point of growth. If the vector angle is small, the coil could not complete a full turn within reasonable dimensions. Because of this narrow range of vector angles for most gastropods, it is obvious that there is an even smaller range of variation possible within taxonomic units on or above the generic level.

Most formulas for the logarithmic spiral are based on a spiral in a single plane and thus can be applied directly only to planispirally coiled gastropods. Most gastropods, including pleurotomarians, however, are turbinate, so that it is necessary to take into account the fact that the spiral does not lie in a plane. The relationship between the axis and the spiral is not necessarily uniform, as the rate of increase in the length of the axis is much more

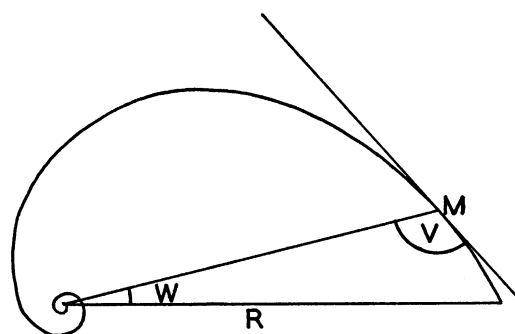


FIG. 3. Angular relationships of the logarithmic spiral. From Lison (1949, p. 17).

variable than the incremental development of the logarithmic spiral. The rate of growth change outward from the point of origin is usually constant, but the change downward is less likely to be constant. Whenever downward growth is uniform, there is a steady increase in volume and surface area, so that the sides (outer shell face) will be straight and even. It has been demonstrated that strongly concave- or convex-sided forms do not grow downward at a uniform rate (see fig. 16). Thus the angle between the growth surface and the axis (the axial spiral angle) may change with growth (see fig. 5).

It is not necessary here to discuss fully the usage of the logarithmic spiral, but several methods may be cited. Lison (1949, pp. 33-35) has suggested that a valuable character for differentiation and characterization would be the calculation of a formula for the complete area of the shell (this was done by Lison for certain lamellibranchs). This formula would be extremely difficult to obtain for gastropods and would involve a great expen-



diture of time not commensurate with the advantages. The results would yield a general formula, but could not give the total area of secretion, because it would be difficult to measure the surface of spines and other irregularities.

Ida (1952, pp. 17–18) has developed a method of obtaining the spiral formula and vector angle by projecting the shell surface of each whorl on a plane in the form of a truncated cone. The method is not sufficiently clarified in the paper, so that it has not been possible to reproduce the method. According to Ida, the legs of the resulting cone are equal to the radius vectors, and the vector angle is formed by these two legs. From a series of these cones, the logarithmic spiral formula for the entire shell could be obtained. One difficulty with this method is that it tends to obscure any changes in the axial spiral angle, taking an average of the whole shell instead. It may also obscure changes of growth directions when comparisons are made between the smaller taxa.

Both of the above-mentioned methods are accurate representations of the spiral. The formulas, so developed, provide by far the most significant quantitative characters of the planispiral shell, from both a statistical and a taxonomic view. However, in a faunal or population study involving large numbers of individuals, a compromise must be made and accuracy somewhat sacrificed.

The methods developed by Ida and Lison can be employed in limited ecological and taxonomic problems in which minute differences in populations are believed to be important. Both of these methods can be used in such a manner that they emphasize small differences, but much accuracy is needed in taking the measurements, and frequently specimens must be sectioned to obtain these figures. Fossil gastropods are particularly difficult to measure because of poor preservation, distortion of the specimens, abrasion or destruction, during life, of the apex of the shell, and broken apertures. Consequently, it is desirable to develop study methods that will provide a rough estimate of the logarithmic spiral or some gross measurement which may be partly or entirely controlled by the spiral growth.

Thompson (1942, pp. 772–774) has sug-

gested the use of suture ratios as a character which gives some indication of the rate of growth. If the successive heights of the whorls are measured and their ratios are calculated, it is possible to obtain a mean suture ratio for the shell. This is easily measured and calculated and appears to be best suited for high-spired shells. Low-spired shells, or those with few whorls, are not well suited to this treatment. In the present study, suture ratios of several samples from different species were calculated. This character was found to be normally distributed in the sample and can be conveniently adapted to statistical treatment. Unfortunately, suture ratios are not well correlated with other quantitative characters. No correlation coefficient for this and other characters was found to be higher than 0.65. The correlation between the height of the shell and the mean suture ratio was particularly low. Furthermore, it is not a particularly sensitive character, as its range is quite restricted. For example, identical suture ratios can be obtained between different species, genera, or even families. In some cases, it was found to be of value for discrimination, but on the whole it is a character of secondary importance. *Shwedegonia elegans* Batten, 1956, for example, is separable from *Shwedegonia mariana* (Gemmellaro) by the use of the suture ratios.

An application of the logarithmic spiral employed by both Ida (1952, p. 8) and Young (1952, p. 819) is the direct comparison of whorl height and whorl width. The logarithmic plot of these measurements indicates a rectilinear relationship of high correlation between these two characters. This method indicates an important relationship between either whorl height or whorl width and shell shape. There seems to be a direct relationship between the suture ratios and shell shape. This method is adapted in the present paper and has served as a very important specific character.

In turbinate forms there are two principal growth directions that control the shape of the shell: the vector angle and the axial spiral angle. Two methods can be employed to obtain suture ratios from whorl height.

The first method is to orient the specimen so that the shell axis is parallel to the line of vision. Measurements are then made along a

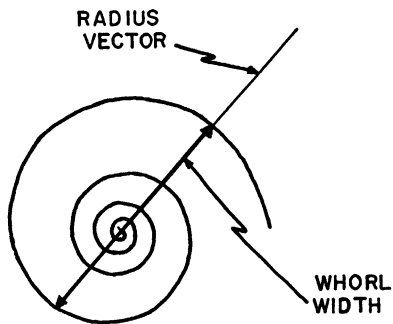


FIG. 4. Diagram of shell oriented so that the axis is parallel to the line of vision. Measurement is made as if the axis were visually equal to zero.

radius from the point of origin outward to the periphery (see fig. 4). These measurements are directly related to the vector angle, as the axis appears to be equal to zero when viewed from above.

The second method is to orient the specimen so that the axis is perpendicular to the line of vision (see fig. 5).

Measurements of whorl height are taken along a projection of the axis. The vector angle to a smaller extent influences the progressive spacing of the sutures. The axial spiral angle now becomes a dominating factor, influencing the height of the whorls along the axial trend.

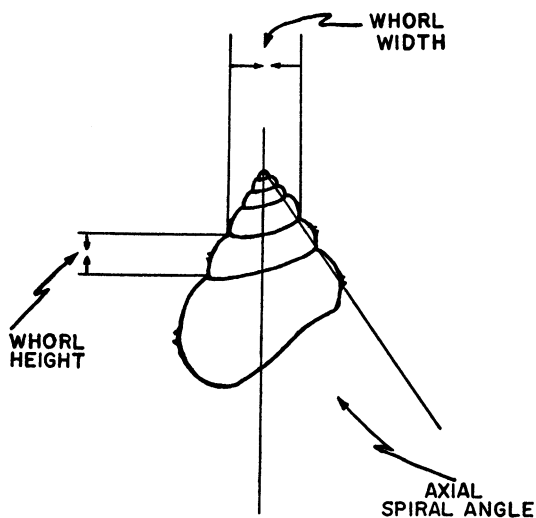


FIG. 5. Diagram of a shell oriented so that the axis is perpendicular to the line of vision. Measurements made with this orientation take into account the effect of axial changes.

As there is a small range of vector angles, it is less desirable to measure whorl heights when the vector angle has the greatest influence, that is, by orienting the specimen with the axis parallel to the line of vision (method 1 above). Therefore all measurements in this paper are based on the orientation of the axis perpendicular to the line of vision, in which case the axial spiral angle can be grossly related to the suture ratios.

Specimens from two samples of *Shwedegonia elegans* from the Permian of west Texas were studied by direct comparison of the whorl width and whorl height. It was found in the first sample that there were two changes in growth rates corresponding with the second to fourth whorls and sixth to eighth whorls (fig. 16). These were observed in those specimens that had strongly concave shell shapes. The changes are interpreted to indicate that there had been an ontogenetic change in the axial spiral angle which, in turn, reflects a change in length rates of the axis. This is accompanied by a change in volume of the shell. In the second sample, containing forms that are more straight-sided, there was a sudden increase in the whorl height at about the sixth to eighth whorls, but no changes were observed in the earlier whorls. There is also a change in the suture ratios at approximately the same stage of development (see p. 228). Thompson (1942, pp. 814-817) discusses the changes in the rate of increase of the axis, but, so far as I am aware, this has not been determined previously for fossil gastropods, nor has a relationship been determined between suture ratios and shell shape or whorl width and whorl height and shell shape.

Shell height and width generally have been considered to be important taxonomic characters in gastropods. During the course of this study, it was found that a very low correlation exists between shell height or width and suture ratios, or between whorl height and width and total dimensions of the shell. There is, however, a relationship between the logarithmic spiral and the outside dimensions of the shell. Low correlation is probably due to inability to measure these characters accurately, and probably explains low correlation of the length of axis and the axial spiral angle.

In conclusion, it must be stated that gastropod shells and structures of other organisms that follow mathematically definable growth patterns are subjected to the vagaries of their environment and consequently will

vary from any fixed growth formula. This variation is, of course, important, as we may gain clues of taxonomic and ecological significance by a study of these changes.

## SOME EVOLUTIONARY CONSIDERATIONS

THE EVOLUTIONARY DEVELOPMENT and diversification of Paleozoic Pleurotomariacea reached a climax in the Permian. Because of the rarity of fossil gastropods above middle Guadalupian horizons, we cannot yet complete the story of the Permian pleurotomarians. However, we can speculate from the known conditions found in the west Texas Permian that there was a progressive reduction of available ecologic situations during the Permian period. Thus many species with restricted environmental tolerances became extinct and were not subsequently represented in the much more restricted assemblages of the Triassic. Some attention is given here to variation and development of species, perhaps suggestive of adaptive radiation or differentiation during the early Permian.

One of the most interesting features of the Permian pleurotomarians is the great amount of variation within the genera and species. This may be related to adaptive response to great environmental changes characteristic of the Permian. These changes appeared gradually. The history of the region began with stable shelf seas and presumably stable ecological conditions of the early Permian Hueco and Wolfcamp formations of west Texas and the various Wolfcampian deposits of north central Texas. From late Wolfcampian upward these stable conditions were gradually replaced by more varied conditions associated with reef development. These environments included shore zones, lagoonal areas, reef and forereef zones, and stagnant basin environments.

Many species are restricted to particular facies; others are widespread and found in several different sedimentary environments. Many of the species are known only locally. Very possibly they originated in small local populations. Some of these later became widespread, presumably as their particular ecologic position widened geographically. For example, *Tapinotomaria rugosa* is known only from the Bone Spring in the Sierra Diablo area and is not known in other areas of Permian outcrop below upper Leonard. *Tapinotomaria globosa*, on the other hand, apparently had a wide ecological tolerance and is

widespread even in the Wolfcampian, the time of presumed origin. The known geographic range of this species is from the Glass Mountains to Arizona in a variety of facies including conglomerates, shales, and limestones. However, this is a limited distribution compared with that of modern marine gastropods. *Tapinotomaria crassa* also is widespread but had a more restricted environmental range, if lithologic facies can be used as a rough indication of environment. *Tapinotomaria mirabilis*, *T. submirabilis*, and *T. pyramidalis* are known only from local areas. These three species have reduced ranges of variation compared with those of other known members of the genus and apparently were short lived.

The adaptation of these organisms to the specialized and perhaps unstable conditions of the Permian might well have caused "chain reactions" leading to adaptive radiation or eruptive evolution. The pleurotomarians reflect this reaction by a sudden rise in taxonomic diversity during the early and middle Permian.

The family Phymatopleuridae contains several genera which seem to have been stable throughout the Pennsylvanian with little specific differentiation. *Glyptotomaria* (*Dictyotomaria*) and *Glyptotomaria* (*Glyptotomaria*) are known from single species throughout the Pennsylvanian. *Glyptotomaria* (*Dictyotomaria*) is not known above the Pennsylvanian, but *G. (Glyptotomaria)* is represented in the Permian by two variable species, one having a highly specialized ecological status. *Discotomaria*, which is derived from *Glyptotomaria*, is known from a single specimen in the upper Pennsylvanian, but in the Permian, five variable species appeared. Three of the Pennsylvanian genera of this family (*Phymatopleura*, *Paragoniozona*, and *Borestus*) are unknown above the middle Wolfcampian. Representatives of these genera have been collected only from shales. Their extinction may have been coincident with the reduction of the area of mud sedimentation (p. 164 and fig. 6).

Variability among genera and species of some of the Permian pleurotomarian families may have been associated with ecological

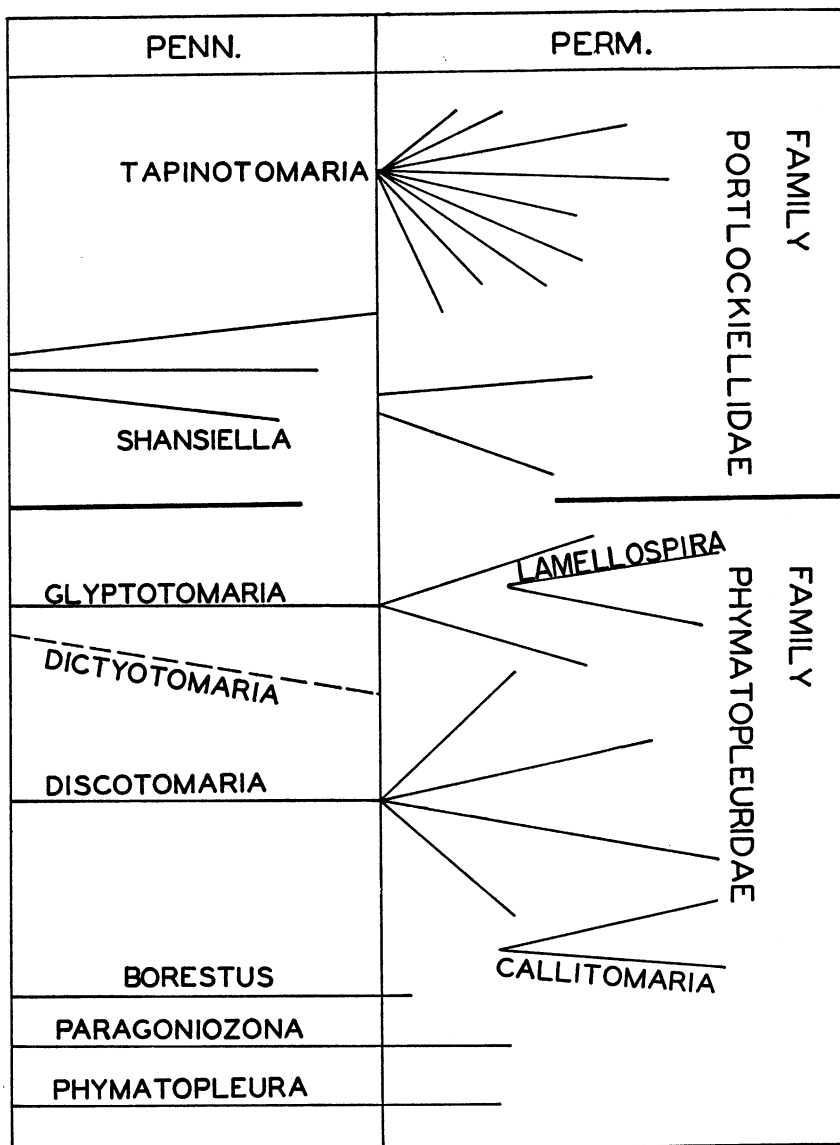


FIG. 6. Permian speciation in the families Portlockiellidae and Phymatopleuridae.

changes. *Tapinotomaria costata* may serve as an example of variation which appears to have changed progressively. It also serves to illustrate small progressive changes leading to taxonomic differentiation. When fossil species are dealt with, mutational effects can be considered in only the most general way, as we are able to observe only a small portion of the phenotypic characteristics. The assumption is made that phenotypic variation

is correlated with genotypic variation (see Simpson, 1953, p. 61).

In *T. costata* there are three major groups which might be considered to be of subspecific rank for purposes of discussion (see p. 196). *Tapinotomaria costata* group 1 first appeared in upper Wolfcampian and persisted until the end of deposition of Word limestone number 1. It is rather variable in all populations found. Sometime during the upper Leonard-



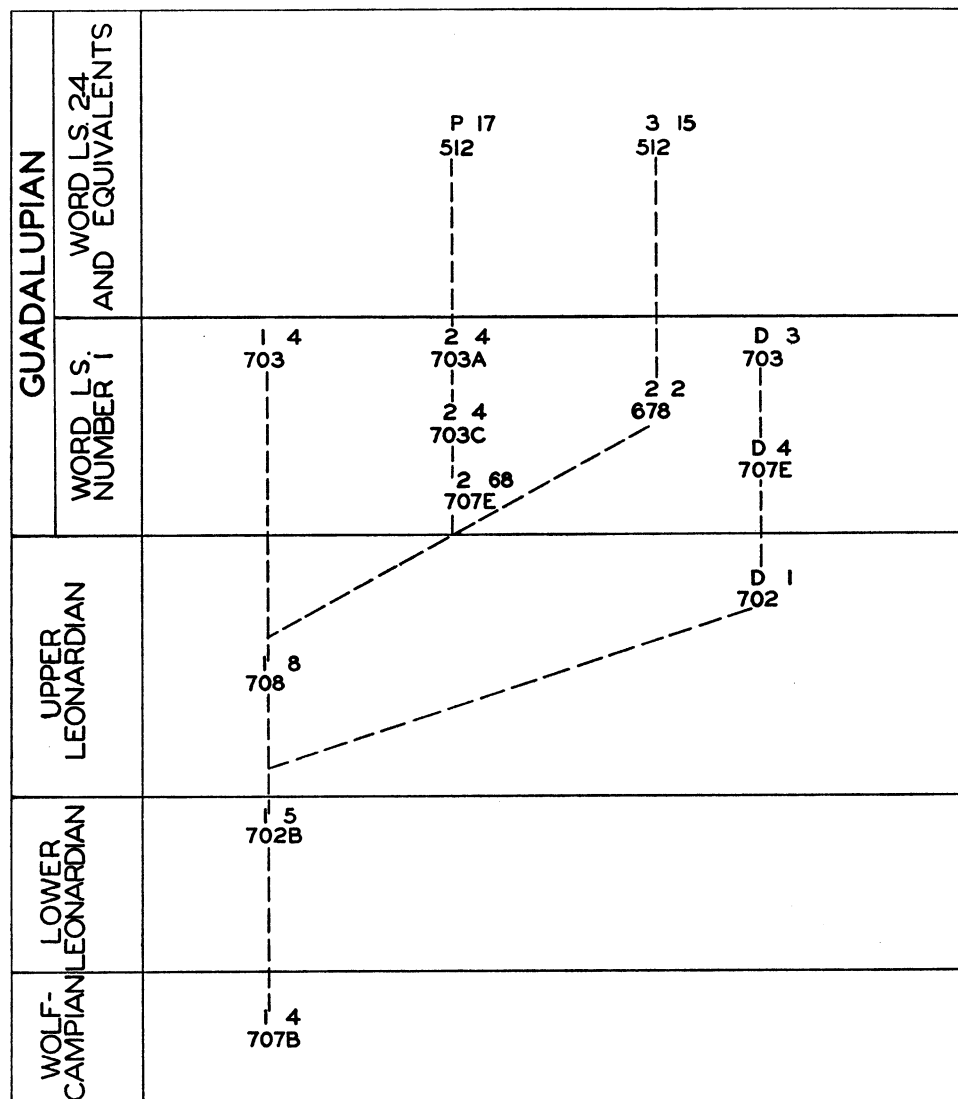


FIG. 7. Chart showing the development of three species of *Tapinotomaria*. Abbreviations: 1, 2, 3, symbols of the three major variant groups of *T. costata*; P, *T. pyramidalis*; D, *T. duplicostata*. The number under each symbol indicates the locality where the species are found and the numbers to the right side of the symbol are the numbers of the specimens. The scale is not in proportion to time.

ian *T. duplicostata* arose from this group by loss of collabral ornament. In all other characters observable the two are almost identical except that the collections of *T. duplicostata* show very little variation. The species is known from rocks of the late Leonardian and Word limestone number 1. I interpret this to indicate that a small genetic modification caused loss of collabral ornamentation, giv-

ing rise to the development of this species from *T. costata* group 1.

Group 2 of *T. costata* is also highly variable but is short lived, lasting only during the deposition of Word limestone number 1. There is only slight overlap in the ranges of variation of *T. costata* groups 1 and 2, and it might be interpreted that group 2 was periodically isolated from group 1 or occupied a

separate ecological niche. Group 2 probably contained the important materials used for differentiation of group 3 and another new species, *T. pyramidalis*. While groups 1 and 2 display much variation, *T. duplicostata* and *T. pyramidalis* and group 3 of *T. costata* are rather stable in having small ranges of variation and are short lived. The most striking trend within this species is the gradual development of a heavy, reticulate first major cord (see p. 196), which reaches its maximum development in group 3 and in *T. pyramidalis* (see fig. 7).

In *T. crassa* there is also a large amount of variation, but this variation appears to be less directional than in *T. costata*. There are two major variants, one group having a single cord above the first major cord, and the other group with two cords above the first. Each of these groups seems to have characters that vary in a different manner so that each appears to have a different range of variation. These groups have been found at the same locality but also occur in separate localities. There is a third group which is poorly represented and has a much more narrow range of variation. This third group is characterized by a more rounded whorl profile and a reticulate base; both characters are minor, but separating. These three groups may have been intermittently isolated from one another, but they probably represent a lower stage of differentiation than the three groups of *T. costata*. The characters that are the most highly variable in *T. crassa* seem to have become fixed in the three species *T. coronata*, *T. submirabilis*, and *T. mirabilis*, which were possibly derived from it.

By late Leonardian time, the six species of *Tapinotomaria* cited above had differentiated from the two Wolfcampian species. As the number of available ecological niches increased during the Leonardian with increase in reef development, the evolutionary rate was stepped up. These ecologic changes may have caused an unbalanced gene pool in which those populations having high variability and high adaptability were more successful in meeting these sweeping environmental changes.

Another example of directional variation, a trend within a species, is exhibited by *T. rugosa*. The most obvious and highly variable

character of the genus *Tapinotomaria* is the gap or width between the first major cord above the selenizone and that next above it. This gap, in most species, is greater than the distance between any two other cords above the selenizone. In the Wolfcampian both *T. globosa* and *T. rugosa* have equally spaced cords, including the spacing between the first major cord and that next above. By early Leonardian *T. rugosa* displayed some changes in this gap, and by late Leonardian it had increased and was quite pronounced. *Tapinotomaria costata* and *T. crassa*, presumed to have been derived from this species, not only show a greatly expanded gap but also great variation in the dimensions of this feature. Species thought to have been derived from *T. costata* and *T. crassa* (*T. duplicostata*, *T. pyramidalis*, *T. coronata*, *T. submirabilis*, and *T. mirabilis*) are all short lived and exhibit little variation in the distance between the first and second cord or any other character, which indicates that perhaps this gap was firmly fixed in the genotype and finally stabilized (see fig. 8).

One of the more striking trends is that found in *Shwedagonia elegans*. In the late Wolfcampian this species is characterized by having a very large body whorl, but the earlier whorls are very much smaller in proportionate volume. This gives the appearance of an almost planispirally coiled gastropod with a very short, sharp spire (see pl. 39, fig. 3). The sides of the shell are deeply concave. By late Leonardian time, the volume change between the whorls was not so great and the spire was higher but the sides were still concave. In the Wordian, the populations contained exclusively straight-sided forms. The volumes of the whorls are evenly proportionate, and the spire is much higher than in older forms. The chronocline is formed by the gradual lengthening of the axis of coiling caused by a gradual tendency of the axial spiral angle to be more constant.

In conclusion, "eruptive evolution" of the pleurotomarians in the Permian is not uniform in all groups. Some Pennsylvanian species extended into the Permian where they became extinct, perhaps because of narrowness of adaptive range which prohibited them from shifting with a changing environment. Other Pennsylvanian and early Permian species seem to have served as "character pools,"



which provided the needed materials for differentiation into descendent species (fig. 6).

It is recognized that large mutations may have occurred, but this does not seem to be expressed in the phenotypes, at least in those characters thought to be of significance. Most derived species, in the collections studied, were produced by modification and elaboration of characters that already existed in the ancestral stock. It is believed that increased variability characteristic of so many Permian pleurotomarian species represents increased adaptive instability over the species in the Pennsylvanian and that this instability was accompanied by an increase in evolutionary rates.

In this study it was observed that in some cases an increase in variation was accompanied by an increase in rates of speciation. Whether or not this was exactly simultaneous or if one or the other was antecedent is not known. In other cases, however, high variability, as in *Euconospira pulchra*, new species, has not led to observed speciation.

It is naturally expected that most taxonomic groups will display much variation and exhibit evolutionary trends during a period of taxonomic diversity, but this has not previously been demonstrated for upper Paleozoic pleurotomarians. The genus *Tapinotomaria*, and particularly *T. costata*, illustrates gradual phyletic speciation.

## SYSTEMATIC PALEONTOLOGY

### SUPERFAMILY PLEUROTOMARIACEA SWAINSON, 1940

THE PLEUROTOMARIANS were first recognized as a family in 1841 by d'Orbigny. He included four genera, three of which were described from Paleozoic rocks. During the latter half of the nineteenth century, many species were described, but most were placed within a single, all-inclusive genus, *Pleurotomaria*. In spite of this ultraconservative trend, when Ulrich and Scofield published their great "Lower Silurian gastropods of Minnesota" in 1897 there were some 41 Paleozoic genera placed in four families. Two of these families, the Trochidae and Euomphalidae, have since been removed from among the pleurotomarians. Ulrich and Scofield (1897, p. 930) raised the pleurotomarians to the status of a suborder (equivalent to the category of super-

family of current taxonomy), calling the unit Eotomacea. At present, 118 genera and subgenera are recognized from the Paleozoic. These are classified in 14 families, 16 subfamilies, and three tribes (Knight, Batten, and Yochelson, MS). The graph (fig. 9) indicates the total number of pleurotomarian genera known from each geologic series and the number of genera that first appear in each geological system.

The single most important feature of the group is the anal emargination with its various associated characters, such as the sinus, slit, notch, selenizone, or selenizone margin of the shell. The anal emargination is extremely variable in both shape and depth, ranging from a primitively broad and shallow sinus, which may occupy as much as half of the area of the outer lip, to a very narrow

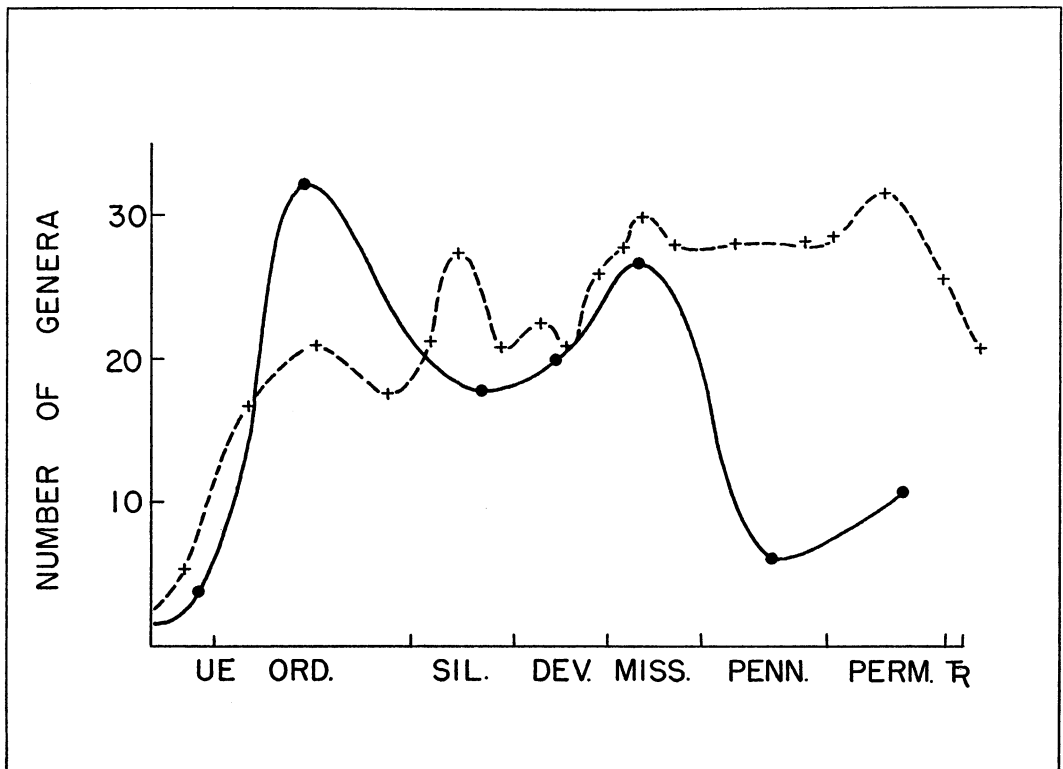


FIG. 9. Graph showing rate of origination of Paleozoic Pleurotomariacea. Solid line represents number of genera originating per period. Dashed line represents total number of genera per series. Time scale from Kay, 1951.

slit which may be almost a complete whorl in depth. The anal emargination is considered to be important, as it gives an approximation of the placement of such anatomical features as the anal and ctenidial complexes when the organism was alive. It is the most significant feature of the shell and can be used as a point of reference for measurements of whorl characters.

The selenizone which traces the position of the emargination in the completed stages on the shell also exhibits a wide range of variation. The selenizone may be externally concave, flat, or convex in section; it may be either deeply recessed beneath the surface of the shell, with overgrowths of the margins concealing a portion of it, or raised on a keel. Lunulae or spiral threads commonly ornament the selenizone.

The accumulated experience of all students indicates that the selenizone and associated characters of pleurotomarians are of greater importance for discrimination of species and genera than height, width, or other gross features. On the family level the position of the selenizone on the whorl, umbilical characters, basal features, shell shape, and shell layers on a more generalized basis seem to be important. There is so much variation between groups and within groups that it is difficult to make any generalization regarding what is or is not an important or significant character for classification or discrimination. In some genera (*Tapinotomaria* and *Callitomaria*) the selenizone is important in the differentiation of species and even exhibits considerable variation within populations. Certain characters, such as the nature of the parietal surface and columella, are usually significant on the generic level. Details of ornament, general shape, and characters of the shell base are most likely to be of specific significance.

Most of the Permian genera, which are also known from older horizons in the fossil record, are first found in the Mississippian. A few (seven) of the genera included in this study apparently originated in the Pennsylvanian. This number may be increased, however, when the Pennsylvanian forms are better known. Even if incomplete knowledge of Pennsylvanian pleurotomarians be discounted, there probably was a real decrease in rate of

origin of pleurotomarian genera during that period.

By far the greatest number of genera in the Permian first appear in Wolfcampian and Leonardian rocks. It must be borne in mind, however, that known younger Permian deposits (Guadalupian, Ochoan) rarely contain well-preserved gastropods. Thus, although origin rates for the later Permian show a marked decrease as the Triassic boundary is approached, this probably is greatly exaggerated by the deficiencies of the record.

Many pleurotomarian lines of descent became quite diverse and variable in the Permian, including some that seem to have been quite stable during a long pre-Permian history. A sweeping generalization cannot be derived from this, however, as there are others that continued with greater amounts of variation and still others that originated and became extinct during the Permian with development of few species.

#### FAMILY PORTLOCKIELLIDAE BATTEN, 1956

**DESCRIPTION:** Genera of this family are characterized by dominant, usually rather coarse spiral ornament, and a selenizone low on the whorls. The shell shape is globose to turreted. Moderately spaced collabral elements tend to form rounded to elongated nodes at the intersections with spiral ridges. The protoconch is simple and ornamented by a few rather fine spiral threads. The selenizone is usually concave, rather strongly bordered, and always rather low on the whorl. Ornament on the parietal surface area is either resorbed or covered by a very thin inductura. The columellar lip is reflexed and is either vertical or forms a sharp angle with the lower lip.

**DISCUSSION:** The selenizone varies in width, but is of moderate proportions compared to the total height of the whorl. The slit is only a shallow notch. Lunulae vary in intensity depending on the development of collabral ornament. This ornament varies from rather closely spaced growth lines to widely spaced rugae or costae. In the latter case, large spines may develop at the intersections with spiral elements (see *Tapinotomaria mirabilis*, p. 200).

The earliest known genus of the family is



*Agniesella* Cossmann, 1909, from the lower Devonian. It was not until the Mississippian that the family became well established with the appearance of *Portlockiella* Knight, 1945, ranging from the lower Mississippian through a portion of the Pennsylvanian, and *Shansiella* Yin, 1932, ranging from Mississippian through Wolfcampian. Representatives of this family in the United States National Museum collections show little variation either between or within species until the early Permian when several species of *Shansiella* appeared almost simultaneously. In earliest Wolfcampian, *Tapinotomaria* first appears, and from there on through the Guadalupian developed nine separate species exhibiting a wide range of variation in many characters.

The family apparently became extinct at the end of Permian time, as there is no record in the Triassic of any species that can be assigned to this group. I have examined several excellent undescribed lower Triassic faunas in the collections of the United States Geological Survey from Kuiu Island, Alaska. Although other families of Paleozoic pleurotomarians are represented among the material, there are no genera assignable to this group.

RANGE: Lower Devonian to Permian.

#### TAPINOTOMARIA BATTEN, 1956

TYPE SPECIES: *Tapinotomaria rugosa* Batten, 1956.

DIAGNOSIS: Trochiform pleurotomarians with rounded to step-like whorls, dominant spiral costae separated by concave interspaces and a flat to concave selenizone low on whorls; whorls inflated, shape dependent on development of costae; whorls in contact just below lower margin of selenizone; outer lip gently opisthocline from suture to selenizone margin, except for an abrupt increase in angle near selenizone; gently prosocline from lower selenizone margin to umbilicus; selenizone formed by a very shallow slit or notch and a relatively narrow sinus; selenizone margin defined by a thread, separated from first spiral element above by a shallow depression; spiral ornament above and below selenizone; commonly with a large gap between first major cord and that next above greater than between any other spiral element; lunulae formed by growth lines, threads, or cords;

collabral ornament usually present and may be strongly developed; base flat to rounded, anomphalous or minutely phaneromphalous columellar lip vertical in most cases, slightly reflexed; parietal lip with inductura thin or absent and ornament resorbed; a series of nodes present on first cords about the umbilicus; outer shell layer variable in thickness.

DISCUSSION: *Tapinotomaria* is distinguished from *Portlockiella* Knight, 1945 and *Shansiella* Yin, 1932, by a more turreted shell shape, slightly more impressed sutures, a wider selenizone in proportion to the whorl profile, a deflected lower lip, a thinner parietal inductura, a variable character complex about the selenizone, and more strongly developed collabral elements. *Portlockiella* and *Shansiella* rarely have collabral ornament stronger than very light threads and these may be confined to the uppermost portion of the whorl where nodes may form at the intersections of revolving cords. Neither genus has prominent elements clustered about the selenizone.

Several undescribed species of *Phymatopleura* Girty, 1939, have some characters that resemble those of this genus, particularly in the basic ornament pattern and in the selenizone region. One of these species from the Wann shale of Oklahoma resembles *T. pyramidalis* and *T. costata* in the development of collabral and spiral ornament above the selenizone and in the reticulate pattern found on the first major cord and the base. It differs from *Tapinotomaria* in having a characteristically more acute angle of the columellar lip with the base. The selenizone of this *Phymatopleura* is much wider and higher on the whorl than in species of *Tapinotomaria* and gives a much more flattened appearance to the almost vertical whorl face on which it is located (see pl. 36, fig. 18).

*Borestus* Thomas, 1940, and *Callitomaria* Batten, 1956, have a similar dominant spiral ornament. The shapes are quite similar to the shape in *Tapinotomaria*, but their flat to convex selenizones are placed higher on the whorls and are located in the central portion of vertical whorl faces. They differ further in having deeper slits and wider selenizones.

Each of the species of *Tapinotomaria* exhibits a wide range of variation in many characters. A statistical analysis was made

of some of these characters, in an attempt to determine which were statistically most significant. Standard tests of comparison were used (see p. 173). Results of this analysis show that the distance between the upper edge of the selenizone and suture and the distance between the first major spiral cord and the next above it (SS and CS, respectively) appear to be more important than height and width, as these two characters show the greatest variation and are closely correlated with other qualitative features used to separate species. Essentially these qualitative features are the distribution, shape, and number of spiral elements above the selenizone.

The earliest known species of this genus, *T. globosa*, is found in the lower Wolfcamp shales in the eastern Glass Mountains of Texas. It closely resembles some of the species of *Portlockiella* in having dominant spiral ornament with rather light collabral lirae. Spiral cords are evenly distributed both above and below the selenizone, with little individual variation. The Leonardian species, *T. globosa*, shows some degree of individual variation, which is best seen in the number and size of cords above the selenizone. There is a further tendency for the distance between the first major cord and that next above to be increased. *Tapinotomaria rugosa*, probably derived from this species during the early Leonardian, displays a more pronounced variation in the CS character. By middle and late Leonardian, *T. crassa*, presumed to have had its origin in *T. rugosa*, reached the ultimate in variation of the character CS. This is reflected in the variable shell shape and whorl profile of individuals of the species, and by the appearance of clusters of variants within the species.

There are two principal lines of development in *Tapinotomaria*. One line tends in time to stabilize cord placement above the selenizone, to reduce the number of cords, to have a greater amount of variation in the character CS, and to develop stronger ornament, especially by a heavy accent on collabral ornament. This is the line of *T. globosa*, *T. rugosa*, *T. crassa*, *T. submirabilis*, *T. mirabilis*, and *T. coronata*.

A second line displays a trend to reduce the number of cords above the selenizone to only the first major cord and one other cord

which is coincidental with the upper edge of the whorl. The first major cord, in time, gradually becomes larger and more ornate. Most variation is involved with the number, placement, and emphasis of spiral threads in the area between the upper edge of the whorl and the first major cord. This group is represented by *T. costata*, *T. duplicosta*, and *T. pyramidalis*. The line is believed to have been derived from *T. rugosa* sometime during the lower Leonardian.

There seems to be a second trend within this group to develop a thin outer edge on the aperture, separated from the interior of the shell by a groove. This condition is caused by retardation in secretion of the inner shell layer. In the earliest member of this line, *T. costata*, this condition is found only in the columellar lip, but in *T. pyramidalis* it is found completely around the aperture except in the region of the parietal lip. Collabral ornament is rather variable in this lineage, ranging from growth lines only to threads which form nodes with revolving ornament.

RANGE: Lower Wolfcampian to middle Guadalupian; found in west Texas and New Mexico. Thus far, the genus is represented elsewhere by only a doubtful specimen of *T. globosa* from the Apache limestone of northern Arizona.

***Tapinotomaria globosa* Batten, new species**

Plate 32, figures 1-11

DESCRIPTION: The shell is characterized by globular whorls with four or five well-developed and rounded cords above the first major cord. The first major cord is about as well developed as the other spiral elements above the selenizone. The cords above the selenizone are generally braided by numerous and evenly spaced collabral threads which form elongated nodes. These nodes are reinforced if there is a series of spiral threads on the cords (see pl. 32, fig. 8). There may be a well-developed interspace between the selenizone margin and the first major cord, or between the first major cord and that next above, but in most specimens the tendency seems to be for even spacing of the cords. The selenizone may contain a bisecting thread. Lunulae are generally formed by collabral threads, but in some cases may be formed by growth lines alone. The base is well rounded.

Nine to 13 basal spiral cords are present and are pronounced compared to collabral ornament, but are not so heavy as the cords above the selenizone. Most shells are minutely phaneromphalous. The columellar lip is well reflexed and tends to flare outward at or near its juncture with the lower lip. The columellar lip is more strongly reflexed than in other members of the genus. The shell is moderately thick, and the two layers appear to be about equally well developed.

cantly (on 5% level) different from other species of the genus. This same result was obtained by the use of a dispersion test based on the reduced major axis (see p. 173). *Tapinotomaria rugosa* is most closely related to *T. globosa* and most easily confused with it.

Variations of several characters are found within a single population and in populations from different horizons, but these seem to be without pattern. These character variations are: increase and refinement of spiral orna-

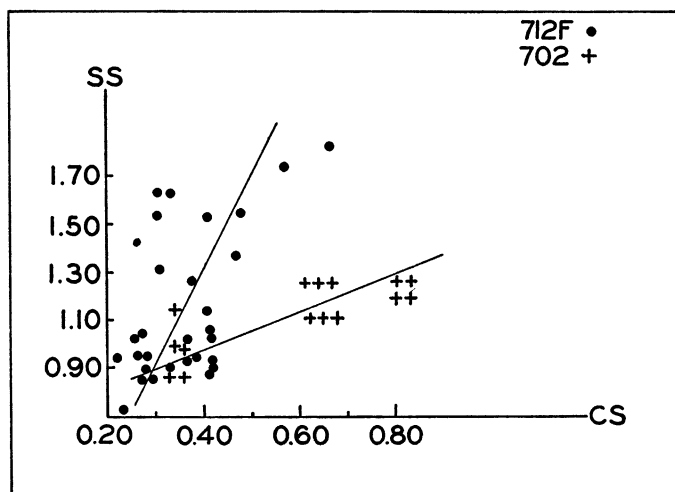


FIG. 10. Scattergram of the characters SS and CS of two samples of *Tapinotomaria globosa* from an earlier and a later horizon. No significance is here attached to the difference in the lines of relative growth. Forms from U.S.N.M. 702 (upper Leonard) tend to increase the distance between the first major cord and that next above at a faster rate in relation to the distance between the suture and selenizone than does the population from U.S.N.M. 712f (middle Hueco).

**DISCUSSION:** Some of the more rounded specimens of *T. crassa* and *T. rugosa* somewhat resemble this species, but their ornament is markedly different, having fewer and sharper spiral cords. *Tapinotomaria globosa* rarely has the large interspace between the first major cord and the next cord above as in these two species.

*Tapinotomaria globosa* has more phaneromphalous individuals than other species of the genus. A statistical study of the quantitative characters SS, CS, and SW was made, and differences in sample means were tested for significance. The statistical conclusions indicate that this species is highly and signifi-

cantly (usually found in populations in the uppermost Leonard), change of width of the umbilicus, and variation in the distribution of spiral cords above the selenizone. These variations are shown, in part, in figure 10. There may be a trend for the distance between the first major cord and the next cord above to be reduced, but more specimens from the Word formation are needed for study.

Correlation coefficients of the characters SS and CS and H and W are 0.637 and 0.96, respectively.

**RANGE:** Lower Wolfcampian to middle Guadalupian.

TABLE 1  
MEASUREMENTS (IN MILLIMETERS) OF *Tapinotomaria globosa* BATTEN, NEW SPECIES

Locality	H	W	SS	CS	CA	CB	SW
U.S.N.M. 702	5.02	5.49	0.94	0.47	4	10	0.47
U.S.N.M. 702	3.77	4.08	0.78	0.31	4	10	0.31
U.S.N.M. 702	5.96	5.96	—	—	4	10	—
U.S.N.M. 702	5.18	5.18	1.10	0.48	4	—	0.47
U.S.N.M. 702	5.96	5.96	1.10	0.47	4	9	0.63
U.S.N.M. 702	5.18	5.34	0.94	0.31	5	10	0.47
U.S.N.M. 702	4.71	4.87	1.26	0.47	5	11	0.31
U.S.N.M. 702	6.59	6.90	1.26	0.47	5	9	0.47
U.S.N.M. 702	5.49	5.49	1.10	0.63	5	9	0.47
U.S.N.M. 702	—	5.18	0.94	0.63	5	11	0.47
U.S.N.M. 702	—	6.13	1.10	0.47	5	9	0.47
U.S.N.M. 702	6.59	6.75	1.26	0.47	5	9	0.47
U.S.N.M. 702	5.65	6.13	1.10	0.47	5	11	0.47
U.S.N.M. 702	4.39	4.24	0.94	0.31	5	9	0.31
U.S.N.M. 702	5.65	5.40	—	—	5	10	—
U.S.N.M. 702	5.18	5.49	1.10	0.31	5	—	0.31
U.S.N.M. 702	5.34	5.49	1.10	0.47	5	—	0.47
U.S.N.M. 702	5.65	5.49	—	—	5	—	—
U.S.N.M. 702	5.18	5.02	—	—	5	—	—
U.S.N.M. 702	4.08	4.40	0.78	0.31	5	11	0.31
U.S.N.M. 702	3.61	4.08	0.78	0.31	5	10	0.47
U.S.N.M. 702	5.49	5.96	1.10	0.47	5	10	0.47
U.S.N.M. 702	6.91	6.44	1.26	0.63	4	9	0.47
U.S.N.M. 702	5.49	5.49	1.10	0.63	4	9	0.47
U.S.N.M. 702	7.69	7.22	1.57	0.63	5	9	0.47
U.S.N.M. 702c	4.55	4.72	—	—	—	—	—
U.S.N.M. 703c	7.23	7.07	1.26	0.63	4	7	0.63
U.S.N.M. 703c	5.49	5.34	0.94	0.31	5	9	0.31
U.S.N.M. 703a	4.87	5.03	—	—	—	—	—
A.M.N.H. 504	4.90	4.98	1.42	0.56	4	9	0.31
A.M.N.H. 504	4.90	4.98	1.26	0.41	5	10	0.31
A.M.N.H. 504	4.46	4.46	1.10	0.24	4	10	0.41
A.M.N.H. 504	4.96	4.96	1.26	0.31	5	9	0.24
A.M.N.H. 504	5.48	5.48	1.42	0.41	5	13	0.47
A.M.N.H. 512b	5.78	5.78	1.42	0.68	5	11	0.47
A.M.N.H. 512b	5.20	5.28	1.42	0.56	6	12	0.47
A.M.N.H. 512	5.64	5.64	1.34	0.31	5	12	0.56
A.M.N.H. 512	3.74	3.88	0.90	0.24	5	11	0.41
A.M.N.H. 512	4.84	4.84	1.10	0.41	5	11	0.41
A.M.N.H. 512	3.74	4.04	0.94	0.41	4	12	0.24
A.M.N.H. 512	5.48	5.42	1.34	0.47	5	11	0.41
A.M.N.H. 512	4.46	4.60	1.34	0.41	4	10	0.31
A.M.N.H. 503	5.64	5.64	1.42	0.41	4	10	0.47
Total	124.76	138.18	22.61	9.71	—	—	9.23
$\bar{x}$	5.42	5.53	1.08	0.46	—	—	0.44
S.D.	0.968	0.828	0.180	0.118	—	—	0.0806
S.E. (m)	0.198	0.033	0.039	0.026	—	—	0.017
N	23	25	21	21	—	—	21

**OCCURRENCE:** The hypodigm includes 128 specimens listed below: U.S.N.M. 702, 52; U.S.N.M. 712, 15; U.S.N.M. 708, two; U.S.N.M. 702un, one; U.S.N.M. 703b, five; U.S.N.M. 703a and A.M.N.H. 504, 19; A.M.N.H. 503, four; A.M.N.H. 512, 25; and U.S.N.M. 728, five.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133277b; figured paratypes, U.S.N.M. Nos. 133274, 133275, 133276, 133277a, 133278a, 133228b, A.M.N.H. No. 28047:1.

***Tapinotomaria rugosa* Batten, 1956**

Plate 32, figures 12-23

*Tapinotomaria rugosa* BATTEN, 1956, p. 42.

**DESCRIPTION:** The general shell shape of most specimens of this species is much like that of the modern gastropod *Calliostoma* Swainson, 1840, with a well-developed cord located near the periphery. The whorl profile is even and gently convex down to the selenizone. The first major cord is separated from the selenizone margin by a sharp, narrow trough. It is rather large compared to other spiral elements and has heavy elongate nodes which are developed at the intersections with collabral elements. When this cord is exceptionally wide there may be a series of spiral threads on the central portion which interfere with the nodes, causing a further thickening at the points of contact (see pl. 32, fig. 12). There is usually a gap between the first major cord and the next cord above it. There are from four to six spiral noded cords, which vary in their degree of pronouncement, above the first major cord. The collabral ornament above the selenizone is generally weaker, but in some cases may be equally well developed. Basal collabral ornament is rather pronounced and may form a reticulate pattern with the spiral elements. There are from four to 14 basal spiral costae. Most individuals are anomphalous, but some are minutely phaneromphalous. The shell is moderately thick, with the outer layer seemingly somewhat thicker than in other members of the genus.

**DISCUSSION:** The only other species having more than three principal cords above the selenizone is *T. globosa*, which has a more rounded whorl profile and a less well-developed first major cord. The distance be-

tween the first major cord and the next above is much greater in *T. rugosa*. *Tapinotomaria rugosa* has rounded to pointed nodes at intersections of collabral and spiral elements above the selenizone, while *T. globosa* has a braided type of node.

The *t* test for difference in mean of SS and CS for these two species, as well as the characters H and W, shows a significant difference (5% level) between two samples. The coefficient of difference for the characters mentioned above shows less than 25 per cent of overlap.

The character CS shows the greatest amount of variation in *T. rugosa* and is correlated with the character SS. This is reflected in the correlation coefficient (0.688). It appears that individuals from older beds tend to have a greater CS than those in younger beds. Another rather variable character is the degree of emphasis of ornament above the selenizone. This causes some change in the whorl profile and shell shape among individuals. Interference nodes may be simple and rounded or elongated and composed of smaller nodes that result from a grouping of finer spiral threads placed on spiral cords or costae.

**RANGE:** This species seems to be restricted to the Leonard series.

**OCCURRENCE:** The hypodigm is composed of 31 specimens found at the following localities: A.M.N.H. 369, one; A.M.N.H. 369a, two; P.U. 3, six; U.S.N.M. 702d, nine; U.S.N.M. 702e, six; U.S.N.M. 702ent, one; U.S.N.M. 702, four; U.S.N.M. 703, one; U.S.N.M. 703a, one.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 125281; figured paratypes, U.S.N.M. Nos. 133348a, 133348b, 1333280, 133281, 133282a, 133282b, and 133283.

***Tapinotomaria crassa* Batten, new species**

Plate 33

**DESCRIPTION:** This species characteristically has from two to four spiral cords above the first major cord. Generally the first major cord is located rather close to the selenizone margin but is separated from it by a relatively narrow trough. This cord is considered to be a part of the character complex of the shell associated with, but marginal to, the

TABLE 2  
MEASUREMENTS (IN MILLIMETERS) OF *Tapinotomaria rugosa* BATTEN

Locality	H	W	SS	CS	SW	CB	SR
U.S.N.M. 702	6.12	3.92	1.41	0.31	0.47	9	—
U.S.N.M. 702	6.28	4.71	1.57	0.47	0.47	8	—
U.S.N.M. 702	—	3.90	1.10	0.31	0.31	11	—
U.S.N.M. 702ent	5.49	4.24	1.41	—	0.31	—	—
U.S.N.M. 702d	5.97	5.49	1.41	0.63	0.47	7	—
U.S.N.M. 702d	6.44	5.34	1.10	0.63	0.31	8	—
U.S.N.M. 702d	6.91	5.18	—	—	—	8	—
U.S.N.M. 702d	8.32	6.91	—	—	—	7	—
U.S.N.M. 702d	6.28	5.65	1.26	0.63	0.47	8	—
U.S.N.M. 702d	6.90	5.96	1.57	0.63	0.47	8	—
U.S.N.M. 702d	5.18	4.86	—	—	—	—	—
U.S.N.M. 702d	5.65	4.39	1.57	0.78	0.47	7	—
U.S.N.M. 702e	8.63	7.54	2.50	1.10	0.47	8	—
U.S.N.M. 702e	7.38	6.75	1.57	0.94	0.47	7	—
U.S.N.M. 702e	9.58	8.16	2.20	1.10	0.63	7	—
U.S.N.M. 703a	4.40	4.46	1.26	0.31	0.31	9	—
U.S.N.M. 703	5.02	4.87	1.10	—	0.31	—	—
U.S.N.M. 703	8.16	6.76	1.57	0.31	0.47	8	—
U.S.N.M. 703	6.13	5.96	1.10	—	0.47	8	—
A.M.N.H. 369	4.76	4.46	1.26	—	0.31	5	2.22
A.M.N.H. 369	5.78	5.20	1.20	—	0.31	—	—
A.M.N.H. 369	5.20	4.60	1.26	—	0.24	5	2.14
A.M.N.H. 369	5.34	5.04	1.12	—	—	5	2.08
A.M.N.H. 369	5.34	4.32	1.12	—	—	—	—
A.M.N.H. 369	4.68	4.02	1.12	—	—	4	2.03
A.M.N.H. 369	4.46	4.02	0.90	—	0.24	4	2.12
A.M.N.H. 369	3.00	2.86	—	—	—	4	2.32
A.M.N.H. 369	2.72	2.72	—	—	—	4	2.32
A.M.N.H. 369	3.14	3.00	—	—	—	4	—
A.M.N.H. 369	2.42	2.28	—	—	—	4	2.28
A.M.N.H. 369	3.14	2.86	0.86	—	—	—	1.84
A.M.N.H. 369	7.36	6.06	1.56	0.84	0.24	4	2.16
A.M.N.H. 369	8.68	6.06	—	—	—	—	—
A.M.N.H. 369	6.80	5.34	1.42	—	—	—	1.86
A.M.N.H. 369	6.36	5.92	1.26	0.54	0.31	4	1.87
A.M.N.H. 369	6.36	5.20	1.26	—	0.24	4	2.13
A.M.N.H. 369	5.78	4.90	1.23	0.52	—	4	2.04
A.M.N.H. 369	4.90	4.02	—	—	—	—	2.10
A.M.N.H. 369	4.04	3.44	—	—	—	—	—
$\bar{x}$	5.01	4.31	1.15	—	—	—	2.08
S.D.	1.64	1.17	0.24	—	—	—	0.152
S.E. (m)	0.36	0.26	0.06	—	—	—	0.04
N	20	20	14	—	—	—	14



selenizone. It is relatively stable in its position in comparison with the remaining spiral cords above. The next cord above the first major cord is variable in its position but usually is separated from the first major cord by a rather large gap, greater than the distance between any other two cords. The only other spiral ornament above the selenizone is an occasional weak thread near the suture. Col-labral ornament above the selenizone consists

of equally spaced cords which vary directly in their intensity and spacing. Almost without exception nodes are formed at intersections with spiral elements. There are from six to eight well-developed basal spiral cords, if the cord adjacent to the selenizone margin, which acts as a counterpart to the first major cord above, be excluded. The upper first major cord tends to be more fully developed than the lower cord, except in several speci-

TABLE 3  
MEASUREMENTS (IN MILLIMETERS) FROM A SAMPLE OF *Tapinotomaria crassa* BATTEN, NEW SPECIES, FROM U.S.N.M. 702

	H	W	SS	CS	SW	CA	CB	Type
	10.68	9.11	2.04	—	0.78	3	8	1
	9.73	8.32	1.72	—	0.78	3	7	1
	9.73	9.11	1.88	—	0.94	3	7	1
	10.20	9.76	1.88	—	0.78	3	7	1
	8.32	8.17	1.41	1.10	0.78	2	6	2
	9.58	9.43	1.72	1.10	0.78	3	6	2
	7.57	7.85	1.41	0.78	0.78	2	—	2
	6.91	5.97	1.10	0.63	0.47	3	6	2
	6.28	6.59	1.57	—	—	—	—	1
	7.23	6.13	1.26	—	0.47	3	7	1
	5.96	6.28	1.10	0.63	0.63	3	7	1
	10.36	8.79	1.57	0.78	0.78	3	7	1
	10.52	8.79	1.88	0.78	0.78	3	8	1
	9.42	8.63	1.57	0.98	0.78	3	7	1
	6.28	5.81	1.10	0.63	0.47	3	6	1
	10.36	8.63	1.57	0.94	0.63	3	6	1
	8.79	8.16	1.41	0.78	0.63	3	7	1
	10.68	10.36	1.88	0.63	0.94	3	7	1
	10.68	9.58	1.88	0.78	0.94	3	8	1
	8.63	7.54	1.26	0.47	0.63	3	7	1
	10.36	9.11	1.57	0.78	0.78	3	7	1
	9.89	8.63	2.04	0.63	0.78	3	—	1
	8.33	8.17	1.57	0.78	0.94	2	8	1
	9.73	10.05	1.88	1.26	0.94	3	8	2
	8.48	8.17	1.41	0.78	0.78	2	6	2
	7.06	6.91	0.94	0.78	0.63	2	7	2
	10.05	10.36	2.04	1.10	0.94	2	7	2
	7.06	7.38	1.26	0.78	0.63	2	7	2
	11.30	10.68	1.26	1.26	0.94	2	7	2
	9.11	8.63	1.71	1.26	0.78	2	7	2
	10.35	9.73	1.88	1.26	0.94	2	6	2
	7.85	7.35	1.10	0.78	0.78	2	7	2
	10.21	9.11	2.04	1.41	0.78	2	7	2
	7.85	7.38	1.41	0.78	0.63	2	7	2
$\bar{x}$	8.99	8.37	1.57	0.88	0.76			
S.D.	1.51	1.31	0.102	0.23	0.141			
S.E. (m)	0.26	0.22	0.175	0.043	0.0245			
N	34	34	34	29	33			

mens found in the Word limestone number 1. The outer layer normally is poorly preserved in silicified material, but appears to be thinner than the inner shell layer.

**DISCUSSION:** This species is rather variable in whorl profile owing to change in emphasis and position of spiral cords above the selenizone. This variation is due to the change in distance between the first major cord and the next above it, accompanied by a change in intensity of ornament depending on the relative development of secondary ornament. Spiral elements may be very sharp, with weakly developed nodes, or rounded owing to thickening between well-developed nodes.

In the Leonard formation at U.S.N.M. 702, where the largest single collection of specimens was made, three general types or groups of phenotypic variants can be recognized. Group 1 generally has a single prominent cord above the first major cord, with a smaller cord or thread near the suture. The distance between the first major cord and that next above (CS) is very large, and the whorl above this dominant cord is much less steep than the almost vertical outer whorl face beneath it (see pl. 33, fig. 4). This arrangement gives a step-like whorl profile. The lower first major cord of this group is less well developed than in group 2 at this locality, but becomes larger in the beds above.

Group 2 has two prominent cords above the first major cord and usually has a smaller cord or thread located near the suture. The cords are evenly spaced, and the CS is of moderate proportions. The whorl profile, as a result, is somewhat more rounded (see pl. 33, fig. 15).

Group 3 is quite similar to group 2, but the basal collabral ornament is strengthened to form a reticulate pattern and the spiral ornament above the selenizone is less pronounced, which gives the impression of a more globose whorl. The spire of the shell is slightly higher and the outer shell layer appears to be thicker than in the other two groups (see pl. 33, fig. 19 and 20).

These variants fall within the range of a single species but can be readily separated qualitatively. These characters are "presence of or absence of" features; that is, they have either one or two cords above the first major cord. Accompanying characteristics and vari-

ations within each of these groups have led me to believe that these groups may occupy slightly different ecological positions, but may not have been separated for a sufficient time to have become genotypically isolated. This explanation is slightly reinforced by the fact that out of 13 localities from which this species is known, the variants are found together at only four. Groups 2 and 3 do not appear until the Leonardian; group 1 is found in the Wolfcampian (see fig. 11).

To test whether the population at U.S.N.M. 702 is homogeneous, the sample was analyzed as a single population and the statistics were determined for later use. The sample was then separated qualitatively into the two important variant groups for a more detailed study. As a single population, four characters (CS, SS, H, and W) were plotted as frequency distributions. It was found that the height and width were strongly skewed towards the larger sizes. The characters SS and CS were found to be bimodal. These characters are considered to be most significant quantitative features of the species, as they approximate most closely the changes in the distance between the first major cord and the next above. Results of the general statistical analysis did show a significant difference between the two groups, but the difference was not so great as was expected and certainly not great enough to indicate possible taxonomic separation (see fig. 12).

U.S.N.M. 702 of the upper Leonard formation includes mixed collections from a thickness of 300 feet of strata. The collections were made before the stratigraphic interval was thought to be significant, and it is suspected that several successive fossil populations have been mixed. One possible indication of mixing may be the extremely high coefficient of variation,

$$V = \frac{(100 \text{ S.D.})}{\bar{x}},$$

which is as high as 25.00 for the character CS, but may be as low as 1.49 for the height-width ratio. The coefficient of difference shows slightly less than 25 per cent of overlap for CS. The *t* test indicates a significant difference between the two groups for the characters SS and CS on the 1 per cent level of significance.

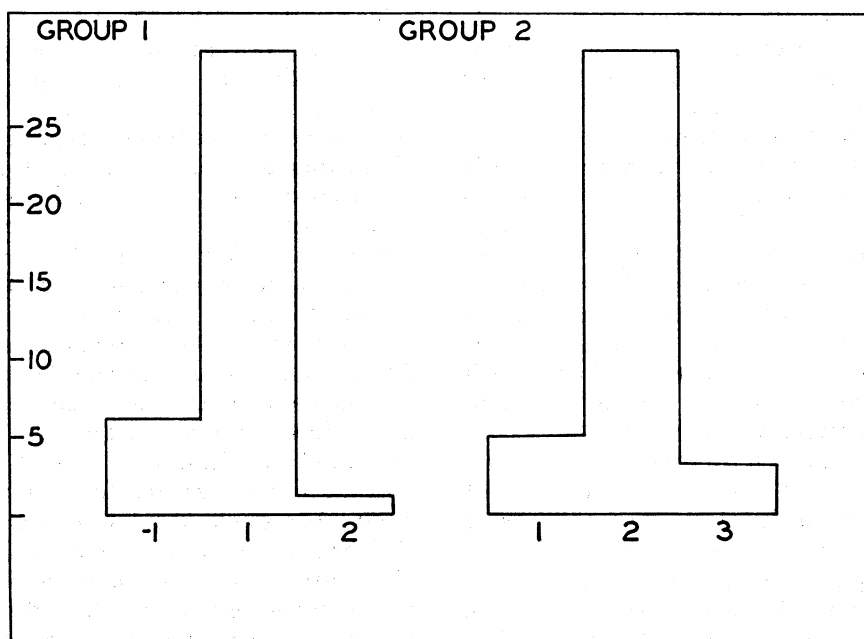


FIG. 11. Frequency diagram showing numbers of individuals of *Tapinotomaria crassa* having from one to three spiral cords above the selenizone. The number -1 to the left of the histogram of group 1 means that only a thread was developed above the selenizone.

Of the two known species of the genus found in older beds, *T. globosa* and *T. rugosa*, the latter might well have been the stock from which this species was derived, because throughout its development *T. rugosa* has a large CS whereas *T. globosa* has more or less evenly spaced cords. I suggest that *T. crassa* gave rise to *T. coronata* found in the beds of the Word limestone number 1. *Tapinotomaria coronata* from these beds has similar, but less strongly developed, spiral and collabral ornament and a rather well-developed lower first major cord. I also suggest that this species may have given rise to *T. costata*, based, in part, on the large CS and the step-like shape formed by the upper edge of the vertical whorl face.

**RANGE:** Uppermost Wolfcampian to uppermost Leonardian.

**OCCURRENCE:** The hypodigm includes 94 specimens. Group 1 is found at the following localities: U.S.N.M. 707d, three; U.S.N.M. 707b, one; P.U. 3, one; A.M.N.H. 433, three; U.S.N.M. 702, 27; U.S.N.M. 702un, two; U.S.N.M. 703, three; A.M.N.H. 624, two. Group 2 is found at the following localities:

A.M.N.H. 592, one; U.S.N.M. 702, 40; U.S.N.M. 703c, one; U.S.N.M. 703, two; U.S.N.M. 703a, one. Group 3 is found at the following localities: U.S.N.M. 702 (base of the upper Leonard), one; U.S.N.M. 702a, one; U.S.N.M. 702, three; U.S.N.M. 703a, two.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133284i; figured paratypes, U.S.N.M. Nos. 133284a-133284h, 133284j-133284l, 133285a-133285c, 133286, A.M.N.H. Nos. 28048:1, 28049:1.

#### *Tapinotomaria costata* Batten, new species

Plate 34, figures 1-14

**DESCRIPTION:** Representatives of this species have a step-like whorl profile formed by an almost horizontal, concave, or convex upper whorl surface and an almost vertical, flat to convex, outer whorl face. A noded thread near the suture has been observed in a few specimens. Commonly, there are one or more spiral threads just below the upper edge of the outer whorl surface. The upper edge is composed of several threads or a cord, but no

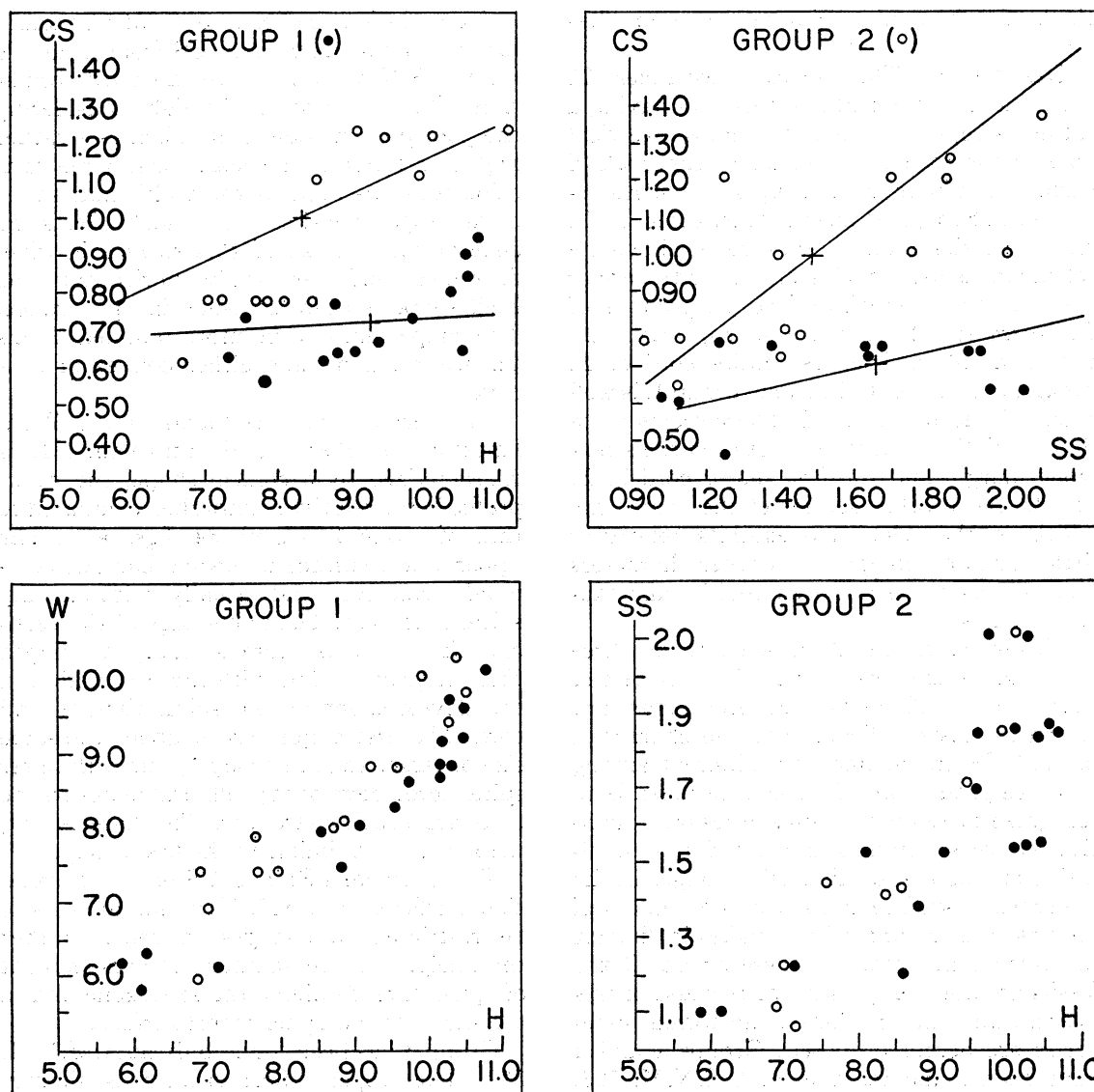


FIG. 12. Scattergrams of significant characters of *Tapinotomaria crassa* from a single sample each of groups 1 and 2 from U.S.N.M. 702, upper Leonard formation. Lines of relative growth estimated by visual means. Joint means are marked by a cross. Measurements are in millimeters.

other spiral ornament is found above the selenizone except for the first major cord, which is the most prominent feature on the shell. This cord may be very large, with a complex of equally spaced spiral threads on its outer surface. Elongated nodes on this cord are formed by collabral threads which may create reticulation with the spiral threads. The selenizone is concave and has a margin composed of a thread, and lunulae of

growth lines or light collabral threads. The lower first major cord resembles its counterpart above the selenizone but is not so well developed. Collabral ornament is formed by evenly and closely spaced threads, with some variation in degree of development. The flat or flatly rounded base has five or more dominant spiral cords, but in some cases collabral ornament may be equally strong, causing a reticulate pattern. The shell is relatively

thick. All known specimens are anomalous.

DISCUSSION: This species resembles *T. crassa*, and in particular group 1, in having a rather steeply inclined or almost vertical outer whorl face and a flattened upper whorl surface. It differs from group 1 in general ornament, shape, and apertural features. In *T. costata* a series of fine spiral threads above the selenizone is usually clustered near the upper edge of the outer whorl face. In group 1 of *T. crassa* spiral cords are sharp, large, and few in number. The first major cord of *T. costata*, in contrast to *T. crassa* group 1, is well rounded and ornamented. There seems to be little variation in distance between the selenizone margin and the first major cord in *T. costata*. As in other species of the genus, the width of the selenizone exhibits relatively little variation compared to other characters and as a result has not been used in quantitative studies.

Within *T. costata* there seem to be three recognizable clusters of variations. A test of correlation coefficients and other standard statistical tests indicate that the characters SS and CS are significantly different among all three groups, and it would be possible to recognize these units as subspecies on a quantitative basis. There is some overlap in qualitative characters, particularly changes in the upper whorl surface and size and ornament of the first major cord, which makes it difficult to discriminate between these groups if the fossils are not well preserved. Because of this overlap and intergradation, no formal categories are herein proposed. Groups 1 and 2 have been found together at U.S.N.M. 703, which prevents the use of the category subspecies.

The first group has been found in the lower and upper Leonard formation and Word limestone number 1. The over-all size of the specimens is larger than in the other two groups. The whorl profile is almost rectangular in outline (see pl. 34, figs. 1-3), and there is a wide, flat, or gently concave upper whorl surface. The upper edge of the outer whorl surface may be formed by one or more threads. The first major cord is relatively small, with elongated collabral nodes and occasional spiral threads. The base is flatly rounded.

A correlation coefficient of 0.956 was found for the characters SS and CS from a sample from U.S.N.M. 702, upper Leonard formation. This is exceptionally high, considering the poor preservation, and indicates a rather high correlation of the characters. Some variation was observed in the width and shape of the upper whorl surface, which affects the general shell shape. If this surface is wide, flattened, and essentially horizontal, the shell shape is quite step-like in appearance. The shape tends to be more rounded if this surface is narrow and either convex or concave.

The second group is found in the Word limestone number 1 and equivalents. It is characterized by a conical shape, the whorl profile being relatively unbroken compared to that of group 1 (see pl. 34, figs. 4-7). The upper whorl surface is always narrow, commonly concave, and usually without any spiral ornament. The upper edge of the vertical whorl face is more strongly developed than in group 1, but with more variation in the development of the spiral threads and cord. The first major cord is about the same size or larger than in group 1, but with fewer spiral cords developed; collabral nodes on the cord are usually stronger. The base is flat, with ornament similar to the first group.

The characters SS and CS have a correlation coefficient of 0.887. Variation appears to be restricted to changes in width, rather than height, in the number and arrangement of spiral threads above the selenizone and in the shape of the upper whorl surface.

Group 3 has been found only at A.M.N.H. 512. The upper whorl surface is slightly wider than in group 2 and is either flattened or convex (see pl. 34, figs. 8-14). The upper edge is well developed, with three to six spiral threads reticulated with collabral elements. The first major cord is much larger than in the other two groups and has from four to 10 spiral threads equally distributed on the outer surface. There are from seven to 13 spiral cords on the flatly rounded base. These cords are variable in development, and there may be secondary intercalated threads. The parietal lip is unornamented owing to resorption. The edge of the aperture is thin, but there is a thickening on the lower and inner lips just behind the edge. A groove is

TABLE 4  
MEASUREMENTS (IN MILLIMETERS) OF *Tapinotomaria costata* BATTEN,  
NEW SPECIES

(Each locality is a sample from groups 1 to 3, respectively.)

Locality	H	W	SS	CS	SW
U.S.N.M. 702	10.13	10.13	2.90	1.74	1.01
U.S.N.M. 702	8.13	7.83	2.19	1.45	0.94
U.S.N.M. 702	—	—	2.10	1.45	0.94
U.S.N.M. 702	—	—	2.18	1.45	0.65
U.S.N.M. 702	7.24	7.54	2.18	1.30	0.72
U.S.N.M. 702	6.10	5.51	1.60	1.01	0.65
U.S.N.M. 702	7.11	6.38	1.81	1.16	0.58
U.S.N.M. 702	—	—	1.81	1.16	0.72
U.S.N.M. 702	—	—	1.81	1.16	0.65
U.S.N.M. 707e	6.32	6.06	1.60	0.87	0.51
U.S.N.M. 707e	6.82	6.23	1.60	1.01	0.51
U.S.N.M. 707e	6.53	6.53	1.52	1.01	0.51
U.S.N.M. 707e	5.51	6.96	1.30	0.87	0.51
U.S.N.M. 707e	5.94	6.08	1.38	0.87	0.51
U.S.N.M. 707e	5.51	6.08	1.38	0.94	0.51
U.S.N.M. 707e	6.53	6.82	1.60	1.16	0.55
U.S.N.M. 707e	7.54	7.10	1.74	1.23	0.51
U.S.N.M. 707e	6.82	6.67	1.88	1.16	0.43
U.S.N.M. 707e	6.23	6.67	1.45	1.01	0.58
U.S.N.M. 707e	5.79	6.38	1.67	1.01	0.51
U.S.N.M. 707e	6.38	6.53	1.60	1.01	0.51
U.S.N.M. 707e	6.08	6.08	1.52	0.94	0.58
U.S.N.M. 707e	6.23	5.78	1.60	1.01	0.51
U.S.N.M. 707e	5.79	5.79	1.45	0.87	0.48
U.S.N.M. 707e	5.08	5.79	1.16	0.72	0.51
U.S.N.M. 707e	5.94	5.66	1.52	0.80	0.58
U.S.N.M. 707e	5.08	5.23	1.16	0.72	0.37
U.S.N.M. 707e	5.51	5.23	1.30	0.80	0.43
U.S.N.M. 707e	5.08	5.23	1.30	0.87	0.37
U.S.N.M. 707e	5.37	4.93	1.30	0.72	0.43
U.S.N.M. 707e	5.23	5.66	1.16	0.80	0.43
U.S.N.M. 707e	4.34	4.64	1.23	0.72	0.43
U.S.N.M. 707e	4.06	3.91	1.08	0.58	0.37
U.S.N.M. 707e	4.06	4.21	0.94	0.58	0.29
A.M.N.H. 512	7.39	7.24	1.96	1.16	0.55
A.M.N.H. 512	4.64	4.78	1.30	0.72	0.37
A.M.N.H. 512	6.08	5.79	1.38	0.72	0.43
A.M.N.H. 512	5.37	5.23	1.60	0.87	0.43
A.M.N.H. 512	5.65	5.65	1.45	0.87	0.65
A.M.N.H. 512	6.08	5.94	1.60	0.80	0.43
A.M.N.H. 512	5.51	5.65	1.67	0.80	0.51
A.M.N.H. 512	8.42	7.98	2.02	1.23	0.65
A.M.N.H. 512	4.64	5.08	1.16	0.72	0.43
A.M.N.H. 512	6.67	6.38	1.45	1.01	0.51
A.M.N.H. 512	6.38	6.08	1.45	0.87	0.58
A.M.N.H. 512	5.51	5.79	1.38	0.72	0.43
A.M.N.H. 512	7.83	7.68	2.18	1.30	0.51
A.M.N.H. 512	5.37	5.65	1.23	0.72	0.43
A.M.N.H. 512	6.67	6.67	1.88	1.00	0.43

formed between the edge of the aperture in this area and the thickened portion. The correlation coefficient for the two significant characters SS and CS is 0.904. The suture ratios have an over-all average of 1.867, which is very high. This group is quite similar to *T. pyramidalis* in its basic ornament pattern and first major cord, but differs in having a shoulder. The outer apertural margin of *T. pyramidalis* is thin, but thickens abruptly inward, much as in group 3.

No trends were observed within the three groups. The much enlarged first major cord

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133290a; figured paratypes, U.S.N.M. Nos. 133287a, 133287b, 133288, 133289, 133290b, A.M.N.H. Nos. 28050:1, 28050:2, 28050:3, and 28060:1.

*Tapinotomaria duplicostata* Batten, new species

Plate 34, figures 15-16

DESCRIPTION: Representatives of this species have a step-like whorl profile formed by a relatively narrow, flattened, upper whorl surface and an almost vertical whorl face.

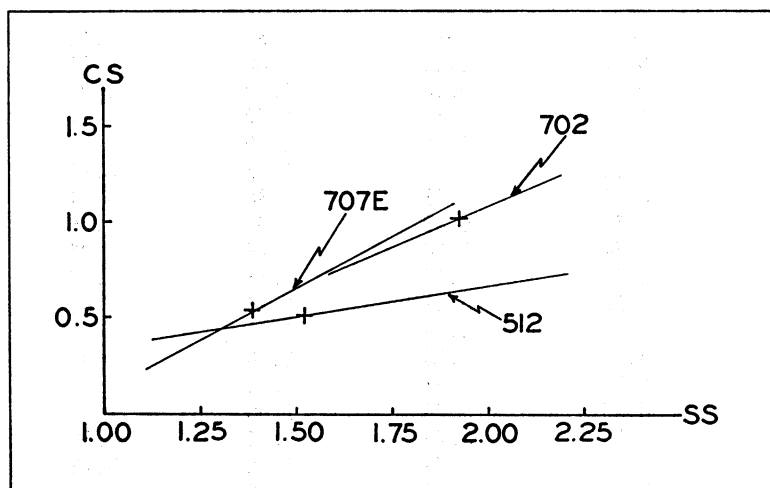


FIG. 13. Growth lines and means for a sample from each of the three groups of *Tapinotomaria costata*.

above and below the selenizone in the fossils from A.M.N.H. 512, compared to that in other groups, may be indicative of gradual enlargement of this feature, in time, but this cannot be substantiated. Growth lines of the groups are shown in figure 13.

RANGE: Leonardian through Guadalupian.

OCCURRENCE: The hypodigm includes 110 specimens listed below: Group 1 is found at the following localities: U.S.N.M. 707b, four; U.S.N.M. 702b, five; U.S.N.M. 702, eight; U.S.N.M. 703, four fragments. Specimens from group 2 have been found at the following localities: U.S.N.M. 707e, 60; U.S.N.M. 703c, two; A.M.N.H. 509, eight; A.M.N.H. 503, two; A.M.N.H. 678, two. Group 3 is found in the Getaway formation from a single locality, A.M.N.H. 512, and is represented by 15 specimens.

The upper edge of the outer whorl face is formed by one or more spiral threads. There is a single thread located just below this upper edge, which, like the other spiral ornament, varies in intensity. The first major cord is much like that of *T. costata*, but not so rounded and without nodes. The selenizone is concave, and the lunulae are formed by growth lines alone. The base is flat or flatly rounded, with about five spiral cords. With the exception of growth lines, there is no collabral ornament.

DISCUSSION: The step-like shape and the arrangement of spiral elements above the selenizone and on the base are similar to those of group 2 of *T. costata* from Word limestone number 1 or equivalent beds. *Tapinotomaria duplicostata* differs principally in the absence of collabral ornament. Generally, the



upper whorl surface in this species is narrower than in *T. costata*. There is in *T. duplicostata* some variation in the intensity of spiral ornament above the selenizone. There appears to be little intergradation, even though the two groups are superficially much alike.

RANGE: Upper Leonardian (including Word limestone number 1).

OCCURRENCE: The hypodigm includes the eight specimens listed: U.S.N.M. 702, one; U.S.N.M. 703, two; U.S.N.M. 707e, four; A.M.N.H. 503, one.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133291.

*Tapinotomaria pyramidalis* Batten, new species

Plate 35, figures 6–11

DESCRIPTION: This species characteristically has a semi-globose whorl profile and a simple shell shape. The sutures are sharply incised, and the whorl surface above the selenizone is convex and without any spiral cords other than the first major cord. There are from five to 18 spiral threads above a gap that separates them from the first major cord. The first major cord is broad, rounded, and with from five to 12 spiral threads which intersect the fine collabral threads, forming a reticulate pattern. The concave to flat selenizone may have a median thread. Lunulae are composed of growth lines and collabral threads. If the first lower major cord is weak or absent, the outer whorl face beneath the selenizone may conform to the surface of the flatly rounded base. Five or more closely spaced spiral threads may act as a border of the shell under the selenizone in lieu of the first lower major cord. Eight or nine basal spiral cords may be separated by about 25 intercalated threads. The apertural margin is grooved except in the parietal lip (see pl. 35, fig. 7).

DISCUSSION: This species is distinguished from *T. costata* by the lack of an upper edge of the outer whorl face and by a smooth, convex whorl profile. Spiral threads above the selenizone are fairly equally distributed over the surface, except for a gap between the lowest spiral thread and the first major cord and by a slight decrease in spacing of the threads near the suture. The absence of a well-defined lower first major cord and a flattened upper

TABLE 5

MEASUREMENTS (IN MILLIMETERS) OF  
*Tapinotomaria pyramidalis* BATTEN,  
NEW SPECIES, FROM A.M.N.H. 512

	W	H	SS	SW
	3.96	4.18	1.00	0.32
	4.10	4.40	1.12	0.32
	4.46	4.46	1.06	0.32
	4.76	5.20	1.12	0.54
	5.42	5.34	1.34	0.32
	8.46	7.52	2.12	0.62
	6.94	6.64	1.70	0.40
	8.40	7.47	2.00	0.68
	7.22	7.66	2.28	0.68
	10.28	9.68	—	—
	7.52	7.38	1.06	0.76
	5.48	5.34	1.28	0.32
	7.52	7.02	2.78	0.40
	6.14	5.78	1.48	0.46
	4.32	4.46	1.12	0.40
	6.94	6.64	1.84	0.54
	8.10	7.60	2.00	0.46
$\bar{x}$	6.41	6.23	1.62	0.45
S.D.	1.87	1.58	0.54	0.13
S.E. ( <i>m</i> )	0.49	0.39	0.14	0.34
N	16	16	15	15

whorl surface serves to separate this species from other members of the genus. *Tapinotomaria globosa* has a much more rounded whorl profile and a fairly heavy, noded set of cords above the selenizone. The shell layers are thicker in *T. pyramidalis*, and the aperture, instead of gradually thinning, abruptly ends in a groove at the edge of the aperture. This groove could have served as a guide for an operculum, but this is only an assumption. Ornament in this species is much finer than in other species, with the exception of *T. duplicostata*, which has no collabral ornament at all.

Variation in *T. pyramidalis* includes changes in the width of the first major cord, width and convexity of the selenizone, and changes in number and distribution of spiral threads. There is also some variation in roundness of the whorl profile with some forms slightly less globose, owing to flattened bases or slightly higher spires. I suggest that this species may have been derived from *T. costata*.

RANGE: Lower Guadalupian.

OCCURRENCE: The hypodigm consists of 17 specimens: A.M.N.H. 512, 10; U.S.N.M. 728, seven.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133294; figured paratypes, A.M.N.H. Nos. 28051:1, 28051:2, 28051:3.

***Tapinotomaria mirabilis* Batten, new species**

Plate 34, figures 17–19

DESCRIPTION: This species characteristically has a shape similar to that of *T. coronata* but is modified by two rows of spines. These spines are formed by the intersection of collabral cords with the first major cord and the single spiral cord above it. Concave flanges between spines are formed by a lateral thickening of spiral ornament and strengthened by collabral cords. These flanges are concave in the areas bounded by spines and the outer thickened edge of the flange. Collabral elements above the selenizone are well developed, but thin, between spiral ornament (see pl. 34, fig. 17). Collabral cords terminate at the bottom of the first major cord. A weakly developed, extremely narrow gap separates the first major cord from the selenizone. Lunulae are composed of growth lines alone. Basal collabral ornament is represented by growth lines or light threads. The shell is relatively thick compared to that of other species of the genus. Apertural features are unknown with the exception of the outer lip, which may be inferred from the growth lines. Basal spiral ornament consists of a few well-developed cords.

DISCUSSION: This remarkable species is the extreme member of a series of variations of ornament above the selenizone in this genus. The species is known from five broken specimens, and it must be hoped that future collecting will furnish more material for study. *Tapinotomaria submirabilis* is closely related to this species and has a single cord above the first major cord. It does not have spines, as does *T. mirabilis*, but does have cup-shaped collabral ornament.

RANGE: Upper Leonardian.

OCCURRENCE: U.S.N.M. 702, four; U.S.N.M. 708u, one.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133292.

***Tapinotomaria submirabilis* Batten, new species**

Plate 34, figures 20–21; plate 35, figures 1–5

DESCRIPTION: This species is characterized by a single, centrally located spiral cord above the first major cord. There is no other spiral ornament, except a thread near the suture. Collabral ornament above the selenizone is represented by growth lines and cords. Where these cords intersect spiral elements, they may become cup-shaped nodes, open towards the aperture much as in the Recent species *Melongena coronata*, or they may develop short, hollow spines. The nodes, when present, resemble scalloping on the spiral cords (see pl. 35, figs. 2–3). There are from four to six cords on the base. Lunulae are composed of growth lines alone. Shells are not well preserved at the same localities that yield excellent material of other species, which suggests that the outer shell layer is thin.

DISCUSSION: Broad collabral elements or cup-shaped nodes serve to separate this species from other members of the genus. A portion of the extremely thin outer shell layer is present in the holotype specimen, which indicates a rather delicate type of collabral ornament. *Tapinotomaria mirabilis* resembles this species in placement of spiral ornament, but is readily distinguished by its intense collabral cords and spines.

It is possible that *T. mirabilis* and *T. submirabilis* were derived from *T. crassa*. This assumption is based partly on the presence of a single spiral element above the selenizone and partly on the heavy type of collabral ornament found in *T. crassa*, group 1. In the specimens known, variation seems to be limited to development of the spiral cords above the selenizone which affects general shell shape and variation in degree of intensity of collabral ornament.

RANGE: Uppermost Leonardian.

OCCURRENCE: U.S.N.M. 703, four.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133293a; figured paratypes, U.S.N.M. Nos. 133293b–133293d.

***Tapinotomaria coronata* Batten, new species**

Plate 35, figures 12–13

DESCRIPTION: The most characteristic feature of this species is the heavy develop-

ment of both collabral and spiral ornament above the selenizone, with collabral elements predominant. Two broad spiral cords above the first major cord are accentuated by spinose nodes formed by the intersection of collabral cords. There is an increase in number of these nodes by intercalation, which is particularly evident on the first major cord. This cord has predominantly elongate nodes, with spiral threads on the upper and outer surfaces. A sharp, narrow trough separates the selenizone margin from the first major cord. Lunulae are formed by growth lines and collabral cords. The upper slit boundary is longer than the lower boundary, because the flatly rounded base modifies the shape of the aperture. Six to nine basal spiral cords are sharply defined, forming a reticulate pattern, with numerous collabral threads. The columellar lip is angular and reflexed about the umbilicus, forming a depressed callosity. The lower lip is deflected in mature specimens, forming a slightly concave flange in the outer portion of the aperture. Basal ornament is almost completely resorbed in the parietal

lip. All known specimens are anomphalous.

**DISCUSSION:** This species was probably derived from *T. crassa*. One population of *T. crassa* from Word limestone number 1 has a rather heavy development of collabral and spiral ornament, a flatly rounded base, resorbed ornament in the parietal lip area, and an arrangement of spiral cords above the selenizone, all of which suggests affinities with this species (see pl. 33, fig. 3). *Tapinotomaria coronata* differs from *T. crassa* by having heavier ornament and a much more flattened and ornamented base.

The correlation coefficient for the characters SS and CS is 0.920 for 18 well-preserved specimens from A.M.N.H. 512. The coefficient of variation for height and width is 4.83. The *t* test for the character CS for *T. coronata*, compared to that for *T. crassa*, is 9.44, significant on the 5 per cent level. The coefficient of difference for the same samples indicates slightly more than 25 per cent of overlap. Thus discrimination tests seem to show a general pattern of significant differences between these two groups.

TABLE 6  
MEASUREMENTS (IN MILLIMETERS) OF *Tapinotomaria coronata* BATTEN, NEW SPECIES, FROM  
A.M.N.H. 512

	H	W	SS	CS	SW	CB	SR
	11.00	9.56	1.64	1.06	0.84	7	1.72
	10.06	9.34	1.70	1.06	0.68	7	1.82
	7.96	6.06	1.20	0.84	0.60	—	1.77
	6.64	6.22	1.06	0.68	0.50	7	1.80
	8.68	7.08	1.20	1.00	0.06	7	1.70
	9.26	9.34	1.26	0.84	0.68	9	1.57
	9.42	8.10	1.42	0.90	0.60	7	1.66
	10.72	9.42	1.42	1.12	0.68	8	1.57
	9.26	8.10	1.42	1.00	0.60	6	1.61
	10.72	9.56	1.42	1.00	0.60	9	1.67
	10.28	9.42	1.42	1.00	0.76	8	1.64
	9.34	7.88	1.34	0.84	0.68	—	1.74
	7.74	6.94	1.26	0.68	0.54	6	1.80
	11.16	9.62	2.00	1.26	0.90	7	1.83
	8.04	7.66	1.42	0.84	0.54	6	1.77
	8.40	7.44	1.42	0.76	0.54	6	1.76
	11.94	7.52	2.14	1.42	0.76	7	1.83
$\bar{x}$	9.37	8.19	1.44	0.95	0.65	—	1.72
S.D.	1.58	1.23	0.272	0.308	0.111	—	0.90
S.E.( <i>m</i> )	0.37	0.30	0.064	0.072	0.026	—	0.022
N	18	18	18	18	18	—	18

Changes in the intensity of collabral ornament above the selenizone and in the number of spiral elements on the base area are two of the more obvious variations observed.

RANGE: Guadalupian.

OCCURRENCE: The hypodigm consists of 28 specimens: A.M.N.H. 512, 25; U.S.N.M. 728, one; U.S.N.M. 706b, one; A.M.N.H. 364, one.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133295.

SHANSIELLA YIN, 1932

*Latischisma* THOMAS, 1940, p. 59, pl. 4, figs. 1a-c.

TYPE SPECIES: *Shansiella altispiralis* Yin, 1932.

DIAGNOSIS: Pleurotomarians with dominantly globose whorl profiles, moderately wide selenizones located about mid-whorl or slightly lower, and dominant spiral ornament; sutures sharp and relatively deep; protoconch simple; sutures in contact with whorls either at lower edge of outer whorl face, beneath selenizone or at mid-selenizone; selenizone convex, flat, or concave, with lunulae formed by growth lines or fine threads, commonly with a series of spiral threads grouped near its center; slit relatively shallow; spiral ornament fine or coarse threads both on base and above selenizone; collabral ornament, growth lines alone; columellar lip slightly reflexed, parietal lip with thin inductura; ornament may be impressed on inner shell layer; shell relatively thin; anomphalous or narrowly phaneromphalous.

DISCUSSION: The genus *Latischisma* Thomas, 1940, is here included as a synonym, as the type species, *L. globosus*, appears to have characters overlapping those found in species of *Shansiella*. In the past, these two genera have been separated primarily on the basis of the coarser ornament of *Shansiella* and finer ornament of *Latischisma*, but these two character complexes have been found to intergrade within a single species. Detail of ornament, therefore, is probably of specific rather than generic significance in this group. Several undescribed species from the American Pennsylvanian formerly placed in *Latischisma* have consistently finer ornament and a selenizone that appears to be different from that of known species of *Shansiella*. This apparent separation is due in part to rarity of

individuals. No large samples are available.

The two species from the Permian described below seem to fall into the range of characters generally associated by authors with *Latischisma*, rather than *Shansiella*. Both species are quite different from those found in the Pennsylvanian, having a globose shell and an elongated whorl profile, and lack broad nodes near the suture. Permian forms have a selenizone that is somewhat wider than that actually exposed on the exterior of the shell. The edges of the shell extend over both sides of the selenizone, hiding the margins. This feature was also observed in several specimens of an undescribed species from the Pennsylvanian of Indiana. Other species are not known to exhibit this characteristic. These Permian species may represent a new genus.

Some important specific characters in this genus are the relative development of ornament, shape and elevation of selenizone, and the shape of the whorl profile.

RANGE: Pennsylvanian to Permian.

*Shansiella tabulata* Batten, new species

Plate 35, figures 16, 19-20

DESCRIPTION: The whorl profile is rather elongated, but somewhat interrupted by a short and flat to concave upper whorl surface that extends from the suture almost horizontally to the upper edge of the outer whorl face. The upper whorl surface is variable in width; when it is narrow, the surface tends to be concave, and when wide, flat. Whorls are in contact at the lower edge of the outer whorl face below the selenizone. Several spiral threads are located on the upper whorl surface. About 10 spiral threads occur between the upper edge and the selenizone. In some cases, the upper edge of the outer whorl face may develop a cord so that the upper surface appears concave. Between the upper and lower edges, the outer whorl face is flat to convex and nearly vertical. The selenizone is very narrow and flat to gently concave, with no observed lunulae, but with three or four spiral lirae clustered near the center. It is slightly depressed beneath the surface of the whorl face, and its borders are formed by overlapping of the shell (see pl. 35, fig. 16). The base is flatly rounded and bears about 25 spiral threads between the lower

TABLE 7  
MEASUREMENTS (IN MILLIMETERS) OF *Shansiella tabulata* BATTEN, NEW SPECIES

Locality	H	W	SS	SW
U.S.G.S. 9802	4.35	4.27	1.23	0.29
U.S.G.S. 9802	6.96	6.24	1.52	0.40
U.S.G.S. 9802	6.24	5.36	1.38	0.36
U.S.G.S. 9802	6.81	5.94	1.67	0.22
U.S.G.S. 9802	6.81	6.53	1.74	0.43
U.S.G.S. 9802	7.10	6.09	1.52	0.43
U.S.G.S. 9802	5.44	5.08	1.23	0.36
U.S.G.S. 9802	6.74	6.30	1.60	0.36
U.S.G.S. 9802	9.71	7.97	2.02	0.43
Plummer 42-T-18	6.08	5.58	1.45	0.44

selenizone margin and the umbilicus. The columellar lip is thickened and slightly reflexed (see pl. 35, fig. 19). Most known specimens are anomphalous. Ornament is apparently resorbed in the parietal lip; parietal inductura is seemingly absent. Collabral ornament consists of growth lines alone.

DISCUSSION: Variation in this species seems to be confined to changes in the width of the upper whorl surface, number and position of spiral elements, and change in general shape of the whorl profile. This species has ornament similar to that of *S. planiscostata* Girty, 1937, but can be distinguished from that species by the shape of the whorl profile, which is angular rather than globose, and by the overlapping condition of the edges of the shell that border the selenizone.

RANGE: Wolfcampian.

OCCURRENCE: U.S.G.S. 9802, 19; U.S.G.S. 9861, 14; Plummer collection 42-T-18, five.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133298; figured paratype, U.S.N.M. No. 133299.

***Shansiella conica* Batten, new species**

Plate 35, figures 14, 15, 17, 18

DESCRIPTION: This species characteristically has a whorl shape that is gently concave about midway between the suture and the selenizone, then becomes convex, with the sharpest convexity at the lower edge of outer whorl face (see pl. 35, fig. 15). Whorls are in contact on this lower edge. Sutures are relatively shallow, but sharply impressed. The selenizone is located just below the lower edge of the outer whorl face and is flat or con-

vex, conforming to the general whorl surface. The slit is rather short. Lunulae are developed by growth lines alone. Ornament consists of from six to 10 spiral threads above the selenizone and 20 or more spiral threads on the base. A thin parietal inductura is present. The base is flatly rounded.

DISCUSSION: This species resembles *S. tabulata* in general shell shape and elongated whorl profile. *Shansiella conica* differs from *S. tabulata* in having a selenizone flush with the whorl surface and by having a more even whorl profile. In some silicified specimens, in which the outer shell layer has been removed, the selenizone may appear to be raised above the whorl surface (pl. 35, fig. 17). As the ornament is usually impressed on the inner shell layer, some caution should be exercised when silicified material is examined.

Within *S. conica* variation is limited to degree of coarseness of spiral elements and in the shape of the whorl profile.

RANGE: Wolfcampian.

OCCURRENCE: The hypodigm consists of 38 specimens: U.S.N.M. 712f, 30; U.S.G.S. 9861, eight.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133297a; figured paratypes, U.S.N.M. Nos. 133296 and 133297b.

**FAMILY PHYMATOPLEURIDAE BATTEN, 1956**

DESCRIPTION: Discoid to moderately high-spired pleurotomarians with a selenizone located at or above the periphery. The outer whorl face is usually vertical or sloping and

TABLE 8  
MEASUREMENTS (IN MILLIMETERS) OF A SAMPLE  
OF *Shansiella conica* BATTEN, NEW SPECIES,  
FROM U.S.N.M. 712F

	H	W	SS	SW
	4.35	3.26	0.94	0.29
	4.56	3.48	0.94	0.29
	3.91	3.05	0.87	0.33
	4.35	3.77	0.87	0.29
	3.19	3.12	0.65	0.21
	3.62	3.05	0.58	0.21
	3.34	2.76	0.51	0.21
	3.62	3.26	0.87	0.29
	3.05	2.32	0.58	0.21
	4.64	3.77	0.94	0.29
	4.35	3.48	0.87	0.29
	3.34	2.00	0.58	0.21
	4.26	3.34	0.80	0.21
	3.91	3.26	0.80	0.21
	3.65	3.12	—	—
	3.77	3.19	0.72	0.21
	4.06	3.41	—	—
	4.20	3.34	0.87	0.14
	3.91	3.05	0.87	0.29
	3.48	3.05	0.80	0.21
	3.61	3.12	0.87	0.14
	4.12	3.34	0.72	0.29
	3.77	2.90	0.72	0.29
	2.54	2.46	0.51	0.14
	3.48	2.90	0.72	0.21
	3.70	2.90	0.72	0.14
Total	98.78	80.70	18.32	5.60
$\bar{x}$	3.80	3.10	0.76	0.23
S.D.	0.5012	0.401	0.136	0.057
S.E. (m)	0.098	0.078	0.028	0.012
N	26	26	24	24

may be rather narrow compared to the upper whorl surface. The selenizone is convex to concave and is either heavily ornamented by spiral and collabral elements or by growth lines alone. The selenizone almost always has a well-defined border and is either depressed or flush with the outer whorl face. Spiral ornament is usually dominant. Collabral elements may be of secondary importance, and reticulation is common. The base is generally flat, but may vary from rounded to deeply concave. There may be two basal sinuses, one on the base near the periphery and one on the columellar lip. The parietal lip has a thin

inductural layer; ornament is generally resorbed. The shell is usually moderately thick. Umbilicus from anomphalous to widely phaneromphalous.

DISCUSSION: The generic characters thought to be important in this family involve the selenizone and associated shell features. The selenizone varies considerably from narrow and quite concave, as in some species of *Discotomaria*, to wide and flat or convex, as in *Callitomaria*. The height of spire is important on the generic level, as well as the intensity and distribution of primary ornament. In the species of the *Glyptotomaria-Discotomaria* complex, the shape of the collabral elements on the base, which partly determines the shape of the lower portion of the aperture, is exceedingly important.

The family is first known in the Mississippian by the presence of *Borestus* Thomas, 1940, and *Glyptotomaria* Knight, 1945.

*Borestus* has a step-like whorl profile with an almost vertical outer whorl face. The selenizone is located in the center of this face. *Glyptotomaria* (*Dictyotomaria*) Knight, 1945, in the Mississippian is characterized by inflated, semi-globose whorls with a narrow selenizone placed in the center of the whorl.

*Glyptotomaria* (*Glyptotomaria*) Knight, 1945, was probably derived from *G. (Dictyotomaria)* during the Pennsylvanian. By late Pennsylvanian and early Permian times there was an expansion of existing genera and the introduction of new genera. *Callitomaria* seems to have been developed from a stock having characters suggestive of *Borestus*. *Discotomaria* was most probably derived from *Glyptotomaria*, as was *Lamellospira*.

*Phymatopleura* Girty, 1939, and *Paragoniozona* Nelson, 1947, display characters similar to those of the *Glyptotomaria-Discotomaria* complex.

The family apparently continues into the Triassic, represented by an undescribed genus from Triassic beds of Kiuhu Island, Alaska.

#### PHYMATOPLEURA GIRTY, 1939

TYPE SPECIES: *Orestes nodosus* Girty (1912, p. 137).

SYNONYM: *Orestes* Girty, 1912, not Redtenbacher, 1906.

DISCUSSION: The generic name *Orestes* is a

suppressed objective synonym of *Phymatopleura* Girty (1939, p. 31). No attempt is made to redefine or diagnose this genus, because nothing further can be added to the current concept of it.

***Phymatopleura brazoensis* (Shumard)**

Plate 36, figure 16

*Pleurotomaria brazoensis* SHUMARD, 1860, p. 624.

*Orestes brazoensis* (Shumard), GIRTY, 1915, p. 156, pl. 22, fig. 16.

*Phymatopleura brazoensis* (Shumard), GIRTY, 1939, p. 33, pl. 28, figs. 20a and b.

*Phymatopleura brazoensis* (Shumard), KNIGHT, 1944, in Shimer and Shrock, p. 455, pl. 183, figs. 35-37.

**DESCRIPTION:** This species is characterized by a conical shell shape, with the sides of the cone slightly concave. Early whorls are plain and normally coiled. The whorl profile consists of an outer whorl face which extends from the suture down to the angular periphery, this periphery serving as the lower selenizone margin. The whorls are in contact either just below the angular periphery, or where the periphery begins to turn towards the base. There are six to eight spiral cords above the concave selenizone. The selenizone is bordered by cords which have spiral threads intersecting collabral elements and forming a reticulate pattern. There is a noded median thread on the selenizone. These nodes and the lunulae are formed by collabral cords. The basal surface is concavo-convex from the periphery to the umbilicus. Eleven spiral costae on the base are more strongly developed than the collabral elements.

**DISCUSSION:** This species is represented in the available collections by a single specimen. It is fairly common in the Pennsylvanian shales in the Glass Mountains region and occurs as high as the "*Uddenites*" zone, just beneath the Wolfcamp formation (see p. 162). As far as I have been able to determine, this genus seems to be restricted to shale facies such as those of the Pennsylvanian Gaptank, Finis, Graham, and Wewoka formations of the mid-continent area. Thus it is not surprising to find it represented in the Wolfcamp argillaceous shales. This specimen falls within the range of variation of populations of the Pennsylvanian.

The measurements are: W, 6.82 mm.; SW, 0.43 mm.; SS, 1.30 mm.; CS, 0.43 mm.

OCCURRENCE: U.S.N.M. 712.

CATALOGUED SPECIMEN: Hypotype, U.S.N.M. No. 133302.

**PARAGONIOZONA NELSON, 1947**

**TYPE SPECIES:** *Paragoniozona nodilirata* Nelson, 1947.

**DISCUSSION:** Because two specimens from the lower Wolfcamp formation were the only representatives of the genus in the collections under study, nothing further can be added to the present concept of this genus.

***Paragoniozona* cf. *P. nodilirata* Nelson, 1947**

Plate 36, figure 17

*Paragoniozona nodilirata* NELSON, 1947, p. 460, pl. 65, figs. 2a-c.

**DESCRIPTION:** The general shell shape is semi-globose. The whorl profile is gently convex down to the lower edge of the profile. Whorls are in contact just beneath the lower selenizone border. There are six well-developed and braided spiral cords above the selenizone which form a reticulation with almost equally well-developed collabral cords. The selenizone is located on the angular periphery and is convex with a median thread. The upper margin, lower margin, and median thread of the selenizone are strongly noded. The lunulae are formed by collabral cords or threads. The reticulated base commonly has nine equally spaced spiral cords which are dominant.

**DISCUSSION:** *Paragoniozona nodilirata* differs from other species of the genus in having the selenizone placed high on the angular periphery, rather than well above the periphery. *Paragoniozona aspera* Nelson, 1947, appears to be the closest species in similarity

TABLE 9  
MEASUREMENTS (IN MILLIMETERS) OF *Paragoniozona* CF. *P. nodilirata* NELSON FROM  
U.S.N.M. 712

H	W	SW	SS	CS
3.20	3.48	0.36	0.87	0.28
2.18	2.32	0.65	0.65	0.14



of characters found above the selenizone, but differs in shape and basal features. From a study of the types, it is probable that *P. granulistriata* Nelson and *P. woolseyana* Nelson should be placed in synonymy with *P. aspera*.

This species, as is *Phymatopleura brazoensis*, is found in the Wolfcamp shales near Gaptank, Texas, and is represented by two specimens which are tentatively assigned to *P. nodilirata* Nelson on the basis of shape, position of the selenizone, and basal cords. Several specimens identical to these Wolfcamp forms are found in the Gaptank formation (bed 10) among specimens definitely referable to *P. nodilirata*.

The most prominent feature of the specimens mentioned above is the spiral and collabral cords that are equal in development above the selenizone.

OCCURRENCE: U.S.N.M. 712, two.

CATALOGUED SPECIMEN: Hypotype, U.S.N.M. No. 133303.

#### CALLITOMARIA BATTEN, 1956

TYPE SPECIES: *Callitomaria stanislavi* Batten, 1956.

DIAGNOSIS: Medium-spined pleurotomarians with inflated whorls, dominant spiral ornament, and a moderately shallow slit giving rise to a selenizone situated midway on almost vertical outer whorl face; rounded to somewhat rectangular whorl profile; whorls in contact midway between lower selenizone margin and next cord beneath; sutures shallow and sharply defined; a spiral thread or cord is located midway between the first major cord above selenizone and suture; selenizone flat to very gently concave or convex; lunulae not well developed, but reflecting collabral ornament; collabral threads and cords form nodes at intersections with spiral ornament; five to eight basal spiral cords are more pronounced than either spiral elements above selenizone or general collabral ornament; ornament ranging from almost completely dominant spiral ornament to reticulation of well-developed spiral and collabral elements; columellar lip straight and reflexed; arcuate parietal inductura deposited over ornament, except within plane of aperture where ornament is resorbed; shell thin

without thickening in apertural area, except in some mature specimens; lower lip deflected in mature specimens; anomphalous or narrowly phaneromphalous.

DISCUSSION: This genus most closely resembles the Pennsylvanian genus *Borestus* Thomas, 1940, from which it was most probably derived. An undescribed species of *Borestus* from the Wann shales of Oklahoma has characters that suggest that it may well have been the group which gave rise to *Callitomaria*. These characters are the disposition of the selenizone and the general ornament above the selenizone. There is at least one undescribed species of *Callitomaria* in the Magdalena limestone of upper Pennsylvanian age in New Mexico.

*Callitomaria* can readily be separated from *Borestus* by its much more rounded whorls, wider selenizone occupying much of the outer whorl face, and its dominant spiral ornament. *Borestus* has the appearance of a more turreted form owing in part to the sharp, rather narrow, vertical, outer whorl face with a centrally placed selenizone. Species of *Callitomaria* may resemble some forms of *Tapinotomaria* in the general whorl profile and emphasis on spiral ornament, but the selenizone of *Tapinotomaria* is much narrower and located lower on the whorl.

Evolutionary trends were not recognized in this genus. Variation seems to be limited to changes in the whorl shape owing to the position and emphasis of spiral ornament, to changes in the degree of development in the collabral ornament, and to changes in overall size.

The most obvious difference between the two new species described below is size, but in the quantitative characters studied there is virtually no overlap between samples of the two species, as shown in figure 14. This may negate the possibility that *C. magna* represents a group of large-sized specimens of *C. stanislavi*. The most significant characters of the genus, both qualitatively and quantitatively, seem to be the characters SS, CS, and SW, that is, the distance between the suture and selenizone, the distance between the first major cord and the next cord above, and in the width of the selenizone.

RANGE: Upper Pennsylvanian through middle Guadalupian.

***Callitomaria magna* Batten, new species**

Plate 36, figures 1-4

**DESCRIPTION:** This species is characterized by a subrectangular whorl profile and a rather large size compared to the other species of the genus (10.7 mm. to 17.8 mm.). The vertical whorl face occupies the largest portion of the whorl profile and is flat or slightly convex, depending on the strength of development of spiral cords. There is a major cord forming the upper edge of the outer whorl face and a small cord developed about two-thirds of the distance to the suture from the upper edge. The centrally placed, flat to concave selenizone is wide and covers approximately one-half of the vertical whorl face. The upper and lower edges of this face are separated from the margins of the selenizone by con-

shell shape. In other specimens the shape is almost globose. This change, along with various developments of collabral ornament, was the only observed variation within this species.

**RANGE:** Uppermost Leonardian.

**OCCURRENCE:** The hypodigm consists of six specimens from U.S.N.M. 703.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133300b; figured paratypes, U.S.N.M. Nos. 133300a, 133300c.

***Callitomaria stanislavi* Batten, 1956**

Plate 36, figures 5-15

*Callitomaria stanislavi* BATTEN, 1956, p. 43.

**DESCRIPTION:** This species characteristically has a somewhat step-like whorl profile that is inflated. Early whorls are simple, with

TABLE 10

MEASUREMENTS (IN MILLIMETERS) OF *Callitomaria magna* BATTEN, NEW SPECIES, FROM U.S.N.M. 703

H	W	SS	CS	SW
17.8	16.4	4.60	2.14	1.84
15.3	15.0	3.82	1.70	1.28
—	16.0	4.46	2.15	1.34
15.3	14.3	3.74	1.70	1.42
—	12.3	3.00	1.48	1.34
10.4	11.1	2.63	1.28	1.28

cave interspaces. Collabral ornament is usually restricted to growth lines or light cords. These light cords generally appear in earlier whorls, where they occupy the area between the suture and the first spiral cord below it. There are from five to seven well-developed, basal, spiral cords. There may be nodes on the first several cords near the umbilicus (see pl. 36, fig. 2).

**DISCUSSION:** This species is readily distinguished from *C. stanislavi* by its much greater size, lower spire, and lack of heavy collabral ornament. The last whorl of adult specimens usually has much lighter collabral ornament than earlier whorls. Elongate nodes are well developed in intensity on spiral cords above the selenizone. Beneath the selenizone, collabral ornament is apparently restricted to growth lines. In several specimens the major spiral cords are rounded and have more fully developed nodes, which results in a step-like

dominant spiral threads. In later whorls a spiral cord or thread forms the upper and lower edges of the outer whorl face. A spiral cord is located approximately midway between the suture and the upper edge of the outer whorl face. The upper edge is separated from the selenizone by a rather flat to slightly concave or convex area, which generally occupies a large part of the outer whorl face. The selenizone is relatively narrow; lunulae are composed of growth lines alone. Collabral ornament is highly variable, generally forming nodes at intersections with spiral ornament. The collabral ornament may be restricted to cords occupying the area above the spiral cord situated on the upper whorl surface or may cover the entire shell down to the umbilicus. There are from six to eight revolving cords on the base; the shell is thin. Individuals vary from anomphalous to minutely phaneromphalous.

**DISCUSSION:** This species ranges in size from 6.10 mm. to 12.05 mm. and thus is much smaller than *C. magna*. The shape is more globose than that of *C. magna*, which has a wider and more flattened outer whorl face. The ornament is usually coarser in *C. stanislavi*. There is some convergence on general shape and appearance between this species and group 1 of *Tapinotomaria crassa*. They are similar in having dominant revolving ornament and two spiral elements above

the two species of the genus one might consider *C. magna* to be the second stage of a trend towards larger size accompanied by a decrease of ornament.

**RANGE:** Lower Leonardian through middle Guadalupian.

**OCCURRENCE:** The hypodigm is composed of 19 specimens from these localities: P.U. 3, 13; A.M.N.H. 433, two; U.S.N.M. 703, one; A.M.N.H. 512, three.

**CATALOGUED SPECIMENS:** Holotype,

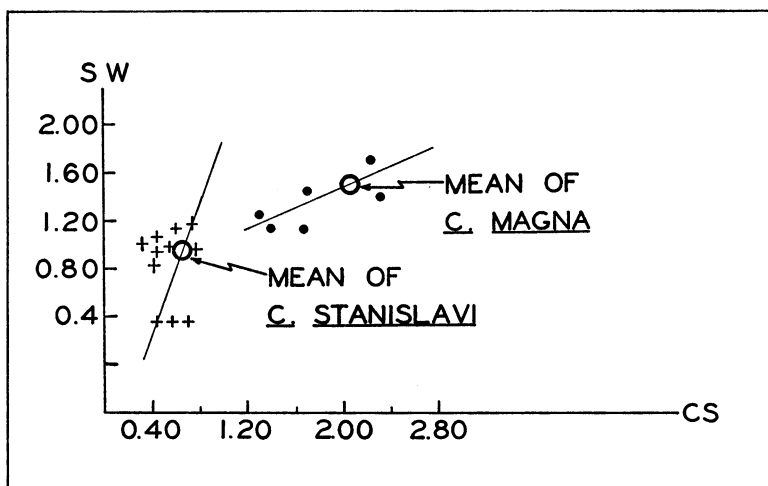


FIG. 14. Approximated allometric growth lines for two small samples, one each of *Callitomaria stanislavi* and *C. magna* from the lower Bone Spring formation, Sierra Diablo, Texas.

the selenizone. More important characters, such as width and position of the selenizone and thickness of the shell, place these two species in different families.

Collabral ornament may be restricted to the area between the suture and the next spiral element beneath it or may extend down to the selenizone in varying degrees of development. Beneath the selenizone this ornament may be restricted to the first several cords near the umbilicus where it forms nodes at intersections or may extend over the entire base. Collabral ornament may be as pronounced as the spiral ornament and form a reticulate pattern with it. These changes form morphoclines in the Bone Spring samples.

There were no observable trends found in *C. stanislavi*, based on a study of representatives found in successive horizons. Between

A.M.N.H. No. 27953; figured paratypes, U.S.N.M. Nos. 133301a-133301d, and A.M.N.H. No. 28052:1.

#### GLYPTOTOMARIA KNIGHT, 1945

**TYPE SPECIES:** *Glyptotomaria apiarium* Knight, 1945.

**DIAGNOSIS:** Discoidal to moderately high-spired pleurotomarians with a flat or deeply concave base and a selenizone located one-third of the distance down from upper edge of an almost vertical outer whorl face; protoconch flattened to depressed; sutures angular, shallowly impressed, but not deep; upper whorl surface convex or concave, with collabral threads which may form nodes at intersections with spiral threads; upper edge of outer whorl face in some species marked by a noded cord; vertical area between upper edge and upper margin of selenizone with collabral

threads only; ornament above selenizone occasionally reticulate; slit moderately shallow; selenizone concave, with lunulae developed by collabral elements or growth lines only; whorl face below selenizone strongly concave, if smooth, or flat and with spiral threads, collabral threads prosocline; lower edge of outer whorl face either a wide flat angle or a rope-like cord with spiral threads; base concave or flat, with dominant spiral elements, growth lines and collabral elements forming a broad sinus; anomphalous, phaneromphalous, or hemiomphalous, with a callus which forms a thickened, reflexed, columellar lip,

Pennsylvanian and from the Permian Wolfcamp and Leonard series have disclosed not only intermediate forms of these two genera, but also a separate genus, *Discotomaria* Batten, 1956, clearly derived from them. The three taxa are all represented in the Pennsylvanian, but only two of these, *Glyptotomaria* (*Glyptotomaria*) and *Discotomaria*, are found in beds of Permian age.

As there are intermediate forms between the genera mentioned above, they should be brought together and recognized as subgenera. *Glyptotomaria* is preferred as the generic name, because representatives of the ge-

TABLE 11  
MEASUREMENTS (IN MILLIMETERS) OF *Callitomaria stanislavi* BATTEN, 1956

Locality	H	W	SS	CS	SW
P.U. 3	9.86	9.44	2.00	0.54	0.76
P.U. 3	7.43	7.43	1.48	0.40	0.76
P.U. 3	—	6.14	1.40	0.40	0.54
P.U. 3	—	12.40	3.24	1.00	0.06
P.U. 3	—	9.72	2.64	0.76	1.06
P.U. 3	—	—	2.64	0.64	0.76
P.U. 3	—	—	2.94	0.76	1.00
P.U. 3	11.60	11.70	2.86	0.64	1.28
A.M.N.H. 433	10.70	10.30	2.28	0.76	0.90
A.M.N.H. 433	—	—	1.56	0.54	0.90
A.M.N.H. 433	10.0	8.78	2.28	0.54	1.00
A.M.N.H. 433	8.26	7.10	2.40	1.08	0.72
A.M.N.H. 433	9.28	11.30	1.80	0.78	0.78
A.M.N.H. 433	11.90	12.17	2.89	1.44	1.23
A.M.N.H. 433	—	13.50	3.18	1.73	1.23
A.M.N.H. 433	6.10	5.50	1.44	0.67	0.60
A.M.N.H. 512	12.03	11.30	2.32	0.72	1.01

this callus usually ornamented by spiral cords; a thickened parietal inductura, when present, obscures all basal ornament except a deep groove just under the lower edge of outer whorl face; sinus, if present, in upper columellar lip located at juncture with parietal lip; shell thin or thick, with layers about equal in thickness.

DISCUSSION: Knight (1945, pp. 576–577) described two genera, *Dictyotomaria* and *Glyptotomaria*, from Mississippian and Pennsylvanian beds. On the basis of material then studied, these genera were sharply defined, and little overlap was observed between the type species representing them. Collections from the Cisco and Canyon series of the

nus are fairly common and better known than *Dictyotomaria* and is more important from the standpoint of variation and geographic distribution.

Several observations can be made from this series. In general, *G.* (*Glyptotomaria*) is the more variable subgenus, while *G.* (*Dictyotomaria*) is the more conservative. *Glyptotomaria* (*Glyptotomaria*) is particularly variable in general shell shape and base, which may well be related to the height of the shell. The protoconch also varies between species noted as above, and may be related to the shell shape.

RANGE: Middle Mississippian through lower Guadalupian.

**GLYPTOTOMARIA (DICTYOTOMARIA)**

(KNIGHT), 1945

TYPE SPECIES: *Dictyotomaria scitula* (Meek and Worthen, 1861).

DISCUSSION: *Dictyotomaria* does not occur in the Permian. I have nothing further to add to the original concept except to suggest that it be reduced to the subgeneric rank. *Glyptotomaria* (*Dictyotomaria*) is first encountered in the Salem limestone of Indiana, but is best characterized by forms found in the Pennsylvanian.

The chief characters of this subgenus, in so far as this study is concerned, are a depressed selenizone located approximately in the center of the nearly vertical outer whorl face, inflated whorls with impressed sutures, rounded upper and lower whorl faces, a narrow umbilicus, and semi-reticulate ornament on the early whorls and base. This group is considered to be the basal stock from which the other groups originated. Knight (1945, p. 576) assigned an undescribed species from the Canyon and Cisco series (Keechi Creek shale) to this subgenus, but it may be more properly referred to *G. (Glyptotomaria)*. This assertion is based on the presence of a broad sinus on the base, an enlarged, cord-like lower edge of the outer whorl face, a selenizone above the surface of the whorl rather than depressed, and a conical shell shape.

RANGE: Mississippian to Pennsylvanian.

**GLYPTOTOMARIA (GLYPTOTOMARIA)**

KNIGHT, 1945

TYPE SPECIES: *Glyptotomaria apiarium* Knight, 1945.

DIAGNOSIS: Discoidal to high conical pleurotomarians with a concave to convex upper whorl surface, a concave or conforming outer whorl face, and a flat to deeply invaginated base; whorls low and wide; protoconch low spired to depressed; upper edge of outer whorl face a cord which is smaller in size than lower edge cord, upper edge separated from upper margin of selenizone by a narrow concave trough ornamented by collabral elements alone; slit moderately deep; selenizone one-third of the distance between upper edge of outer whorl face and reticulate basal angle, sharply bordered by spiral threads, and either depressed or raised in relation to the surface

of outer whorl face; lower edge of outer whorl face with many spiral threads which may form reticulation with collabral ornament; collabral elements on base forming a broad sinus, another sinus being located on columellar lip near juncture with parietal lip; columellar lip reflexed and straight; moderately thick parietal inductura; basal ornament dominant spiral elements or reticulation; anomphalous or widely phaneromphalous, when phaneromphalous, sutures within umbilicus deeply impressed and sharp.

DISCUSSION: This subgenus is highly variable in many important features. The most obvious variation is in the general shell shape which may be that of a disc to that of a cone with convex sides; many intermediate stages between these two extremes are known. In general, forms having flat bases have a low-spired to planispiral protoconch. This has been observed in the undescribed species from the Keechi Creek shale, in *G. (Glyptotomaria) apiarium* Knight, and in *G. (Glyptotomaria) marginata*. In the species *G. (Glyptotomaria) pistra*, which has a deeply invaginated base, the protoconch is either flat or depressed.

Other variations involve typical changes in the type and intensity of ornament. There are a large number of specimens from those species having a rather high spire in which the outer lip has been broken during life and has been repaired. There appears to be no particular reason for this, as the shell is relatively thick. It has been claimed that ornament is adaptable and used for strengthening, but if this is so it is difficult to see why breakage occurs in such heavily ornamented forms as these.

Significant quantitative characters used to separate the species are the distance between the suture and the upper margin of the selenizone; the distance between the upper edge of the outer whorl face and the first spiral element about it (CS); and the width of the lower edge cord (CSS).

*Glyptotomaria (Glyptotomaria)* has a variety of environments; *G. (Glyptotomaria) marginata* is unique in being found within the cloaca of *Heliospongia* (see p. 170).

RANGE: Pennsylvanian through Guadalupian.

***Glyptotomaria (Glyptotomaria) marginata***

Batten, new species

Plate 37, figures 1-4

**DESCRIPTION:** The general shell shape of this species is a low-spined to a high-spined cone with sutures that are angular, depressed, and shallow. Whorls are in contact in about the center of a narrow trough just under the selenizone. There are usually four spiral threads on the convex upper whorl surface. The upper edge of the outer whorl face is developed by a noded spiral cord; if this element is rounded, the nodes are elongated. Three or more spiral threads may be found on this cord. There is a depression between the upper edge and the upper selenizone margin which contains only collabral ornament. Collabral ornament above the selenizone commonly forms nodes with spiral elements. The

selenizone is relatively wide and is situated close to the upper edge, occupying about one-third of the vertical whorl face. The selenizone margins are sharply defined by spiral threads. Lunulae are developed by collabral threads or growth lines. There are from eight to 22 spiral threads on the base which are coarse if few in number (see pl. 37, fig. 2). There is a sharply defined marginal trough just under the lower edge on the base. From this trough to a point near the umbilicus the basal surface is convex but gradually becomes concave towards the umbilicus (see pl. 37, fig. 4). Collabral elements on the base form a broad sinus. Umbilicus is phaneromphalous or hemiomphalous, with a callus which may be ornamented by strongly developed spiral elements (see pl. 37, fig. 2).

**DISCUSSION:** This species can be distinguished easily from *G. (Glyptotomaria) pistra*

TABLE 12

MEASUREMENTS (IN MILLIMETERS) OF *Glyptotomaria (Glyptotomaria) marginata* BATTEN, NEW SPECIES

Locality	SR	H	W	SS	CS	CSS	SW
U.S.N.M. 712f	—	5.94	7.54	1.08	—	—	0.42
A.M.N.H. 369	—	—	—	1.22	0.56	—	0.34
U.S.N.M. 707d	—	3.94	8.04	—	0.28	—	0.28
U.S.N.M. 707d	—	4.04	7.54	0.94	0.42	—	0.28
U.S.N.M. 707d	—	5.20	9.56	1.08	0.64	—	0.42
U.S.N.M. 702d	2.42	9.71	15.40	2.40	0.94	1.30	0.98
U.S.N.M. 702d	1.91	14.20	20.07	2.16	0.80	1.74	0.80
U.S.N.M. 702d	2.30	—	—	1.44	0.72	1.44	0.50
U.S.N.M. 702d	—	11.89	22.20	3.04	0.72	1.74	0.86
U.S.N.M. 702d	1.98	12.00	17.50	2.98	1.00	1.44	0.80
U.S.N.M. 702d	1.99	10.70	16.40	1.96	0.80	1.44	0.72
U.S.N.M. 702d	2.02	8.40	16.80	1.82	0.64	1.00	0.63
U.S.N.M. 702d	2.12	6.95	11.45	1.14	0.56	1.08	0.50
U.S.N.M. 702d	1.74	7.83	11.75	1.66	0.64	1.00	0.56
U.S.N.M. 702d	2.41	8.12	12.75	1.88	0.72	1.14	0.64
U.S.N.M. 702d	2.46	5.80	11.30	1.08	0.56	0.94	0.42
U.S.N.M. 702d	2.09	6.53	11.45	1.44	0.72	1.00	0.50
U.S.N.M. 702d	2.49	5.94	12.60	1.22	0.63	1.00	0.42
U.S.N.M. 702d	2.22	6.53	—	1.36	0.56	1.00	0.42
U.S.N.M. 702d	2.09	7.54	11.90	1.30	0.64	1.14	0.42
U.S.N.M. 702d	2.13	6.54	12.20	1.30	0.64	1.00	0.50
U.S.N.M. 702d	2.00	5.94	9.55	0.94	0.50	0.94	0.56
U.S.N.M. 702d	2.40	4.78	9.14	0.80	0.42	0.72	0.42
U.S.N.M. 702d	2.09	6.10	10.40	0.94	0.64	0.94	0.42
U.S.N.M. 702d	2.24	5.22	8.13	0.94	0.50	0.86	0.34
U.S.N.M. 702d	2.20	4.65	9.30	0.86	0.56	0.86	0.34
U.S.N.M. 702d	2.02	4.13	6.94	0.72	0.50	0.80	0.42
U.S.N.M. 702d	2.34	3.33	—	0.64	0.34	0.56	0.28

which has a flattened or discoidal protoconch rather than a normally developed protoconch. The spire of *G. (Glyptotomaria) marginata* is not so high as that of *G. (Glyptotomaria) apiarium*, and the upper whorl surface is at a greater angle in relation to the axis.

This species is very similar to a group of specimens found in middle and upper Pennsylvanian shales, such as the Keechi Creek, Graham, Wewoka, Gaptank shales and to those found in the "*Uddenites*" zone. These can be distinguished from *G. (Glyptotomaria) marginata* on the basis of the number and arrangement of the spiral ornament and on the shape and height of the spire. It may be, however, that some specimens fall within the ranges of variation of the characters of this species. In any event, it seems probable that *G. (Glyptotomaria) marginata* as defined here is a part of the lineage that includes these Pennsylvanian forms.

Variation, other than the expected changes in number and intensity of ornament, includes size and shape of the upper and lower edges, height of spire and corresponding changes of the width, and finally the characters associated with the umbilicus. The changes in the area of the umbilicus include a cryptomphalous to phaneromphalous condition of the umbilicus itself, development of an ornamented callus, and depth of sutures within the umbilicus. There appears to be a trend towards a lower and flatter spire with time, accompanied by a widening of the umbilicus and larger size (fig. 15).

**RANGE:** Wolfcampian to the top of the Leonard.

**OCCURRENCE:** The hypodigm includes 57 specimens from these localities: U.S.N.M. 702t, one; U.S.N.M. 712, one; U.S.N.M. 712b, two; U.S.N.M. 712d, one; U.S.N.M. 712f, one; A.M.N.H. 391a, one; A.M.N.H. 369, two; U.S.N.M. 707d, three; U.S.N.M. 702d, 45.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133306b; figured paratypes, U.S.N.M. Nos. 133305 and 133306a.

***Glyptotomaria (Glyptotomaria) pistra*** Batten,  
new species

Plate 37, figures 5-8

**DESCRIPTION:** This species ranges from a discoidal shape to a thimble shape, with the

protoconch flat or depressed and the base very deeply invaginated and concave. The sutures are rather angular and shallow, and frequently the shell is broken along the sutures and repaired, forming irregular sutures (see pl. 37, fig. 5). There are about four spiral threads on the concave upper whorl surface. The upper edge of the outer whorl face is a noded spiral thread. The outer whorl surface is flat, angular, and sloping towards the axis. The lower edge of the outer whorl face is L- or V-shaped, if this edge is angular in conjunction with a high-spined shell, or a pronounced cord if the shell is discoidal. A trough just under the lower selenizone margin has only collabral ornament. There are about 10 spiral threads on the basal angle or cord. Just under the lower edge on the base there is a narrow trough followed by a sharp, rather heavy spiral cord. Next to this element, there is a slightly narrower trough which in turn is followed by a very shallow trough. This second trough is bordered on the umbilical side by a spiral thread and from this point on to the umbilicus there is a broad concave area culminating in a ridge about the umbilicus (pl. 37, figs. 6 and 8). There is a broad sinus on this base formed by collabral ornament and a sinus on the columellar lip. Color pattern is dominantly spiral, and spiral ornament is darker than the general whorl surface beneath it.

**DISCUSSION:** This species is readily separable from other species of the genus and from species of *Discotomaria* by its unique, concave base.

The principal variation in the species involves shape and height of shell and variable development of collabral ornament. Basal characters are particularly plastic. There are usually two heavy spiral cords and a single thread towards the outer portions of the base. Collabral ornament on the base does not appear to form nodes with spiral elements as it does above the selenizone. There appears to be a direct relationship between height of spire and depth of the invaginated base, accompanied by changes in the intensity of ornament on the base.

A number of specimens from A.M.N.H. 512 have been distorted. This distortion is entirely confined to a downward compression which tends to decrease the total height of the shell.

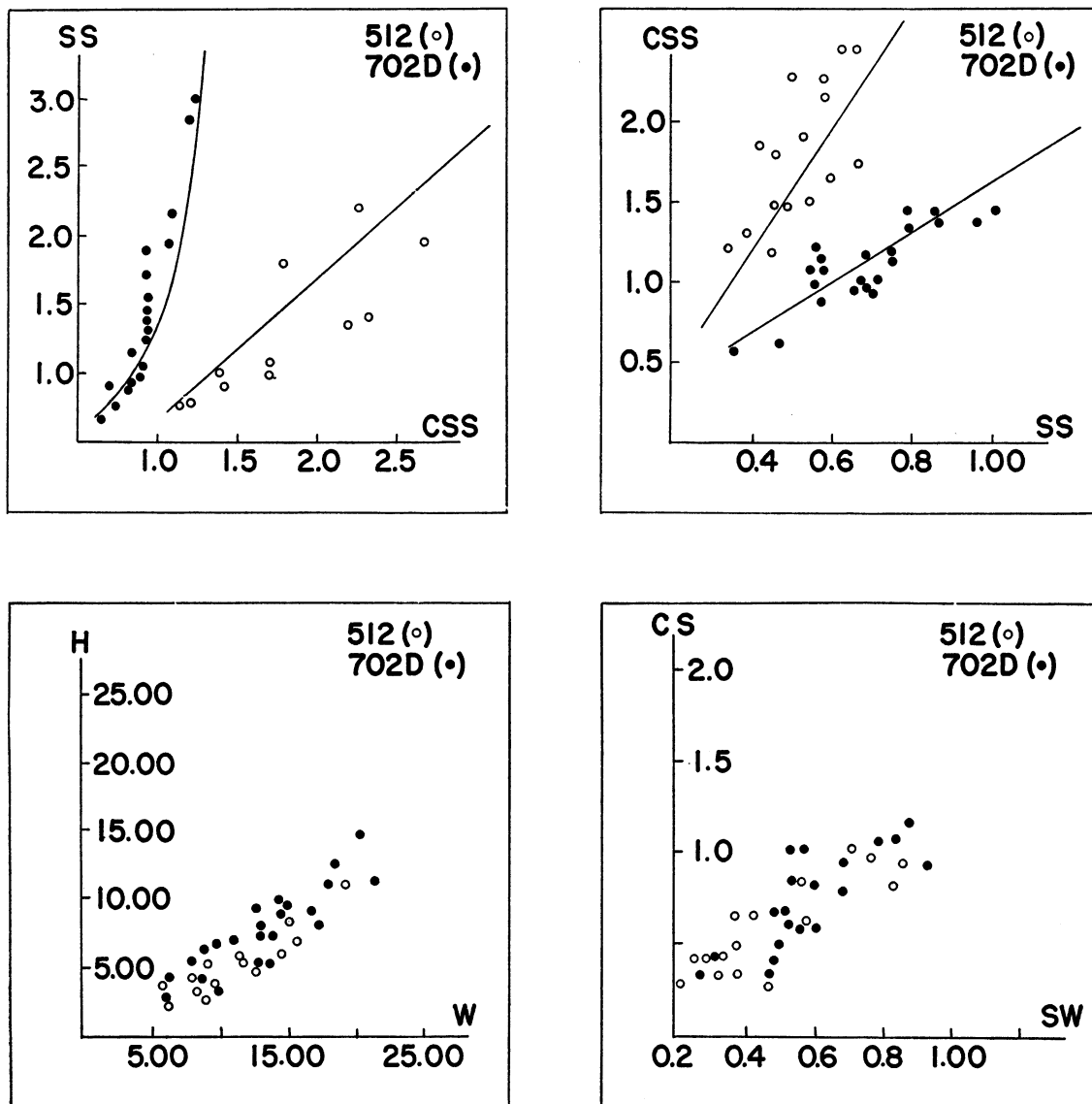


FIG. 15. Scattergrams showing relationship, correlation, and variation between four characters from two populations, one of *Glyptotomaria* (*Glyptotomaria*) *marginata* from U.S.N.M. 702d of upper Leonard age and one of *G. (Glyptotomaria)* *pistra* from A.M.N.H. 512 of Guadalupian age. Growth lines are estimated.

RANGE: Upper Leonardian through middle Guadalupian.

OCCURRENCE: The hypodigm includes 74 specimens: U.S.N.M. 703, one; U.S.N.M. 706b, one; U.S.N.M. 707b, two; U.S.N.M. 706c, three; U.S.N.M. 702a, one; U.K. 27 (U.S.N.M. 706c), one; U.S.N.M. 703c, one; U.S.N.M. 728, 12; A.M.N.H. 512, 25.

CATALOGUED SPECIMENS: Holotype,

U.S.N.M. No. 133307; figured paratype, A.M.N.H. No. 28053:1.

#### DISCOTOMARIA BATTEN, 1956

TYPE SPECIES: *Discotomaria basisulcata* Batten, 1956.

DIAGNOSIS: Low-spired pleurotomarians with a concave selenizone depressed beneath the surface of an almost vertical outer whorl



TABLE 13

MEASUREMENTS (IN MILLIMETERS) OF A SAMPLE OF *Glyptotomaria* (*Glyptotomaria*) *pistra* BATTEN,  
NEW SPECIES, FROM A.M.N.H. 512

H	W	SS	CS	SW	CSS
7.24	14.00	1.30	0.64	0.72	1.60
7.24	13.80	1.30	0.63	0.50	2.40
12.00	18.40	2.18	0.72	0.72	2.60
9.84	14.90	1.88	0.72	0.64	2.60
11.90	14.90	2.04	0.64	0.72	2.18
8.12	14.20	1.44	0.56	0.50	2.18
4.64	10.00	0.94	0.56	0.34	1.60
4.64	9.27	0.72	0.42	0.28	1.30
4.64	11.16	0.80	0.50	0.34	1.52
4.93	9.57	1.08	0.56	0.34	1.44
3.34	6.38	0.56	0.28	0.20	1.08
2.90	6.96	0.56	0.42	0.28	1.00
4.93	10.00	1.88	0.42	0.34	1.60
3.76	9.00	—	0.42	0.34	1.30
3.62	9.14	—	0.34	0.42	1.14
4.34	8.26	0.80	0.50	0.34	1.34

face; whorls in contact on outermost portion of the lower edge cord; protoconch discoidal to low spired; upper whorl surface concave, with dominant collabral cords; upper edge of outer whorl face with or without elongate nodes and spiral threads; outer whorl face concave, ornamented only by collabral elements except for selenizone and a sharp narrow trough just beneath; sinus moderately deep; selenizone bordered by sharp spiral threads, occupying about one-third of outer whorl face; commonly with a spiral thread located just below narrow trough under selenizone; selenizone and trough depressed; trough on base beneath with collabral threads forming a shallow but sharp sinus; a sharp ridge noded or with collabral and spiral elements forming a margin on umbilical side of this sinus; spiral cords dominant on base; basal surface gently convex or concave; columellar lip straight but with a well-developed sinus near parietal lip, apparently without an inductura, or without resorption of ornament on parietal lip.

**DISCUSSION:** This genus is closely related to *Glyptotomaria* from which it most probably was derived. In common with this genus, *Discotomaria* has a sinus on the base and on the columellar lip, a selenizone located about in the center of an outer whorl face, and a trough just under the lower dominant edge of

the outer whorl face. It differs from *Glyptotomaria* in having dominant collabral ornament, a basal sinus almost entirely confined to a basal trough, a selenizone and adjoining trough depressed beneath the general surface of the outer whorl face, a very prominent upper edge which is well ornamented by nodes and spiral threads, but, most obvious of all, a base that is more nearly "normal" in having a flattened or convex surface. In *Glyptotomaria* the shell shape may be almost discoid, but the upper whorl surface is always convex. The trend between or within the species is confined to an increase in height of spire. In *Discotomaria* the axis of coiling is fairly uniform, and the upper whorl surface is always strongly and deeply concave, with only collabral elements as ornament.

Collections at the United States National Museum from Pennsylvanian shales of Texas and Oklahoma contain a species of *G.* (*Glyptotomaria*) that has a flat base, a relatively short axis of coiling, a sinus in the columellar lip, and a broad sinus on the base. These characters, with general ornament, a general shell shape, and position of the selenizone, suggest that this species may have been the source of the genus *Discotomaria*.

The chief source for separation of species in *Discotomaria* is in the range of variation involving general shell shape and the outer

whorl face. Specific variation is limited to the relative development of the upper and lower edges of the outer whorl face, ornament on the upper edge, degree of concavity of the upper whorl surface, number and intensity of ornament on the base, and shape and placement of the basal sinus.

RANGE: Upper Pennsylvanian through middle Guadalupian.

***Discotomaria nodosa*** Batten, new species

Plate 37, figures 12-14, 19-20

DESCRIPTION: The whorl profile of this spe-

character, for it appears that earlier forms have less well-developed nodes than the later ones. Basal ornament varies from specimen to specimen, so that in some forms a reticulated pattern may exist, while in others either collabral or spiral ornament may be dominant.

RANGE: Wolfcampian through upper Leonardian.

OCCURRENCE: The hypodigm includes 10 specimens: U.S.N.M. 712b, one; U.S.N.M. 712f, one; U.S.N.M. 707d, four; U.S.N.M. 702d, two; U.S.N.M. 706c, two.

CATALOGUED SPECIMENS: Holotype,

TABLE 14

MEASUREMENTS (IN MILLIMETERS) OF *Discotomaria nodosa* BATTEN, NEW SPECIES

Locality	H	W	CS	SW	CSS	Ha	Wa	B
U.S.N.M. 702d	3.62	5.80	0.72	0.28	0.28	0.42	0.06	0.86
U.S.N.M. 702d	3.34	5.36	0.42	0.12	0.28	0.28	0.28	0.86
U.S.N.M. 702d	3.19	4.77	0.56	0.28	0.56	0.12	0.56	0.56
U.S.N.M. 702d	4.50	5.80	0.56	0.36	0.42	0.20	0.12	—

cies is more or less rounded and the axis of coiling is shorter than in other members of the genus. Rather strong, rounded nodes are developed on the upper edge of the outer whorl face and form the most prominent feature of the upper whorl. The upper edge in profile is indented so that the area between the upper edge and the selenizone slopes outward and gives the outer whorl face a convex appearance. There is a less strongly developed and noded spiral cord near the suture. The lower edge of the outer whorl face is moderately well developed, with spiral threads which begin at the lower edge of the narrow trough beneath the selenizone. The base has from nine to 12 spiral threads that form the dominant basal ornament. The basal sinus is sharp and confined to the basal outer trough; there is no other ornament in the trough (see pl. 37, fig. 13).

DISCUSSION: This species is easily separable from other species of the genus by its rounded shell shape and whorl profile. It has a much stronger development of nodes on the upper edge than in other species.

There is some variation in the intensity of ornament of *D. nodosa*, particularly in collabral elements which form the nodes on the upper edge. There may be a trend in this

U.S.N.M. No. 133311; figured paratype, U.S.N.M. No. 133312.

***Discotomaria dubia*** Batten, new species

Plate 37, figures 15-16

DESCRIPTION: This species is characterized by having the early whorls rounded, with only simple spiral ornament, an upper whorl surface that is deeply concave, and upper and lower edges of the outer whorl face thin, flange-like, and without collabral ornament. The almost vertical outer whorl face is markedly concave, with the selenizone situated about one-third of the distance down from the upper edge. The selenizone is relatively narrow and concave. There is a fairly strong cord midway between the upper and lower edges just below the selenizone. This cord acts as a lower margin to a very narrow trough which has as its upper margin the lower selenizone border. Beneath this cord the remaining portion of the outer whorl face has collabral ornament only. Six basal spiral threads are irregularly spaced. The columellar lip is straight and rather elongate. The specimens are anomphalous to narrowly phaneromphalous.

DISCUSSION: No other species of the genus

has the upper and lower edges of the outer whorl face so thin, extended, and unornamented as *D. dubia*. In contrast to that of other species the protoconch is simple and rounded. Because the specimens of *D. dubia* are anomphalous, the columellar lip appears as a solid pillar. This, with the almost horizontal lower lip, forms a rectangular aperture unique to this species.

Unfortunately this species is known from but two specimens in the upper Leonard formation, so that nothing can be said regarding its variation. Though badly preserved, they do not even remotely resemble extreme variants of other species. *Discotomaria costata*, is most similar, with its rather wide vertical outer whorl face and narrow selenizone. The two species are quite different in the base and condition of the umbilicus.

RANGE: Upper Leonardian.

OCCURRENCE: Two specimens are included in the hypodigm, one from U.S.N.M. 703b and one from U.S.N.M. 702 (Split Tank).

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133313.

***Discotomaria basisulcata* Batten, 1956**

Plate 37, figures 9–11, 17, 18, 21–23

*Discotomaria basisulcata* BATTEN, 1956, p. 43.

DESCRIPTION: The early whorls of the species are flat and plain, but the upper edge of the outer whorl face is developed very much earlier than any other element. The concave upper whorl surface has dominant collabral elements. The upper edge is strongly noded, with fine spiral threads. The outer whorl surface above the selenizone is narrow and, as is the area above the lower edge, is ornamented by collabral threads or growth lines alone. The selenizone and the trough just under it are depressed. This trough is strongly bordered but narrow. A flat, collabrally ornamented shelf forms the upper surface of the large, rounded, and reticulated lower edge of the outer whorl face. This face may be vertical or slanted upward towards the axis. The base is convexo-concave, with a shallow trough just under the lower edge. The basal sinus is larger than this trough. Most specimens are phaneromphalous.

DISCUSSION: The rounded flanges marking the lower edge of the almost vertical outer

whorl face form a step-like whorl profile that serves to distinguish this species from other members of the genus. *Discotomaria costata* has a rectangular whorl profile but does not develop a flange as in *D. basisulcata*. Variation in *D. basisulcata* involves the width of the lower edge shelf, the width and disposition of the outer whorl face, and the length of the axis of coiling.

A single specimen of *Discotomaria* from the Pennsylvanian Wayland shale at Gunsight, Texas, is tentatively included in this species. This specimen has an upper and lower edge of the outer whorl face about equal in development, but the lower edge has a short shelf that does not occur in any other species. It is more high spired than most specimens of this species, and the base varies considerably in ornament, but not in essential shape. The selenizone is wide, occupying about one-half of the area of the outer whorl face. The narrow trough usually found just under the selenizone is absent, but there seems to be a double spiral thread that acts as the lower selenizone margin. This thread is also found on the upper selenizone margin but is not so widely spaced as in the lower margin. The basal sinus is quite wide, so that only a portion of it occupies the basal trough.

RANGE: Upper Pennsylvanian through uppermost Leonardian.

OCCURRENCE: Fifty-seven specimens are included in the hypodigm: U.S.N.M. 702c, four; U.S.N.M. 702, 13; U.S.N.M. 703a, 10; U.S.N.M. 703b, 19; A.M.N.H. 504, 10; one specimen from the Wayland shale, 1.2 miles south of Gunsight, Texas.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 125280; figured paratypes, U.S.N.M. Nos. 133308–133310.

***Discotomaria costata* Batten, new species**

Plate 37, figures 24–25

DESCRIPTION: This species characteristically has a relatively high spire. There is a prominent, weakly noded spiral thread at the suture. The upper whorl surface is narrow and quite concave. The upper edge of the outer whorl face is angular and somewhat flange-like, with very weakly developed elongated nodes. The wide and gently concave outer whorl face is almost vertical. This, with

TABLE 15  
MEASUREMENTS (IN MILLIMETERS) OF *Discotomaria basisulcata* BATTEN, 1956

Locality	H	W	CS	SW	Ha	Wa	CSS	B
U.S.N.M. 702	4.92	9.57	0.56	0.36	0.56	0.20	0.72	—
U.S.N.M. 702	2.76	4.35	0.20	0.18	0.28	0.10	0.20	—
U.S.N.M. 702	2.18	5.36	0.28	0.18	0.14	0.18	0.28	—
U.S.N.M. 702	3.26	8.12	—	0.28	0.28	0.36	0.50	1.44
U.S.N.M. 702	5.64	10.00	0.56	0.36	0.28	0.36	0.50	1.44
U.S.N.M. 702	3.04	7.24	0.36	0.20	0.28	0.20	0.42	1.00
U.S.N.M. 702	3.48	—	0.28	0.20	0.20	0.14	0.20	0.70
A.N.M.H. 504	3.20	8.83	0.36	0.20	0.42	0.28	0.42	1.44
A.M.N.H. 504	3.20	8.40	0.42	0.36	0.36	0.28	0.42	1.44
A.M.N.H. 504	2.76	6.38	0.42	0.20	0.28	0.14	0.36	1.00
A.M.N.H. 504	1.73	5.80	0.28	0.14	0.28	0.28	0.28	0.72
A.M.N.H. 504	2.90	6.82	0.42	0.20	0.20	0.20	0.36	0.86
U.S.N.M. 703b	3.48	7.24	0.42	0.20	0.28	0.28	0.42	1.14
U.S.N.M. 703b	4.04	7.38	0.42	0.36	0.28	0.20	0.42	1.22
U.S.N.M. 703b	2.46	5.23	0.36	0.20	0.14	0.20	0.42	—
U.S.N.M. 703b	3.20	—	0.36	0.14	0.28	0.28	0.50	—
U.S.N.M. 703b	4.35	8.55	0.56	0.36	0.36	0.28	0.56	1.30
U.S.N.M. 703b	3.62	7.11	0.36	0.20	0.28	0.28	0.56	1.00
U.S.N.M. 703b	4.04	7.83	0.42	0.20	0.28	0.42	0.56	0.86
U.S.N.M. 703b	3.48	6.82	0.36	0.28	0.36	0.28	0.42	1.00
U.S.N.M. 703b	3.76	7.23	0.42	0.28	0.28	0.28	0.42	1.14
U.S.N.M. 703b	3.76	7.10	0.42	0.28	0.28	0.14	0.50	1.14
U.S.N.M. 703b	3.48	7.10	0.42	0.28	0.28	0.20	0.56	1.00
U.S.N.M. 703b	2.32	5.51	0.42	0.20	0.20	0.14	0.36	0.86
U.S.N.M. 702c	1.88	—	0.20	0.14	—	—	0.28	—
U.S.N.M. 703a	2.88	5.36	0.42	0.20	0.14	0.14	0.36	0.86
U.S.N.M. 703a	2.76	5.22	0.36	0.20	0.20	0.20	0.42	0.86
U.S.N.M. 703a	2.46	4.50	0.28	0.14	0.14	0.20	0.42	0.56
U.S.N.M. 703a	2.96	4.63	0.36	0.20	0.06	0.20	0.36	0.64

equally well-developed upper and lower edges, forms a step-like whorl profile. The selenizone and narrow trough under it are similar to those of most species of the genus, but the outer whorl face beneath the trough has spiral as well as collabral ornament. The species is widely phaneromphalous.

DISCUSSION: As this species has relatively weak collabral ornament, it can easily be distinguished from such species as *D. nodosa* and *D. basisulcata*. *Discotomaria dubia* which also is without strong collabral elements is anomphalous and has much thinner upper and lower edges. The outer whorl face is much wider than in other species with the exception of *D. dubia*, but the upper and lower edges of *D. costata* are quite rounded by comparison to it.

Little variation was noted within the sample from A.M.N.H. 512 or in those forms

from equivalent localities.

RANGE: Upper Leonardian to middle Guadalupian.

OCCURRENCE: The hypodigm includes 12 specimens: U.S.N.M. 703, three; U.S.N.M. 702 (*Aulosteges* bed), one; A.M.N.H. 512, eight.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133314.

#### LAMELLOSPIRA BATTEN, NEW GENUS

TYPE SPECIES: *Lamellospira conica* Batten, new species.

DIAGNOSIS: Moderately high-spined conical pleurotomarians with a well-developed flange located at base of whorl; early whorls orthostrophic and normal, or flattened (planispiral) and enlarged; sutures sharp and incised; whorls in contact at lower portion of flange or on next basal cord below; growth

lines roughly normal to suture and flange swinging sharply near or at slit margin; slit presumably moderately deep (less than one-sixth of a whorl); selenizone located at or above center of whorl; selenizone flat to concave, with weak to well-developed selenizone margins; whorl profile flat to rounded; col-labral ornament above flange either growth lines alone, light threads, or gentle undulations near suture or near flange; spiral orna-

*conica* occurring below the middle Guadalupian have whorls in contact both on the lower and outer margins of the basal cord beneath the flange. The single population from the middle Guadalupian mostly displays whorl contact on the lower margin of the flange itself.

A possible morphocline in the lower Geta-way population shows a range from evenly distributed basal cords which are equal in in-

TABLE 16

MEASUREMENTS (IN MILLIMETERS) OF A SINGLE SAMPLE OF *Discotomaria costata* BATTEN, NEW SPECIES, FROM A.M.N.H. 512

H	W	CS	SW	Ha	Wa	CSS	B
5.44	8.27	0.72	0.28	0.86	0.12	0.56	1.30
3.62	6.53	0.42	0.28	0.56	0.12	0.36	—
3.19	6.36	0.50	0.28	0.56	0.12	0.28	0.94
3.34	5.80	0.42	0.20	0.28	0.12	0.28	0.86
4.50	6.53	0.42	0.28	0.72	0.28	0.36	1.00
1.59	4.50	0.28	0.20	0.20	0.12	0.36	0.72
3.34	4.93	0.42	0.20	0.28	0.28	0.42	1.00

ment above flange, if present, consists of a few spiral threads on upper surface of flange and basal portion of outer whorl face; growth lines swing sharply back on base, becoming gentler near umbilicus; base may be flat or sharply depressed beyond lower margin of flange; basal ornament composed of growth lines alone or well-developed spiral cords which are either grouped in center of base or evenly distributed; area around umbilicus generally without ornament; columellar lip straight and reflexed and generally at a considerable angle to base; narrowly phaner-omphalous, cryptomphalous to anomphalous.

DISCUSSION: Intraspecific variation involves changes in basal ornament, relative development of the flange, general shell shape, changes in width and position of the selenizone, and correlative selenizone characters. Although this genus ranges throughout most of the Permian, and there are several morphoclines within various populations, there appears to be little over-all directed variation, and it is quite difficult to recognize any consistent temporal changes. Two possible exceptions to this are position of whorl contact and basal cord distribution. A few members of each population of *L.*

tensity (with the exception of the area immediately surrounding the umbilicus) to evenly distributed cords, with or without intercalated threads, which become weaker in intensity towards the umbilicus.

There is some indication that the rate of coiling about the axis may vary as it does in *Glyptotomaria* (*Glyptotomaria*) *apiarium* Knight, 1945, that is, the rate of coiling is faster than the rate of descent on the axis. This can be seen in the specimens from the lower Getaway formation (see pl. 38, figs. 3 and 4).

With only a single well-represented population, it is impossible to study, critically, quantitative changes or variations between populations within this genus. It must be hoped that more material can be found. This genus is one of the more promising genera for quantitative study, as the numerous characters are so well correlated with one another and have such an important relationship with qualitative characters.

I have carefully searched the literature and have been unable to discover the existence of the genus in described faunas in other parts of the world. From the undescribed lower Triassic fauna of Kuihu Island,

Alaska, there are forms that probably are members of this genus.

It appears likely that this genus should be placed in the family Phymatopleuridae close to the genus *Discotomaria*. *Lamellospira* has many characters shared by other members of this family, in particular, *Glyptotomaria* and *Discotomaria*. These characters are: (1) a similar range of variation of basal characters; (2) almost vertical growth lines above and below the selenizone; (3) the presence of a flange which in *Discotomaria* is represented by a well-developed cord at the base of the outer whorl surface; (4) the flattened early whorls which are present in several species of *Discotomaria*; and (5) similarity of primary ornament, when present.

*Lamellospira* can be separated from *Discotomaria* and related genera by the fact that it is more high-spined and has a more fully developed flange. The ornament is not so well developed in *Lamellospira*.

**RANGE:** Approximately middle Wolfcampian through Guadalupian and possibly lower Triassic.

***Lamellospira conica* Batten, new species**

Plate 38, figures 1-17

**DESCRIPTION:** This species is characterized by being conical, with a centrally placed selenizone and a flat base. The early whorls may be flattened and expanded. Whorls are in contact either on the lower margin of the flange or on a basal cord beneath the flange. The slit appears early in the ontogeny, as evidenced by the selenizone development on the first whorl surface seen. The second to the fourth whorls generally do not have a flange, but do have a basal cord which becomes more intense ontogenetically. The selenizone is moderately wide and is located in the center of the whorl. The selenizone margins are more or less developed depending on the degree of ornamentation. The flange generally has a flat upper surface which may be ornamented by light spiral threads. From three to 14 basal cords vary in position, distribution, and intensity. Collabral ornament consists of either light threads or broad undulations. Spiral ornament, if present, is restricted to the flange or outer whorl surface near the flange. The columellar lip is reflexed and

thickened. Minutely phaneromphalous to cryptomphalous.

**DISCUSSION:** Quantitative characters that are thought to be of importance specifically and that appear to be correlated with the qualitative characters that exhibit the greatest degree of variability are: (1) whorl height related to whorl width; (2) whorl height related to the areal width beneath the selenizone; (3) whorl height related to the width of the area between the suture and the selenizone; and (4) whorl height related to selenizone width. Whorl width related to the characters above show the same type of variation. On the whole, most of the above sets of characters are well correlated.

Those forms having the planispiral type of early whorls appear to have a different range of variation from forms possessing normal orthostrophic early whorls, even though both types appear in the same populations. This difference is particularly noticeable in the character sets mentioned above. For example, successive whorl widths plotted against successive selenizone widths indicate that allometrically and allomorphologically the planispiral type is less variable and the width is proportionally greater than the selenizone width. A comparison of the successive widths of the area beneath the selenizone to the selenizone widths indicates that in the early stages of growth there is a proportionately faster rate of growth of the selenizone width in the planispiral type.

Successive whorl heights and widths are the most highly correlated character set, but variability is low. From observation and from the construction of 36 bivariate plots that involved the nine separate characters measured, it was noticed that the planispiral type in all populations differs from the other type and is smaller in size. However, it has been found that the samples of the two types were drawn from the same statistical population. Thus there is quantitative and qualitative overlap of the two groups. Interpretation of the existence of these two groups is difficult. However, three possible explanations can be made: (1) they represent male and female forms; (2) the early developmental stages differ in the two types owing to slightly different early environments; (3) they were planktonic and spent different lengths of time in

TABLE 17

MEASUREMENTS (IN MILLIMETERS) OF A SINGLE SAMPLE OF *Lamellospira conica* BATTEN,  
NEW SPECIES, FROM A.M.N.H. 512, LOWER GETAWAY FORMATION

Each Whorl								SW	WBC	CSS	CBS	H	W
H	0.5	0.75	1.2	1.9	2.7	4.2	—	0.9	0.9	1.0	1.4	11.5	11.7
W	0.9	1.8	3.0	5.0	7.9	11.7	—						
H	—	—	2.5	3.7	4.8	—	—	0.9	0.9	1.2	1.7	—	—
W	—	4.5	6.9	10.3	15.2	—	—						
H	—	1.4	2.1	3.3	5.0	—	—	1.1	0.8	1.4	1.7	—	15.0
W	1.6	3.2	6.5	10.5	15.0	—	—						
H	0.3	0.6	1.05	1.5	2.0	2.7	3.75	0.9	0.7	1.0	1.2	13.5	11.5
W	1.1	1.7	2.6	3.8	5.55	9.4	11.5						
H	0.5	0.8	1.1	1.7	2.5	—	—	0.75	0.9	1.0	0.9	11.1	11.5
W	1.2	1.8	2.7	4.2	7.4	11.5	—						
H	0.8	1.1	1.7	2.5	3.9	5.5	—	1.2	1.1	1.7	1.85	17.4	17.4
W	1.6	2.7	4.4	7.0	11.5	17.7	—						
H	0.4	0.9	1.3	1.8	2.6	3.5	—	1.1	1.1	1.2	1.7	—	—
W	1.0	2.1	3.1	4.7	7.7	10.9	—						
H	—	0.6	1.0	1.5	2.1	3.3	—	0.7	0.7	0.8	1.05	10.0	10.6
W	0.6	1.5	2.5	4.2	6.7	10.6	—						
H	0.4	0.6	1.1	1.6	2.4	3.7	—	0.7	0.7	1.0	1.3	10.6	11.0
W	1.1	1.8	2.8	4.5	—	11.0	—						
H	0.5	0.9	1.2	1.85	2.5	3.7	—	0.65	0.8	1.1	1.1	11.8	11.3
W	1.2	2.1	3.4	5.0	7.8	11.3	—						
H	—	—	1.0	1.7	2.5	3.5	—	0.75	0.7	0.7	1.3	11.4	10.7
W	1.2	1.7	2.2	3.1	4.7	7.3	—						
H	0.6	1.0	1.5	2.0	—	—	—	0.5	0.4	0.5	0.6	6.4	6.1
W	1.1	1.7	2.7	6.1	—	—	—						
H	0.2	0.3	0.5	1.1	1.5	2.3	—	1.0	1.0	1.3	1.6	14.5	14.8
W	0.6	1.05	1.4	2.8	4.0	6.4	—						
H	0.3	0.6	0.8	1.3	1.8	—	—	0.45	0.3	0.55	0.5	5.5	6.0
W	1.2	1.4	2.3	3.8	6.0	—	—						
H	0.4	0.5	0.7	1.1	1.7	2.5	—	0.55	0.5	0.7	0.7	7.5	8.0
W	1.1	1.3	2.1	3.2	5.2	8.0	—						
H	—	0.5	0.9	1.35	1.9	2.45	—	0.8	1.0	—	0.9	12.3	12.5
W	—	1.6	2.5	3.8	5.7	8.4	—						
H	0.3	0.6	1.1	1.45	2.15	3.6	—	0.7	0.8	1.0	1.0	10.0	6.9
W	1.1	1.6	2.9	4.5	6.9	—	—						

TABLE 17—(Continued)

Each Whorl								SW	WBC	CSS	CBS	H	W
H	0.5	0.7	1.15	1.7	2.4	—	—	0.5	0.5	0.55	0.9	7.0	7.7
W	1.2	1.85	3.0	4.9	7.7	—	—						
H	0.35	0.5	0.8	1.2	1.85	2.8	—	0.6	0.6	0.8	0.9	8.0	8.0
W	0.95	1.3	2.1	3.3	5.1	8.0	—						
H	0.3	0.5	0.7	1.5	2.3	—	—	0.45	0.5	0.6	0.7	6.9	6.2
W	1.1	1.3	1.9	2.3	4.4	6.2	—						
H	0.5	0.75	1.0	1.45	2.15	—	—	0.45	0.4	0.6	0.75	6.3	6.3
W	1.1	1.9	2.8	4.1	6.3	—	—						
H	0.35	0.65	1.0	1.4	—	—	—	0.3	0.2	0.4	0.4	3.8	3.9
W	1.2	1.6	2.5	3.9	—	—	—						
<i>N</i>		H		115	<i>N</i>			22	22	21	22	19	20
		W		120									
Total		H		183.70	Total			15.95	15.50	19.10	24.15	185.50	197.10
		W		525.60									
Average		H		1.60	Average			0.725	0.70	0.91	1.10	9.76	9.85
		W		4.38									
<i>S.D.</i>		H		0.2728	<i>S.D.</i>			0.376	0.323	0.455	0.543	3.52	4.40
		W		1.083									
<i>S.E. (m)</i>		H		0.0254	<i>S.E. (m)</i>			0.080	0.069	0.099	0.116	0.807	0.982
		W		0.312									

the plankton. The largest population of this species comes from the lower Getaway patch reef, and about 20 per cent of the representatives are of the planispiral type.

Perhaps the most obvious qualitative character exhibiting a wide range of variation is the spiral ornament on the base. There is a sequence of conditions ranging from a smooth-based type to one having as many as 14 evenly spaced spiral cords of nearly equal strength to one possessing a few spiral cords near the flange, with a few very fine threads near the umbilicus. In some intermediate forms the spiral cords may be clustered midway between the flange and the umbilicus. Another series of variants is involved in the position of whorl contact, which varies from a contact on the outer flange edge, giving the whole shell an even cone shape, to a contact on a prominent basal cord just under the flange (see pl. 38, fig. 15), giving the shell an

almost step-like appearance. In some cases this latter condition exists in the earlier whorls, with a contact-of-flange type in the later whorls (see pl. 38, fig. 3). All the above stated conditions can be found within a single population and thus represent morphoclines, as there is an overlapping sequence of variants. It appears likely that there is a tendency for the contact-of-the-lower-basal-cord type to be found in the older populations.

Spiral threads are variable in populations. There are usually from three to eight spiral threads on the outer surface of the flange. There are from two to four spiral threads on the lower outer whorl surface or on the proximal portion of the flange, if they are present at all.

RANGE: Upper Wolfcampian through middle Guadalupian.

OCCURRENCE: The hypodigm consists of 95 specimens: U.S.N.M. 707d, two; U.S.N.M.



716, two; U.S.N.M. 702, 13; U.S.N.M. 703b, one; U.S.N.M. 703a, five; A.M.N.H. 678, three; U.S.N.M. 703, seven; A.M.N.H. 512b, two; U.S.N.M. 728, 11; A.M.N.H. 512, 47; A.M.N.H. 369, two.

CATALOGUED SPECIMENS: Holotype, A.M.N.H. No. 28054; figured paratypes, U.S.N.M. Nos. 133333a, 133333b, 133334, 133335a, 133335b, 133336; A.M.N.H. Nos. 28054:1-28054:5, and 28055:1.

*Lamellospira cincta* Batten, new species

Plate 38, figures 18-20

DESCRIPTION: This species has a step-like, conical shell shape. The whorls are in contact on the under side of the flange. The whorl profile is flattened and almost vertical. The selenizone is gently concave, with weak margins, is raised slightly above the general whorl surface, and is located a short distance down from the suture. The ornament above the base consists of very fine collabral threads and broad collabral undulations above the

*L. conica*. I have plotted the ontogenetic characters on a scattergram, and the scatter is sharply different from that of *L. conica* on the following characters: selenizone width against width of the area beneath the selenizone; width of area above selenizone against width of area beneath the selenizone; width of succeeding whorls against width of area above selenizone; height of succeeding whorls to width of succeeding selenizone width; height of whorls to width of area above the selenizone—in other words, most of the characters having to do with the general position and width of the selenizone on the whorl face.

In qualitative characters having to do with ornament, there are sharp differences, particularly in the ornament or lack of it on the base. In *L. conica* there is always some strong ornament of some type, particularly of the spiral cord variety. In *L. cincta* the rather well-developed spiral threads observed at the base of the outer whorl face are stronger than in the populations of *L. conica*.

TABLE 18

MEASUREMENTS (IN MILLIMETERS) OF *Lamellospira cincta* BATTEN, NEW SPECIES

	Early Whorls							H	W	SW	WBC	DSS	DBS
H	0.4	0.7	1.0	1.5	2.05	3.3	4.7	13.2	14.4	0.7	1.2	0.7	2.10
W	0.7	1.4	2.3	3.8	6.7	10.5	14.4						

selenizone, becoming more sharply defined below the selenizone approaching the flange. The spiral ornament above the base consists of a few spiral threads at the whorl base and near the inner edge of the concave upper surface of the flange. The flange appears to have very weak spiral threads developed on the edge and collabral cords. The base is smooth and strongly depressed, with a sharp groove just under the inner lower margin of the flange. The depression itself is flattened or gently concave in the area near the columellar lip. The parietal inductra is thin. Anomphalous.

DISCUSSION: This species is known from but a single specimen, and the above description applies only to this specimen. It is generally undesirable to describe the characters of a species from a single specimen, but there can be little doubt that it is not a member of

*Lamellospira cincta* is similar to *L. conica* in having the broad undulations on the outer whorl face, in the general shape of the aperture, in having a well-developed flange, and in the uniquely vertical growth lines so characteristic of this genus.

RANGE: Lower Word formation.

OCCURRENCE: One specimen from U.S.N.M. 703, Word formation (limestone no. 1).

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133337.

FAMILY EOTOMARIIDAE WENZ, 1938

DESCRIPTION: Low- to high-spired pleurotomarians with weakly to strongly bordered selenizones located either at mid-whorl or on the periphery. The sutures are generally well impressed, and the whorls are inflated and globose to flattened. Ornament, if present, consists of rather light collabral elements.

The slit may be either extremely narrow and deep or wide and shallow. The genera are anomphalous to widely phaneromphalous.

**DISCUSSION:** This is a highly variable family which spans the entire Paleozoic and a part of the Mesozoic. Genera of the family are rather common elements of Paleozoic gastropod faunas. *Mourlonia* Koninck, 1883, is one of the longest ranging gastropod genera to be found in the Paleozoic (middle Ordovician through Permian). The family includes two sinistrally coiled genera. There seems to be within the genera a number of rather stable species.

The first recognized genus, *Taeniospira* Ulrich and Bridge, 1931, is seemingly restricted to the upper Cambrian. The selenizone is centrally placed on the whorl, and the slit is moderately wide and not very deep. The selenizone itself is raised above the surface of the whorl. This genus may have given rise to *Mourlonia* and *Eotomaria* Ulrich and Scofield, 1897, sometime during the early or middle Ordovician. Species of *Mourlonia* developed many variations which were later changed and enhanced as evidenced by diverging genera from this stock.

There are three subfamilies included within the family. Subfamily Eotomariinae Wenz, 1938, includes genera that are rather low-spired, with globose, flattened, or step-like whorls. Subfamily Neilsoniinae Knight, 1956, includes genera that are rather high-spired, with a relatively wide selenizone, and the subfamily Agnesinae Knight, 1956, includes two genera of sinistrally coiled forms which in other respects resemble those of the subfamily Neilsoniinae.

**RANGE:** Upper Cambrian through lower Triassic.

#### SUBFAMILY EOTOMARIINAE WENZ, 1938

**DESCRIPTION:** Low- to moderately high-spired pleurotomarians with globose to flattened whorls and a selenizone located about mid-whorl or on the periphery. Fine to coarse collabral ornament is usually dominant. Growth lines are increasingly opisthocline from the suture to the selenizone and prosocline from the selenizone to the base. The base is flat to rounded. Genera are anomphalous to widely phaneromphalous.

**DISCUSSION:** This subfamily has been di-

vided into two tribes which are described below. The tribe Ptychomphalides Wenz, 1938, has among other significant characters a selenizone margin which is usually complicated by having multiple elements or overgrowths that obscure a portion of the selenizone. Other than fine spiral threads, most variations in ornament are restricted to changes of the collabral elements. Within the tribe Eotomariides Wenz, 1938, if ornament is light the collabral elements are dominant, but if ornament is more intense there is a tendency towards reticulation. The selenizone margin in this tribe is simple and is formed by unornamented cords or threads.

An apparently undescribed genus related to *Euconospira* Ulrich and Scofield, 1897, has been found in collections from the lower Triassic of Alaska. It has rather strong collabral cords and a globose whorl profile. This extends the range of the family into the Triassic.

**RANGE:** Upper Cambrian through lower Triassic.

#### TRIBE PTYCHOMPHALIDES WENZ, 1938

**DESCRIPTION:** Turbiniform to trochiform pleurotomarians with dominant collabral ornament consisting of fine to moderately coarse elements. Spiral ornament may be present but is never dominant. Pronounced costae or cords are restricted to a few species. The depth of the slit is variable, and the selenizone is situated on the periphery or slightly above and is usually strongly bordered and concave. The selenizone margin is usually complex and consists of several components closely or widely separated, the lower margin in some groups being wider and more complex than the upper. The genera are anomphalous to widely phaneromphalous.

**DISCUSSION:** This tribe contains species having rare individuals which have the color pattern preserved. The general pattern consists of enlarged areas that extend downward from the suture and are either parallel to the growth lines or are normal to them. The darkest coloration occurs near the suture and along the margins of the areas. The patterns (see pl. 39) are quite variable, even within a single population.

The known variations of the genera indi-

cate that they have small character ranges except in a few species of *Euconospira* Ulrich, in Ulrich and Scofield, 1897, and *Shwedagonia* Batten, 1956. These two genera contain species that have rather heavy collabral ornament and some development of spiral ornament. *Euconospira* is the only known genus of the family that contains forms having flattened whorls and a flattened base.

RANGE: Upper Cambrian to lower Triassic.

**SPIROSCALA** KNIGHT, 1945

TYPE SPECIES: *Spiroscala pagoda* Knight, 1945.

DIAGNOSIS: Relatively high-spired, cone-shaped pleurotomarians with sharp, flange-like cords bordering a selenizone located just above periphery; whorl profile convexo-concave from suture to selenizone; sutures sharply incised; whorls in contact on periphery just below a trough separating lower selenizone margin from base; moderately spaced collabral ornament dominant; spiral ornament usually fine threads on concave portion of whorl profile and coarse threads on convex portion; selenizone relatively narrow and concave but may be wide, with less pronounced borders; lunulae composed of fine collabral threads or growth lines; selenizone margin seemingly made of several fine, plate-like extensions of shell edge forming flanges which in fullest development may obscure part of selenizone; base flatly rounded to flat; columellar lip straight and reflexed about umbilicus; commonly phaneromphalous.

DISCUSSION: A full discussion of comparisons and referred species is given by Knight (1945, p. 574). This genus displays many of the characteristics of the selenizone margin found in other members of the tribe Ptychomphalides. The mantle edge about the slit created a rather complex border to the selenizone in the form of a series of thin blade-like deposits. This type of margin is common and quite variable within the tribe but, with few exceptions, does not appear to have any specific taxonomic value. Within a single population there may be a very narrow selenizone with thick, leaved borders or a wider selenizone with rather thin margins. As in other genera of the tribe the variable margin is probably restricted to the outer shell layer, being deposited by the mantle edge rather

than by the shell secreting glands on the outer surface of the mantle. Color pattern has not been observed in this genus.

The genus could have been derived from *Euconospira* Ulrich, in Ulrich and Scofield, 1897, which it most closely resembles. It is distinguished from *Euconospira* by virtue of its having an enlarged, flange-like, selenizone margin, a higher spire, stronger ornament, and more whorls. The genus is a rather rare element in the faunas throughout its range. In the United States National Museum collections there are but 10 specimens from the Mississippian and Pennsylvanian and seven from the Permian.

RANGE: Mississippian through Middle Permian.

***Spiroscala pulchra*** Batten, new species

Plate 39, figures 1-2

DESCRIPTION: This species is characterized by having a thin, flange-like, selenizone margin, a relatively wide selenizone, and a rather broad trough located just beneath the lower selenizone margin. The spire is generally somewhat higher than in *S. pagoda*. The selenizone margin appears to consist of a series of thin, plate-like deposits which become progressively shorter towards the selenizone owing to the secretion of shell by the mantle edge. Ornament above the selenizone consists of collabral cords which become less pronounced near the selenizone. Spiral threads are usually found on the convex surface of the whorl profile. The selenizone is flat to gently concave, with apparent widening near the slit owing to a decreased accretion of the margin, and bears lunulae developed by light collabral threads and growth lines. The base is rather flat, with dominant collabral ornament and fine spiral threads. The parietal lip is not well preserved but appears to have a thin inductura, with the ornament preserved.

DISCUSSION: Some variation has been observed in the ornament of *S. pulchra*, particularly on the base. Collabral elements are usually dominant, but some individuals may have growth lines only. Greatest variation is found in the area between the top of the selenizone margin and the selenizone. The selenizone may be partly covered by the deposits of the mantle edge forming the margin, so that it may appear to be narrower than it

actually is and the border as a result may appear to be thick.

In general, the selenizone margin of the species is thinner and more outstanding than in *S. pagoda*. Thus the selenizone margin is more prominent, and the selenizone appears to be wider. The trough underlying the selenizone in this species is much more pronounced and wider than in the type species.

rounded to flatly rounded with collabral ornament; widely phaneromphalous; sutures within umbilicus are deep and sharp; columellar lip is reflexed; lower lip is deflected; parietal lip with ornament covered by a thin inductura.

DISCUSSION: This genus was probably derived from *Mourlonia* Koninck, 1883. The general shape, variation, and ornament pat-

TABLE 19  
MEASUREMENTS (IN MILLIMETERS) OF *Spiroscala pulchra* BATTEN, NEW SPECIES

Locality	H	W	SS	CS	SW
U.S.N.M. 707e	18.40	14.50	2.32	1.45	0.36
U.S.N.M. 703	21.3	15.30	2.72	1.77	0.44
U.S.N.M. 702	11.8	8.40	1.17	1.01	0.29
P.U. 3	28.7	17.95	4.13	2.36	0.29

RANGE: Lower Leonard through Word number 1.

OCCURRENCE: The hypodigm consists of seven specimens from the following localities: U.S.N.M. 707e, two; U.S.N.M. 703, two; P.U. 3, one; U.S.N.M. 702, one; U.S.N.M. 706c, one.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133316.

#### SHWEDAGONIA BATTEN, 1956

TYPE SPECIES: *Shwedagonia elegans* Batten, 1956.

DIAGNOSIS: Low- to relatively high-spined pleurotomarians with a very deep, narrow slit generating a narrow selenizone, a wide umbilicus, usually dominant collabral ornament, and rounded whorls; shell profile varies from straight to concave; protoconch smooth; sutures deep and sharply incised; whorl profile rounded; a deep, narrow slit about eight-tenths of a whorl in depth forms a slightly depressed, concave selenizone with lunulae consisting of growth lines alone; upper selenizone margin a sharp, flattened carina; below slit a flat unornamented area with strongly prosocline growth lines; just below this area there is a very deep, sharp trough followed by a lower selenizone margin similar to upper selenizone margin (pl. 39, fig. 7); a shallow trough and an enlarged cord present and ornamented by both spiral and collabral ornament just under lower selenizone margin; base

terns suggest close affinities, but the genera are distinguishable by the much more complex areas surrounding the selenizone in *Shwedagonia*. Some variants within *Euconospira pulchra* have a tendency to develop a rather complicated interselenizone area and a selenizone margin formed by the introduction of a laminated type of margin (see p. 230) which is quite similar to that found in this genus. The interselenizone area of *Euconospira* tends to have flat areas both above and below the slit. *Euconospira* consistently has a narrower umbilicus and a more nearly flattened base. The axial spiral angle (see p. 176) is more nearly uniform than in *Shwedagonia*. *Shwedagonia* has a selenizone placed much higher on the whorl. The base of *Euconospira* has rarely any ornament other than growth lines.

The general shape and ornament of *Spiroraphella wongi* Grabau, 1936, suggest affinities with *Shwedagonia mariana* (Gemmellaro); the selenizone and the shell around the selenizone in the latter species are identical to those found in *Shwedagonia elegans*. In his description of *Spiroraphella wongi*, Grabau (1936, p. 305) mentions that there was a vague suggestion of a cord just beneath the lower selenizone margin. His material was poorly preserved, and the illustrations and description are not adequate to confirm this observation. If he was correct, *Spiroraphella wongi* should be included in the genus

*Shwedagonia*. Because significant characters of the type species of *Spiroraphella* are identical to those exhibited by *Mourlonia*, it is considered a synonym of that genus.

Both the upper and lower margins of the selenizone of *Shwedagonia* and the area just under the slit are confined to the outer shell layer and are not reflected in the inner shell layer. It appears that only the selenizone itself is impressed on the inner shell layer (see pl. 39, fig. 10).

The ornament is quite variable in this genus and ranges from smooth forms such as *S. mariana* to forms having heavy collabral ornament such as *S. elegans*. The color pattern is similar to the type found in *Euconospira* and consists of large pigmented areas located near the suture and extending downward normal to the growth lines.

The most obvious variation within this genus is an apparent change in the axial spiral angle and in volume with growth. It is thought that these changes cause, in part, the concave shell profile. The last whorl or two are larger in proportion than any of the other earlier whorls. This change affects the suture ratios and height-width of the whorls (see fig. 16).

RANGE: Wolfcampian through lower Guadalupian.

INCLUDED SPECIES: *Ptychomphalina mariana* Gemmellaro, 1885; ?*Pleurotomaria euglyphaea* Girty, 1909 (in part); and *Spiroraphella wongi* Grabau, 1936.

***Shwedagonia elegans* Batten, 1956**

Plate 39, figures 3-8, 11-17

DESCRIPTION: This species has rather strong collabral cords above the selenizone and on the base. There may be weakly developed, fine, spiral threads both above and below the selenizone. The base is rounded, with the collabral cords extending from the lower side of the heavy cord just below the selenizone to the edge of the very wide umbilicus. This cord forms the lower edge of the rounded whorl profile. The most outstanding feature of the species is the extremely varied shell shape which ranged from low-spined with concave sides to relatively high-spined forms with straight sides. Specimens are usually widely phaneromphalous.

DISCUSSION: *Shwedagonia mariana* (Gemmellaro), 1885, can be distinguished from this species by the lack of ornament other than growth lines. It has a much more narrow um-

TABLE 20  
MEASUREMENTS (IN MILLIMETERS) OF TWO SAMPLES ONLY OF *Shwedagonia elegans* BATTEN, 1956

	H	W	SS	CS	SE	CBS	Wh	SR
U.S.N.M. 702								
(base of upper Leonard)	13.75	14.35	1.68	0.12	0.30	0.50	0.56	1.44
	—	—	1.22	0.12	0.20	0.42	0.42	—
	—	—	1.28	0.06	0.12	0.42	0.42	1.61
	12.31	13.91	1.44	0.12	0.12	0.56	0.42	1.38
	13.75	—	1.14	0.12	0.10	0.42	0.42	1.48
	—	13.33	1.28	0.06	0.12	0.42	0.50	1.55
	8.13	9.72	1.00	0.12	0.12	0.34	0.28	1.46
	8.84	—	1.00	0.12	0.12	0.34	0.28	1.56
	9.56	10.85	1.00	0.06	0.12	0.34	0.34	1.41
	8.84	9.43	0.94	—	—	0.34	0.20	1.40
	7.38	7.68	0.72	0.07	0.08	0.20	0.20	1.39
	10.30	11.01	0.12	0.12	0.12	0.20	0.28	1.28
	—	—	0.56	0.08	0.10	0.20	0.24	1.40
	4.48	4.78	0.42	0.02	0.06	0.12	0.12	1.20
	6.53	6.96	0.56	0.04	0.12	0.12	0.20	1.50
	6.67	6.53	0.56	0.06	0.12	0.16	0.20	1.27
N	12	11	16	15	15	16	16	15

TABLE 20—(Continued)

	H	W	SS	CS	SE	CBS	Wh	SR
A.M.N.H. 512	14.20	14.20	1.00	—	0.20	0.42	0.72	1.41
	23.20	25.40	2.24	0.06	0.20	0.78	0.72	1.43
	19.30	20.00	2.32	0.16	0.20	0.56	0.78	1.45
	16.10	17.20	2.60	0.06	0.20	0.56	0.60	1.43
	16.40	17.40	2.32	0.12	0.16	0.64	0.64	1.57
	—	—	1.74	0.10	0.12	0.50	0.50	1.44
	12.50	13.00	1.66	0.06	0.16	0.42	0.56	1.44
	15.10	15.20	1.96	0.12	0.12	0.50	0.42	1.45
	14.50	14.80	1.60	0.04	0.12	0.50	0.42	1.46
	12.80	12.90	1.60	0.02	0.12	0.56	0.28	1.48
	—	—	1.60	0.12	0.12	0.42	0.42	1.66
	11.70	11.40	1.44	0.12	0.12	0.34	0.42	1.40
	11.30	11.70	1.44	0.12	0.12	0.42	0.42	1.48
	11.00	11.70	1.60	0.06	0.06	0.56	0.42	1.41
	11.20	11.30	1.44	0.12	0.12	0.34	0.42	1.49
	10.60	10.90	1.44	0.02	0.08	0.34	0.34	1.42
	9.13	9.72	1.14	0.06	0.12	0.34	0.28	1.54
	10.70	9.43	1.14	0.06	0.12	0.28	0.42	0.52
	9.13	8.54	1.22	0.06	0.12	0.20	0.34	1.43
	5.80	5.23	0.78	0.06	0.10	0.12	0.12	1.56
	10.40	10.40	1.36	0.10	0.12	0.28	0.42	1.42
	8.40	8.54	1.08	0.06	0.10	0.32	0.32	1.38
	7.96	7.54	1.08	0.06	0.06	0.28	0.28	1.50
	9.71	9.43	1.43	0.06	0.08	0.34	0.28	1.38
	7.97	7.10	1.00	0.06	0.08	0.20	0.28	1.49
	7.40	6.53	0.94	—	0.04	0.12	0.28	1.62
	7.38	5.66	0.64	0.06	0.04	0.12	0.12	1.38
	6.53	6.37	0.86	0.06	0.06	0.28	0.20	1.55
	6.23	5.94	0.94	0.06	0.08	0.20	0.20	1.39
	17.10	20.30	2.16	0.12	0.20	0.64	0.56	1.35
<i>N</i>	28	28	30	28	30	30	30	30
$\bar{x}$	11.57	11.71	1.46	0.07	0.12	0.37	0.41	1.46
<i>S.D.</i>	1.27	4.41	0.42			0.48	0.23	
<i>S.E. (m)</i>	0.045	0.16	0.014			0.002	0.008	

bilicus and a smoother, somewhat flatter base than *S. elegans* (pl. 39, fig. 9).

There is a definite trend in the shell shape throughout the observed range of the species, and it is possible to distinguish pre-Guadalupean forms from Guadalupean forms on this basis. In the Wolfcampian, specimens of *S. pulchra* are very low-spined, with a rather sharp, narrow spire (pl. 39, figs. 3–4). The last several whorls are very much larger in proportion to the earlier whorls. By Leonardian time, the spire is higher, but there still is a sudden change in volume between the earlier

and later whorls (pl. 39, figs. 7–8), and sides of the shell are still concave at this stage. By Guadalupean time, the sides of the shell are almost straight, and the proportion of area and volume between the earlier and later whorls is more nearly uniform (pl. 39, fig. 15).

In the plotting of suture ratios from two samples, A.M.N.H. 512 and U.S.N.M. 703a, it was noticed that at the point where there is a change in shape and proportion the suture ratio gradually becomes numerically smaller. Ratios on either side of this point are

about the same. One specimen from U.S.N.M. 703a has the following suture ratios, from the earliest whorls downward: 1.50 mm., 1.19 mm., 1.12 mm., 1.29 mm., and 1.50 mm. At approximately the whorl with suture ratio of 1.12 the sides of the shell become convex and the area and volume increase gradually compared to early whorls. At A.M.N.H. 512, of Guadalupian age, the same decrease has been observed but it is not so sharp a change. Thus there is an indication in the suture ratios of the change observed between the early whorls and the later whorls. This set of data is not precise; in many cases this decrease was not observed, in part owing to errors of measurement.

The height and width of each whorl for several specimens in the samples mentioned above were plotted on log paper. A definite change in the growth pattern was observed at about the second to third whorls and the sixth to seventh whorls in the sample from U.S.N.M. 703a. There is a sudden decrease in rate of growth of height at the second to third whorl, and an increase at the sixth to seventh whorl. At this later point the shell changes from a concave-sided cone to a convex one. (See fig. 16 and p. 176.)

The most significant quantitative characters are height, width, and distance between the suture and selenizone, width of the trough under the selenizone, and width of the flat area just under the slit. These characters are also the best discriminatory characteristics, with the height and width being the best correlated characters.

RANGE: Wolfcampian through Guadalupian.

OCCURRENCE: U.S.N.M. 702, 64; U.S.N.M. 702un, one; U.S.N.M. 702 low, two; U.S.N.M. 702c, two; U.S.N.M. 702a, three; U.S.N.M. 701L, one; U.S.N.M. 703, three; A.M.N.H. 503, six; U.S.N.M. 703a, 49; U.S.N.M. 703b, 58; U.S.N.M. 703c, one; U.S.N.M. 706e, one; U.S.N.M. 707b, 32; U.S.N.M. 708, one; A.M.N.H. 504, one; A.M.N.H. 678, two; A.M.N.H. 655, seven; A.M.N.H. 512, 35; U.S.N.M. 728, 47.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 125279; figured paratypes, U.S.N.M. Nos. 133316, 133317a, 133317b, 133318, 133319a, 133319b; A.M.N.H. No. 28056:1. Hypotypes, U.S.N.M. Nos. 133322a and 133322b.

**EUCONOSPIRA** ULRICH, IN ULRICH AND SCOFFIELD, 1897

TYPE SPECIES: *Pleurotomaria turbiniformis* Meek and Worthen (1861, p. 461).

DIAGNOSIS: Moderately high-spined pleurotomarians with a rounded to flattened whorl profile, rounded to flatly rounded base, a deep slit, and a selenizone on or just above angular periphery; growth lines increasingly opisthocline to selenizone and prosocline to base; depth of slit variable, but always rather deep; selenizone margin varying from a light thread to a flange composed of several blade-like components, lower margin tending to be heavier; selenizone narrow, lunulae composed of growth lines or light threads reflecting collabral ornament; collabral ornament dominant; columellar lip thickened and slightly reflexed; parietal lip with partially resorbed ornament; umbilicus anomphalous or narrowly phaneromphalous, with or without an umbilical callus.

DISCUSSION: This common upper Paleozoic genus has a world-wide distribution and is usually found in dominantly calcareous facies. *Euconospira* is closely related to *Shwedagonia*, but tends to have a flattened whorl profile and a simply constructed lower selenizone margin. The selenizone is generally lower on the whorl, either on or just above the periphery. *Spiroscala* has more whorls, a flange-like selenizone margin, and stronger ornament. All three genera are rather closely related and have, in several characters, similar chronoclines.

There is considerable variation within species, particularly in the upper Pennsylvanian and Permian. The most important of these variations occurs in the selenizone margin, which may be thin or thick, so that a portion of the selenizone may be obscured. The selenizone may be raised, with rather heavy margins, or it may be depressed beneath the whorl surface, with very weakly developed margins. In conjunction with this type of variation there is a change in whorl profile. The details of ornament and color pattern are also variable. Many of these variations may occur within single populations.

RANGE: Mississippian through Permian.

***Euconospira pulchra*** Batten, new species

Plate 39, figures 24–25; plate 40, figures 1–9

DESCRIPTION: The protoconch of this spe-

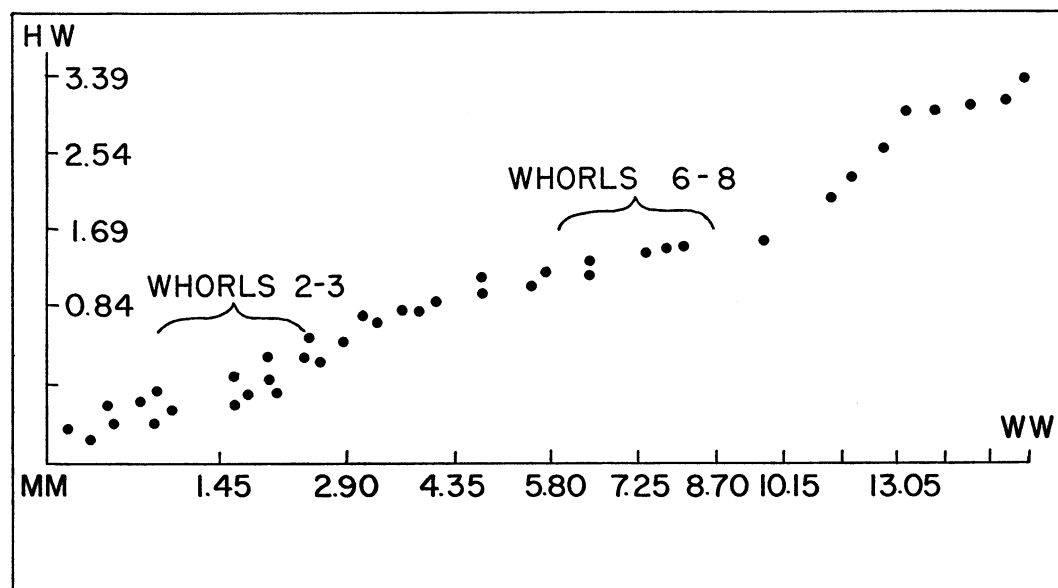
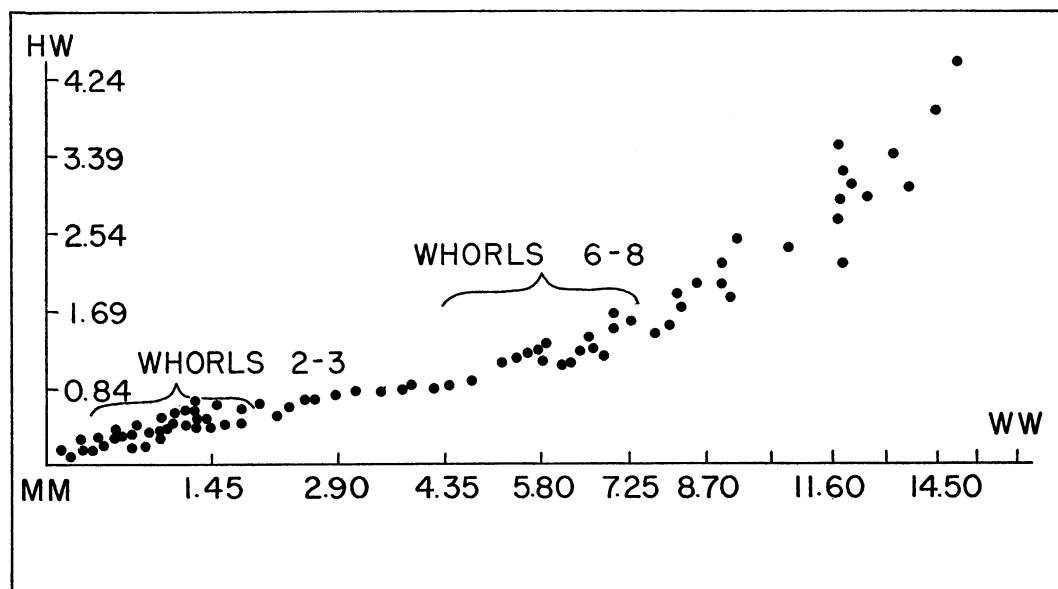


FIG. 16. Two graphs showing the height and width of successive whorls of *Shwedagonia elegans*. The upper graph is a sample from U.S.N.M. 703a and the lower a sample from A.M.N.H. 512. The whorl width is plotted on a logarithmic scale to reduce the effect of growth irregularities.

cies is simple and with growth lines alone. Sutures are sharply incised and rather deep. Whorls are in contact at the angular periphery or on the lower selenizone margin. The whorls are flattened to inflated, with a flatly rounded to flat base. The flat to concave

selenizone is located on an angular periphery or slightly above and may be depressed beneath the whorl surface, flush or elevated above it. The selenizone margins are moderately well-developed cords which may be thin and flange-like, or thickened and wide, with



the lower margin generally more complex in construction. The ornament consists of dominant collabral elements, but spiral ornament may be as strongly developed; in some cases reticulation may form. The columellar lip is reflexed. Specimens may be anomphalous to narrowly phaneromphalous.

**DISCUSSION:** Of the several species of *Euconospira* described from the Permian, *E. obsoleta* Girty, 1909, from the Guadalupian seems to be most like *E. pulchra*, but the few specimens available for study, including the types, are so poor that it is difficult to make comparisons except for gross outline. *Euconospira pulchra* has a more globose whorl profile and considerable more variation and differentiation in the thickness of the selenizone margins than does *E. obsoleta*. *Euconospira permiana* Grabau, 1936, resembles *E. turbiniformis* more closely than it does *E. pulchra*. An undescribed species from the Permian of the Crimea appears to be very close to *E. pulchra*, especially in the whorl shape and development of the selenizone margins. It is quite probably the same species.

The selenizone and associated characters are known to be highly variable in the moulonids. *Euconospira pulchra* displays this variation more clearly than any other species within this group. Much caution should be used in the proper interpretation of these characters, because any attrition completely changes the expression of the selenizone margins. In unworn material the selenizone margins are tapering and well developed, with a flattened area in the same plane as the selenizone on either side of the slit under the margins. This flattened area in some variants may be developed so that it is in the same plane as the lower selenizone margin, thus causing the false impression that the specimen displays a more fully developed lower selenizone margin (see pl. 39, fig. 24). The flattened area developed when the selenizone margins were formed and *before* the slit was healed (see pl. 40, fig. 4). Owing to attrition and recrystallization, the margins may appear as two massive cords, and thus the specimens may be mistaken for other species of the genus (see pl. 40, fig. 6). The flattened area tends to develop as a stronger element in the lower portion of the selenizone area.

The only apparent trend observed in this

species is a gradual dominance of globose forms with time. Populations with flattened bases and whorl profiles appear to be restricted to the Wolfcampian. These forms may have spiral ornament which may form reticulation with collabral elements. The first globose forms to appear have dominant collabral ornament and very well-developed, flange-like, selenizone margins. These forms have been found in the uppermost Wolfcampian (*Orthotichia* bed of the Glass Mountains) and in younger beds.

Color pattern consists of large, dark, elongated masses which extend downward from the suture and expand towards the selenizone. The darkest areas are around the edges of the mass. There is considerable variation, however, and much overlap in pattern with other species.

Variation in intensity of collabral ornament is considerable, ranging from delicate threads to exceedingly strong, cup-shaped ridges similar to the ornament in the genus *Melongena* (see pl. 39, fig. 24).

**RANGE:** Wolfcampian through Guadalupian.

**OCCURRENCE:** The hypodigm consists of the following: U.S.N.M. 701e, three; U.S.N.M. 701f, two; U.S.N.M. 702, four; U.S.N.M. 702c, four; U.S.N.M. 702d, six; U.S.N.M. 721, two; U.S.N.M. 707d, four; U.S.N.M. 707a, one; U.S.N.M. 703b, two; U.S.N.M. 703a, 45; U.S.N.M. 703, four; U.S.N.M. 703c, one; A.M.N.H. 503, three; U.S.N.M. 728, two.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133321b; figured paratypes, U.S.N.M. Nos. 133321a, 133323, 133324a, 133324b, 133325a, 133325b, 133326, 133327, and 133328.

***Euconospira spiroperforata*** Batten, new species

Plate 39, figure 23; plate 40, figures 12-14

**DESCRIPTION:** This species characteristically has a flattened to a convex whorl profile, with a slightly convex surface near the suture and a concave surface near the selenizone. The flat to concave selenizone is located just above the angular periphery and is usually in the same plane as the whorl surface. The selenizone margin is composed of weakly developed threads or none at all. Beneath the selenizone the whorl becomes al-

TABLE 21  
MEASUREMENTS (IN MILLIMETERS) OF *Euconospira pulchra* BATTEN, NEW SPECIES, FROM A  
SAMPLE AT U.S.N.M. 703A

H	W	SS	SW	Wh	SR
20.14	20.14	4.08	0.20	0.94	1.46
20.14	—	4.48	0.56	1.08	1.48
13.03	13.47	2.17	0.24	0.78	1.42
—	—	8.70	0.56	1.88	—
—	—	3.86	0.34	1.00	1.50
13.03	13.12	3.99	0.28	0.86	1.54
—	—	2.39	0.50	0.86	1.42
12.90	11.58	2.02	—	0.56	1.38
14.50	13.03	2.75	0.28	0.86	1.45
13.91	13.32	2.39	0.12	0.78	1.47
14.50	12.31	2.46	0.12	0.78	1.44
—	—	2.39	0.30	0.72	1.43
—	—	2.39	0.18	0.86	1.27
—	8.26	1.60	0.12	0.50	1.44
11.15	11.45	2.02	0.20	0.64	1.56
8.04	7.38	1.14	0.06	0.56	1.40
10.14	10.14	1.60	0.12	0.56	1.40
8.04	7.24	1.28	0.16	0.56	1.36
13.03	—	1.96	0.28	0.86	1.38
—	12.75	2.24	0.20	0.86	1.47

most vertical and flat. The columellar lip is highly arcuate or coiled. This tends to form an open umbilicus. The base is flatly rounded to flat. Some specimens have a thin umbilical callus which is slightly raised as a ridge, forming a corkscrew-shaped axis.

DISCUSSION: This species is readily separable from other Permian species because of the absence of ornament other than growth lines or weakly developed collabral ornament near the suture and because of the weakly developed margins to the selenizone. The color pattern is similar to the type found in *E. pulchra*, but the dark masses are narrower. The light areas have smaller, elongated color bands which are irregular and discontinuous.

Variation seems to be restricted to the development of the selenizone margins, that is,

from one with threads to one in which a raised margin is completely absent. There appears to be a trend in time for the whorls to become more convex, much like the trend in *E. pulchra*. The convex forms first appear in the upper Wolfcampian and become dominant thereafter.

The youngest recognized member of the species is found in the Carlsbad back-reef deposits of the Capitan reef. It has a simple, globose shape with no prominent ornament and with a weakly developed, thread-like, selenizone margin or no margin at all. The selenizone is depressed beneath the whorl surface.

RANGE: Wolfcampian to Guadalupian.

OCCURRENCE: The hypodigm consists of 20 specimens: U.S.N.M. 707d, five; U.S.N.M.

TABLE 22  
MEASUREMENTS (IN MILLIMETERS) OF *Euconospira spiroperforata* BATTEN, NEW SPECIES

Locality	H	W	SS	SW	Wh
A.M.N.H. 492	15.84	12.84	2.75	0.50	1.15
U.S.N.M. 702	—	—	5.50	0.86	2.15
U.S.N.M. 701g (holotype)	—	114.60	29.40	2.60	—

707b, one; U.S.N.M. 701g, one; U.S.N.M. 701f, one; U.S.N.M. 705a, four; U.S.N.M. 707b, one; U.S.N.M. 707a, four; A.M.N.H. 492, one; U.S.N.M. 702, one; A.M.N.H. 512, one.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 133332; figured paratype, U.S.N.M. No. 133331.

*Euconospira varizona* Batten, new species

Plate 39, figures 18–22; plate 40, figures 10–11

DESCRIPTION: This species has a rounded to gently flattened whorl profile and a flat to flatly rounded base. Collabral ornament is dominant and rather strongly developed compared to the spiral ornament. Spiral ornament is usually well developed near the suture and always consists of light threads. The selenizone margins are well developed, varying from relatively thin, tapering margins to

*pulchra* in having the lower selenizone margin more fully developed than the upper margin and in having rather strong collabral ornament above the selenizone. However, *E. pulchra* has a more complex development of the selenizone margins and, in particular, has the curious flattened areas within the selenizone area itself. This last characteristic is not present in *E. varizona*. This species resembles *E. spiroperforata* in having a more flattened base but heavier selenizone margins. *Euconospira varizona* always has a wider umbilicus than other species found in the Permian and does not have an umbilical callus or ridge as in *E. spiroperforata*.

Globose forms are common in the Wolfcampian, but there is no pattern in time. For example, in the lower Leonard formation some forms have a flattened base, with fine collabral threads above the selenizone and a

TABLE 23

MEASUREMENTS (IN MILLIMETERS) OF *Euconospira varizona* BATTEN, NEW SPECIES

Locality	H	W	SS	SW	Wh	SR
U.S.N.M. 701g	7.24	5.21	1.73	0.21	0.47	—
U.S.N.M. 701g	—	13.62	2.75	0.57	1.59	—
U.S.N.M. 716	—	11.36	3.63	0.58	0.45	1.38
U.S.N.M. 702	12.04	11.04	2.04	0.18	0.31	1.39
U.S.N.M. 702	17.27	19.31	3.95	0.27	0.36	1.51
U.S.N.M. 703b	14.09	15.68	3.04	0.23	0.36	1.44
U.S.N.M. 703b	21.73	24.63	5.79	0.28	1.59	—

rounded cords composed of multiple elements. The selenizone may be on the periphery or slightly above it. Lunulae may be very well displayed, thickening towards the center of the selenizone where a median thread may form (see pl. 39, fig. 21). Anomphalous to moderately phaneromphalous. The color pattern above the selenizone consists of elongated dark masses extending downward to the selenizone from the suture. Both above and below the selenizone there is a series of dark dots which are regularly spaced (pl. 39, fig. 19). Below the selenizone these dots extend below a sharp narrow trough. Basal color pattern consists of 10 to 20 alternating dark and light spiral stripes revolving in the opposite direction to the usual spiral ornament (pl. 39, fig. 20).

DISCUSSION: This species is similar to *E.*

relatively simple selenizone margin. The upper Leonard forms tend to be more inflated and have a much enlarged selenizone margin (figs. 10 and 11 of pl. 40 show how abrasion has removed the tapering, flange-like margins, causing the margins to appear wide and massive; compare this to the unworn specimen on pl. 39, fig. 21).

The presence of a rather deep trough is important, because it is a characteristic shown in all specimens regardless of the shape of the whorl profile. *Euconospira pulchra* has a much smaller and sharper trough, but it may be absent, depending on the relative position of the selenizone on the whorl.

The color pattern is unique to this species. The dots surrounding the selenizone are most characteristic, as are the basal stripes. However, the dark masses above the selen-

izone are typical of moulonids. Even within populations color pattern is highly variable, and, at present, it is best not to put too much reliance on the pattern for discrimination.

Evidence suggests that there may be a tendency for the selenizone margins to become thickened and more complex with time. Variation studies were impossible, as only very small samples were found at the numerous localities where they occur.

**RANGE:** Wolfcampian through Guadalupian.

**OCCURRENCE:** Hypodigm consists of 32 specimens; P.U. 7, one; U.S.N.M. 701f, two; U.S.N.M. 701k, 11; U.S.N.M. 701h, five; U.S.N.M. 701g, two; U.S.N.M. 716, two; U.S.N.M. 721, two; U.S.N.M. 702, four; U.S.N.M. 703b, three.

**CATALOGUED SPECIMENS:** Holotype, U.S.N.M. No. 133320a; figured paratypes, U.S.N.M. Nos. 133320b, 133329, 133330.

**EIRLYSIA BATTEN, 1956**

**TYPE SPECIES:** *Eirlysia exquisita* Batten, 1956.

**DIAGNOSIS:** Globose trochiform pleurotomarians with a variable selenizone complex located above periphery; whorl profile globose to step-like, with a convex to flattened upper whorl surface and outer whorl face; selenizone may form upper edge of outer whorl face; slit presumably moderately deep, selenizone flat or gently convex; selenizone margins composed of multiple elements, weak threads or cords; a shallow, broad trough may form beneath selenizone; flat to rounded base generally separated from outer whorl face by an angulation or basal cord; outer edge of base with a sharp, but shallow, trough; collabral ornament dominant, but spiral ornament always present and reticulation is common; parietal inductura thin to wanting; phaneroomphalous to cryptomphalous; columellar lip reflexed.

**DISCUSSION:** It was originally believed that species belonging to the genus *Lacunospira* should be included in this genus because of such similar features as the shallow trough under the selenizone and on the outer edge of the base, the general shell shape, and position of the selenizone. However, the unique pitted outer shell layer of *Lacunospira* serves to separate these two groups of species. There

is virtually no overlap in this character. *Eirlysia* has many characters shared by other members of the tribe, in particular the rounded whorl profile, development of ornament, the umbilical variations, and selenizone character complexes. It is unique in the possession of a basal trough, well-developed spiral ornament, in the extreme variation in the width and form of the selenizone, and in the well-defined basal angulation.

The following quantitative characters appear to be best for the study of variation between species: the distance between the suture and selenizone, compared to the width of the area between the lower selenizone margin and basal angulation; the selenizone width compared to the distance between the suture and the selenizone; height compared to width; and successive widths of the selenizone to whorl width ontogenetically. There is a definite change in the relationship between the height and width of the whorls, both in ontogeny and between the species. The height of the whorls increases at a faster rate than the width does.

*Pleurotomaria subheterospira* Wanner, 1942, properly belongs with this genus.

**RANGE:** Wolfcampian through Guadalupian.

***Eirlysia exquisita* Batten, 1956**

Plate 41, figures 1-6, 18

*Eirlysia exquisita* BATTEN, 1956, p. 44.

**DESCRIPTION:** The shell shape of this species varies from globose trochiform to moderately high-spined and conical. Early whorls are simple and unornamented. The whorl profile is generally convex and inflated, but may be convexo-concave. The selenizone is relatively wide and flat to slightly convex. The selenizone margins are formed by sharp threads or cords composed of two prominent elements. There is a shallow, wide trough just under the lower selenizone margin and a narrow trough just under the lower edge of the outer whorl face. The base is flat to rounded. Collabral cords or threads are usually prominent above the selenizone and reach maximum development near the suture. The lower edge of the outer whorl face is a cord which is more or less developed and has spiral threads. Spiral ornament consists of threads

TABLE 24  
MEASUREMENTS (IN MILLIMETERS) OF *Eirlysia exquisita* BATTEN, 1956

Locality		Each Whorl				H	W	CSS	SW	CBS
P.U. 3	H	0.43	0.94	1.88	—	10.14	12.90	2.17	0.87	1.59
	W	1.45	3.04	6.53	—					
P.U. 3	H	0.43	0.80	1.74	—	10.86	12.32	2.03	0.87	1.45
	W	0.72	1.45	2.76	6.60					
P.U. 3	H	0.29	0.65	1.23	2.54	12.32	12.77	2.10	0.94	1.45
	W	1.08	1.67	3.77	6.67					
P.U. 3	H	—	0.58	2.47	4.78	22.30	25.24	4.34	2.03	3.33
	W	—	2.03	4.06	7.40					
P.U. 3	H	0.43	0.87	1.88	4.77	23.62	23.35	4.06	1.45	2.90
U.S.N.M. 702	H	—	0.87	3.33	—	20.00	25.39	4.64	1.59	3.19
	W	1.30	2.90	5.80	12.32					
A.M.N.H. 512	H	0.51	0.80	1.59	3.04	16.22	17.40	3.62	1.01	1.88
	W	1.30	2.46	4.50	9.13					
A.M.N.H. 512	H	0.72	1.74	3.02	5.80	31.90	35.50	7.97	2.01	4.35
	W	2.46	5.07	9.43	18.85					

which are more strongly developed on the upper whorl surface and the base.

DISCUSSION: This species can be distinguished from other species of the genus by the weaker development of ornament and by having more globose whorls. The selenizone is wider than in other species. All species of the genus have a more or less well-developed basal cord and a wide, shallow trough under the selenizone.

There is a gradual trend towards a more high-spined or a more globose shape, with time. Over-all shell shape appears to be the most variable character. The ornament is rather conservative, and little variation was noted.

RANGE: Leonardian to Guadalupian.

OCCURRENCE: The hypodigm consists of 15 specimens; P.U. 3, six; U.S.N.M. 702, three; U.S.G.S. 14439, one; U.S.N.M. 703, two; U.S.N.M. 703c, one; A.M.N.H. 512, two.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 125282; figured paratypes, U.S.N.M. Nos. 133338, 133339, 133343; A.M.N.H. No. 28057:1.

*Eirlysia reticulata* Batten, new species

Plate 41, figures 7-17, 19

DESCRIPTION: This species has a convexo-concave to convex upper whorl surface and a generally low-spined trochiform shape. The narrow, concave selenizone forms the upper edge of the outer whorl surface. The outer whorl face is almost vertical or slopes outward. The selenizone margins are not well developed, consisting of spiral threads. There tends to be a very shallow and broad trough just under the selenizone. The lower edge of the outer whorl face may end abruptly at the base, or a broad, rounded cord may be present. There may be a trough developed on the outer edge of the base. Base is flat to flatly rounded. Moderately phaneromphalous to hemiomphalous. The spiral and collabral ornaments are equally well developed except above selenizone where the collabral elements may be more fully expressed near the suture. Ornament is resorbed in the parietal lip, and an inductura is located one-third of the distance around the columellar lip to the outer lip. A callus may be present.

TABLE 25

MEASUREMENTS (IN MILLIMETERS) OF A SAMPLE OF *Eirlysia reticulata* BATTEN, NEW SPECIES,  
FROM A.M.N.H. 512

		Each Whorl			H	W	CSS	SW	CBS
H	0.25	0.46	1.16	2.46	11.00	19.00	2.61	0.58	3.19
W	1.01	2.39	4.78	9.72					
H	0.22	0.51	1.08	2.54	11.03	—	2.32	0.80	1.74
W	1.01	2.25	4.35	7.97					
H	—	0.43	0.72	1.67	8.70	12.60	1.67	0.43	2.17
H	0.22	0.65	1.30	—	8.13	11.60	1.59	0.36	2.17
W	1.30	2.90	5.65	—					
H	0.29	0.51	1.45	—	6.24	9.71	1.30	0.29	1.74
W	0.87	2.03	4.93	—					
H	—	0.43	1.01	—	5.80	9.71	1.23	0.22	1.45
W	—	—	2.32	4.64					
H	0.22	0.43	1.08	—	5.80	8.84	0.80	0.29	1.74
W	1.01	2.46	4.64	—					
H	—	0.72	1.59	3.48	—	—	3.48	0.51	3.33
W	—	—	6.53	11.90					
H	0.29	0.43	1.01	—	6.23	9.71	1.30	0.39	1.67
W	1.01	2.17	4.64	—					
H	0.22	0.43	1.01	—	6.23	9.71	1.30	0.32	1.45
W	1.01	2.32	4.78	—					
H	0.14	0.36	0.87	—	5.07	7.11	0.80	0.36	0.94
W	0.87	1.74	3.33	—					
H	0.43	0.43	0.87	—	5.07	7.25	1.01	0.29	1.30
W	—	1.74	3.77	—					
<i>N</i>	H	36							
	W	32							
			<i>N</i>		11	10	12	12	12
<i>Total</i>	H	30.94	<i>Total</i>		79.30	105.24	19.41	4.84	22.89
	W	112.04	<i>Mean</i>		7.21	10.52	1.62	0.40	1.91
			<i>S.D.</i>		2.1913	3.418	0.804	0.1606	0.688
			<i>S.E. (m)</i>		0.66	1.078	0.232	0.046	0.198
<i>Mean</i>	H	0.860							
	W	3.50							
<i>S.D.</i>	H	0.742							
	W	2.66							
<i>S.E. (m)</i>	H	0.124							
	W	0.470							

**DISCUSSION:** The most important character that *E. reticulata* has which separates this species from *E. exquisita* is the reticulate nature of the ornament. Without exception the ornament is much more fully developed. Also the selenizone is narrower.

The most important quantitative characters are: height of shell to selenizone width; whorl width to whorl height; total shell width to the width of area under the selenizone; and height and width.

There appear to be several trends in this species. There is a reduction, in time, of prominent cords above the selenizone. Figure 12 of plate 41, a specimen from the upper Leonard formation, shows well-developed cords above the selenizone; figure 13 of the same plate is a specimen, from the lower Getaway formation, that lacks such cords. There is a gradual change in the whorl profile from convexo-concave to convex forming a smooth, rounded whorl profile. An important change involves the tendency for the selenizone margins to become less pronounced with time. There is also a trend for the basal trough to become shallow. Finally, there is a trend for the spire of the shell to become lower with time—unusual in gastropods.

There is a limited amount of variability in most of the populations in the Leonardian, but by middle Guadalupian time populations have considerably increased the field of variation. This is true if the population at A.M.N.H. 512 can be used as an indicator. Several complete morphoclines can be seen in this population, with several intervening forms found in the chronoclines mentioned above. The most striking morphocline is seen in the extreme variation in whorl profile and shell shape, which on the one hand is globose and on the other is almost rectilinear. An independent morphocline shows a sequence involving ornament of coarse collabral elements with well-developed selenizone margins (although not so pronounced as in the earlier representatives of the species) to evenly developed reticulation with selenizone margins equal in intensity to the spiral threads.

**RANGE:** Upper Wolfcampian through Guadalupian.

**OCCURRENCE:** The hypodigm consists of 66 specimens: U.S.N.M. 707d, one; U.S.N.M. 702, five; U.S.N.M. 703a, five; U.S.N.M. 703,

12; U.S.N.M. 703b, five; U.S.N.M. 707e, six; U.S.N.M. 706b, one; A.M.N.H. 678, three; A.M.N.H. 512, 27; P.U. 3, one.

**CATALOGUED SPECIMENS:** Holotype, A.M.N.H. No. 28058; figured paratypes, A.M.N.H. Nos. 28058:1–28058:4; U.S.N.M. Nos. 133340–133342.

***Eirlysia nodosa* Batten, new species**

Plate 41, figures 20–22

**DESCRIPTION:** This species characteristically has a rectangular outline and large rounded nodes on the upper whorl surface. The selenizone is moderately narrow, with the margins composed of rather pronounced spiral threads. Spiral and collabral threads are equally well developed both above and below the selenizone and form reticulation. There generally is no shallow trough beneath the selenizone. The basal trough, if present, is narrow and moderately deep.

**DISCUSSION:** The species is known from but two specimens, neither of which is well preserved. The shape is similar to that of rounded variants of *E. reticulata* but is readily separable from this and other species of the genus by virtue of the prominent nodes on the upper whorl surface. Several very poorly preserved forms, belonging to the genus from the upper Leonard formation, appear to have nodes, but the shape is suggestive of that of Leonardian *E. reticulata* forms. These specimens probably belong to *E. reticulata* and represent an extreme development of collabral ornament in that species. *Eirlysia nodosa* probably is not a repository for extreme nodose specimens of other species, but until more material is collected, complete understanding of the species will be lacking.

**RANGE:** Guadalupian.

**OCCURRENCE:** U.S.N.M. 706c, one; A.M.N.H. 512, two.

**CATALOGUED SPECIMENS:** Holotype,

TABLE 26  
MEASUREMENTS (IN MILLIMETERS) OF  
*Eirlysia nodosa* BATTEN, NEW SPECIES

Locality	H	W
U.S.N.M. 706c	14.00 ±	10.00 ±
A.M.N.H. 512	16.00 ±	12.00 ±

U.S.N.M. No. 133344; figured paratypes, A.M.N.H. Nos. 28059:1, 28059:2.

**LACUNOSPIRA** BATTEN, NEW GENUS

TYPE SPECIES: *Lacunospira alta* Batten, new species.

DIAGNOSIS: Globose to turbiniform pleurotomarians with flange-like selenizone margins, irregular and pitted whorl surface, and flat to convex selenizones; early whorls are globose, with selenizone in center of whorl; selenizone margins usually flange-like and overhanging, so that portions of selenizone are hidden; slit moderately deep; a broad, shallow trough is located just beneath selenizone; base flat to rounded; basal angulation always present and may be developed into a cord; widely phaneromphalous, hemiomphalous to cryptomphalous; columellar lip reflexed; parietal inductura thick; outer and inner shell layers thick and equally well developed; shell surface irregular and pitted, with growth lines obscure; ornament, if present, growth lines and light spiral threads.

DISCUSSION: The flange-like nature of the selenizone margins, plus the fact that the margins may be composed of multiple elements, indicates that this genus has typical characters of the eotomariids. The trough on the outer margin of the base and under the selenizone is quite similar to that of *Eirlysia*.

The most striking character of the genus is the unique type of shell surface. The ornament and growth lines are both highly variable in nature, ranging from fine spiral and collabral threads to a highly irregular and pitted surface, so irregular, in fact, that it is difficult to find traces of the growth lines. In *L. altsia* the surface is smooth and, in part, pitted, but it was impossible to find any indication of growth lines at all. At first it was thought that the outer shell layer was thin and not preserved, but later studies showed that there are two shell layers preserved and that this is simply an unusual development of the outer shell layer. No other variation within the family even remotely approaches this type of shell surface. *Tropidostropha* Longstaff, 1912, is the only genus of pleurotomarians which has a similar surface. In *Tropidostropha* the growth lines are developed, and the lacunae are scattered at random over the surface, both above and below the selen-

izone. The general whorl profile is similar to that of *Lacunospira*, but the selenizone appears to be convex. The whole problem of the variability in the selenizone complex must be reviewed, both in the case of *Tropidostropha* and in the eotomariids.

*Lacunospira* in other characters such as the selenizone margins and general shell shape is similar to some species of *Euconospira* and *Mourlonia*. Most variation has to do with the relative development of the selenizone margin, the width of the selenizone, and the position the selenizone occupies on the whorl. Umbilical features and the degree of reflection of the columellar lip also show considerable variability. In *L. alta* the height of the whorl appears to increase at a faster ontogenetic rate than the width, while the opposite is true of *L. altsia*. In these characters, as well as many others, *Eirlysia* and *Lacunospira* are quite similar (see fig. 17).

Early-appearing populations consist of globose forms, even in the adult stages. During Leonard time, *L. alta* developed a flattened base and a convexo-concave upper whorl surface. *Lacunospira altsia* became step-like at about the same time and has an almost rectangular whorl profile. Both species appear to become more high-spined with time.

RANGE: Wolfcampian through Guadalupian.

***Lacunospira alta* Batten, new species**

Plate 41, figure 23; plate 42, figures 2-5, 7

DESCRIPTION: This species characteristically is quite large. Early whorls are globose or sub-globose, with later whorls generally convexo-concave in profile; the whorls are in contact on the basal angulation. Selenizone margins are very prominent flanges which taper to a thin edge; the selenizone, in some cases, is slightly convex. In later whorls, the selenizone complex is extended beyond the surface of the whorl. The trough just under the lower selenizone margin is broad and fairly deep for the genus. The shell is smooth to very irregular and pitted. Growth lines actually bend around the pits or lacunae. Usually widely phaneromphalous.

DISCUSSION: This species is distinguished from *L. lirata* by the absence of ornament and a more globose whorl, and from *L. altsia* by



TABLE 27  
MEASUREMENTS (IN MILLIMETERS) OF *Lacunospira alta* BATTEN, NEW SPECIES

Locality		Each Whorl				H	W	CSS	SW	CBS
U.S.N.M. 702	H	4.00	8.50	13.00	57.00	63.20	56.20	14.60	2.00	7.50
	W	7.00	12.00	24.00	40.0					
U.S.N.M. 702	H	—	7.10	9.50	12.50	63.00	55.00	13.60	1.66	6.60
	W	—	9.00	16.20	29.80					
U.S.N.M. 702	H	2.40	4.00	8.80	—	41.90	39.60	9.60	2.00	6.20
	W	4.70	10.80	21.70	—					
U.S.N.M. 702	H	2.00	3.40	6.50	10.60	50.20	44.30	10.90	2.20	7.00
	W	4.40	9.30	16.20	29.80					
U.S.N.M. 702	H	2.00	3.40	6.30	—	26.50	24.50	6.00	0.90	4.00
U.S.N.M. 702	H	—	4.30	6.90	11.20	56.20	48.80	12.60	1.60	6.60
	W	—	8.90	16.20	31.70					
U.S.N.M. 702	H	1.50	3.00	5.80	9.00	47.50	50.00	14.00	2.30	5.00
	W	3.80	6.80	14.00	25.40					
U.S.N.M. 703b	H	1.20	2.80	5.50	9.50	35.50	37.00	10.00	1.50	4.70
U.S.N.M. 703b	H	0.70	1.70	3.00	6.50	28.30	27.40	6.60	1.40	4.40

the lack of an upper edge of an almost vertical outer whorl face.

One of the most striking aspects of this species is the large-sized individuals seen at U.S.N.M. 702, 703, and 703b of upper Leonard age. The largest specimen is well over 60 mm. in length, which is quite an unusual size for Permian pleurotomarians. Samples from localities other than those mentioned above have a much smaller mean size.

It is important to note that young specimens and early whorls have globose whorls and in late ontogeny the whole appearance of the whorl changes with the development of a convexo-concave whorl profile, the trough just under the selenizone, and a basal angulation. This change may be seen also in the development of the species through time. It also is reflected in the quantitative characters.

Growth lines, if recognizable, are coarse, and the lacunae are irregularly developed on the surfaces above and below the selenizone.

RANGE: Upper Wolfcampian through Guadalupian.

OCCURRENCE: The hypodigm is composed

of 35 specimens: U.S.N.M. 707d, six; P.U. 3, one; U.S.N.M. 702, 21; A.M.N.H. 503, two; U.S.N.M. 703b, four; U.S.N.M. 706c, one.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 13346b; figured paratypes, U.S.N.M. Nos. 133346a and 133346c.

*Lacunospira lirata* Batten, new species

Plate 42, figure 8

DESCRIPTION: Early whorls in this species are rounded, but later whorls have a flattened upper whorl surface and a rounded, almost vertical, outer whorl face, much like that of *L. altsia*. The upper whorl surface may be slightly concave and rather wide. The outer shell layer is very thin and ornamented. Ornament consists of rather fine growth lines or collabral threads and spiral threads which may be irregularly grouped above and below the selenizone and form reticulation.

DISCUSSION: This is the only species of the genus which shows any ornament of the usual type found in the family. The general shape is suggestive of that of *L. altsia*, although the width appears to be greater than

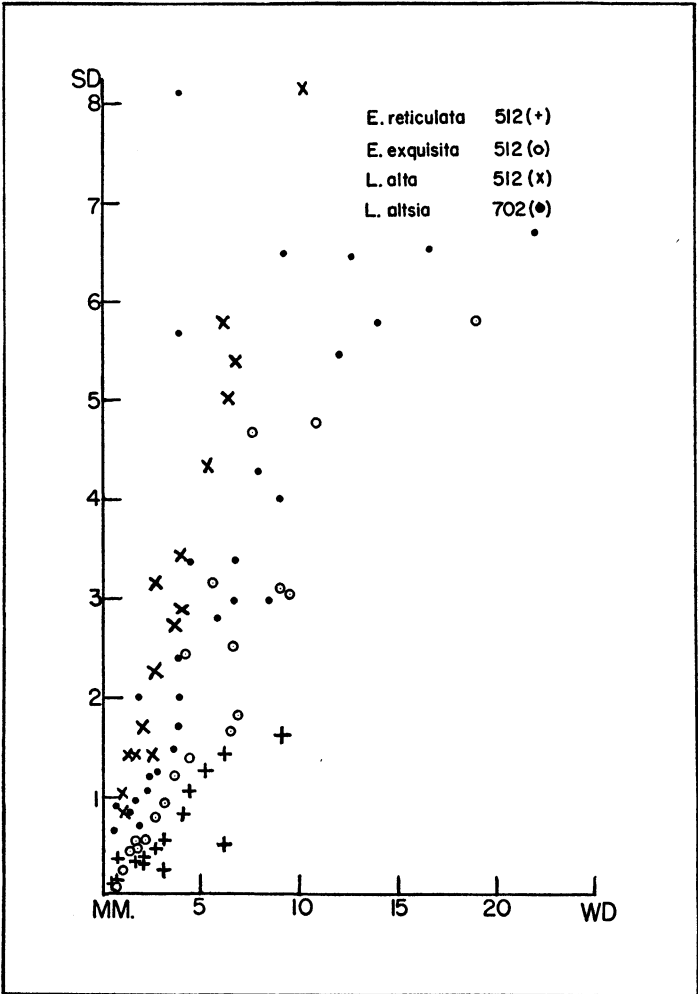


FIG. 17. A comparison of two species each of *Lacunospira* and *Eirlysia*. Note that species of *Eirlysia* have a more rapid rate of increase in whorl width, compared to the species of *Lacunospira*. Abbreviations: SD, height of whorl; WD, width of whorl.

in that species. The important distinguishing character is the ornament. The species is known from but two badly preserved speci-

mens from the Word formation limestone number 1.

RANGE: Guadalupian.

OCCURRENCE: U.S.N.M. 707e, one; A.M.N.H. 509, one.

CATALOGUED SPECIMEN: Holotype, U.S.N.M. No. 133347.

*Lacunospira altsia* Batten, new species

Plate 42, figures 1, 6

DESCRIPTION: This species has early whorls which are globose and normal. The shell shape is step-like in later whorls. The whorl

TABLE 28  
MEASUREMENTS (IN MILLIMETERS) OF  
*Lacunospira lirata* BATTEN, NEW  
SPECIES

Locality	H	W
U.S.N.M. 707e	23.00	25.00
A.M.N.H. 509	24.30	27.40

profile is variable, with an almost vertical outer whorl face and a sloping, rather flat, upper whorl surface. The base is flatly rounded to rounded. Selenizone margins are thin, and the selenizone is in the same plane as the general whorl surface. The flat to gently convex selenizone is relatively narrow and about in the center of the outer whorl sur-

ever, there are two readily observed shell layers.

This species can be separated from *L. lirata* by the absence of ornament and from *L. alta* by the presence of a shoulder and a rectangular whorl profile in adult specimens. All the species belonging to the genus have globose early whorls. The selenizone is narrower in

TABLE 29  
MEASUREMENTS (IN MILLIMETERS) OF *Lacunospira altsia* BATTEN, NEW SPECIES

Locality			Each Whorl				H	W	CSS	CAS	SW	CBS
A.M.N.H. 512	H	—	0.58	1.45	3.20	5.80	24.62	22.00	6.53	3.63	0.87	3.19
	W	—	1.45	2.90	6.24	11.60						
A.M.N.H. 512	H	0.28	0.87	1.74	3.48	—	15.22	14.50	3.33	1.89	0.58	1.88
	W	1.03	2.17	4.20	7.70	—						
P.U. 3	H	—	0.72	1.73	3.62	—	19.56	16.70	3.62	—	0.87	3.19
U.S.N.M. 703	H	—	0.72	1.45	2.75	5.07	29.30	26.10	6.68	3.77	0.72	3.62
	W	—	2.61	3.91	6.54	13.01						
U.S.N.M. 703	H	—	1.03	2.31	4.35	8.26	37.70	—	10.30	—	1.03	2.17

face. There is usually a concave area just above and below the selenizone. A basal angulation separates the outer whorl face from the base; a cord may be developed on this angulation. Moderately phaneromphalous to hemiomphalous. A fairly thin parietal indurata is limited to the plane of the aperture. Shell surface is smooth, with very fine lacunae; no growth lines were observed.

DISCUSSION: This is another remarkable species, in that even in well-preserved specimens growth lines are almost absent, and it is difficult to understand why there is no evidence of growth. One is almost forced to the conclusion that a shell layer is absent. How-

this species compared to that of the others.

Variability involves the relative degree of reflection of the columellar lip, degree of high spire, variation in the whorl profile, and relative development of the upper and lower edges of the outer whorl face.

RANGE: Leonardian through Guadalupian.

OCCURRENCE: The hypodigm consists of 24 specimens: P.U. 3, two; U.S.N.M. 702, one; U.S.N.M. 702 low, three; U.S.N.M. 703, 10; A.M.N.H. 512, eight.

CATALOGUED SPECIMENS: Holotype, A.M.N.H. No. 28061; figured paratype, U.S.N.M. No. 133349.

## REGISTER OF LOCALITIES

### THE AMERICAN MUSEUM OF NATURAL HISTORY

364. Carlsbad limestone: Carlsbad Caverns East Quadrangle, Eddy County, New Mexico.  
369. Bone Spring Formation: Top of Shirttail 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.  
369a. Same as A.M.N.H. 369.  
391. Hueco formation: 1.1 miles northwest of Ruddy Tanks, Aldwell Ranch. About 5 miles southeast of Hueco Inn, Hueco Mountains, El Paso and Hudspeth counties, Texas.  
391a. Same as A.M.N.H. 391.  
433. Lower part of Bone Spring formation (molluscan ledge, about 100 feet above base): South side of mouth of Apache Canyon on county line, Sierra Diablo area, Texas.  
492. Upper Seven Rivers formation: 1 mile from junction of Ussery Trail and trail along Guadalupe Ridge from Dark Canyon Lookout, Carlsbad Caverns West Quadrangle, New Mexico.  
500. Leonard formation: Same as U.S.N.M. 702.  
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.  
509. Same as U.S.N.M. 707e, Word limestone (no. 1).  
512. Cherry Canyon formation, Getaway limestone member: Near break in slope on middle leader on west side of airway station road, between highway and pipeline road, on crest of ridge, Guadalupe Mountains, Texas.  
512b. Same as A.M.N.H. 512.  
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.  
591. Bone Spring limestone: Lowest reef lens, 40 feet above base of formation; between north and middle branches of Black John Canyon, Sierra Diablo, Texas.  
592. Bone Spring formation (molluscan ledge): Between the north and middle branches of Black John Canyon, Van Horn Quadrangle, Texas.  
624. Bone Spring limestone, lower reef beds: South side of Mine Canyon, Sierra Diablo, Texas.  
655. Bone Spring formation: 80 feet above the base on the northernmost of the Baylor Hills on west side of Highway 54, Sierra Diablo area, Texas.  
678. Bone Spring formation, Cutoff shale 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.

### F. B. PLUMMER COLLECTION

- 42-T-18. Admiral formation, Wildcat Creek shale member: South side of Gulf, Colorado, and Santa Fe Railway,  $4\frac{1}{2}$  miles south 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.  
7. Hueco formation: Same as U.S.N.M. 721.  
37a. Hueco limestone: On Eagle Butte, north side of Texas and Pacific Railway, just west of Van Horn Quadrangle, Texas.

### UNITED STATES GEOLOGICAL SURVEY

9802. Admiral formation, local soft shaly limestone in Wildcat Creek shale member, approximately 15 feet below base of Overall limestone: 4.9 miles west of south from center of Coleman, 8.45 miles (240') south of Gulf, Colorado, and Santa Fe Railway, 0.55 mile east-northeast of road crossing of railroad just south of point where U.S. Highway 67 turns west-northwest on approaching railroad, Coleman 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.  
14439. U.S.G.S. specimen number from the Bone Spring limestone: North portal of Apache Canyon, on outside of east rim of second nose north of lower bench; 4.6 miles east and 0.2 mile north of northwest corner of Van Horn Quadrangle, Texas.

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701. Wolfcamp formation (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. Wolfcamp (upper part of bed 9): Head of canyon, just south of forks, Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701b. Wolfcamp formation (beds 7 to 9): Head of canyon just south of forks, Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701c. Wolfcamp formation (beds 9 to 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 to 12): Two small hills 1 mile northwest of Wolfcamp, west end of Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701e. Wolfcamp formation: Shaly bed just under main high peak, south face of Hill 5060, Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701f. Wolfcamp formation (lower part Hueco equivalent): King's locality 199 with *Parenteleles*, saddle 0.2–0.3 mile northeast of Hill 5060, Wolfcamp Hills, north-northeast of Marathon, 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 to 12): Crest of hill, 0.75 mile south, 78° west, of Hill 5060, Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701k. Wolfcamp formation: Near Hill 5060, Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
- 701L. Wolfcamp formation (bed 2): About 4625 feet in 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 0.2–0.5 mile east of Split Tank, 1½ 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): ½ 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 King): ½ mile east of Split Tank, 19 miles north-northeast of Marathon, Hess Canyon Quadrangle, Texas.
- 702c. Leonard formation (upper part of original Leonard of King): Knob on south side of road at elbow just west of south branch of Hess Canyon, 4½ 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 member, eastern facies): Crest of hills 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 in 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 *Enteleles*, 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 member (fossil bed): ½ mile southwest of Hill 5821, 4.4 miles north, 66.5° east, of Hess ranch house, Hess Canyon Quadrangle, Texas.
- 702 low. Leonard formation (upper part): Same as U.S.N.M. 702, but at base of section.
- 702t. Wolfcamp formation: Shales 200 yards south, 45° east, of Gaptank, east side of Stockton Gap, Hess Canyon Quadrangle, Texas.
- 702un. Leonard formation: *Institella* beds of Leonard formation of King (upper Leonard) at U.S.N.M. 702.
703. Word formation (limestone no. 1): Lens with goniatites in platy limestone near top of slope ½ mile southwest of road forks just northeast of old Word Ranch, Hess Canyon Quadrangle, Texas.
- 703a. Uppermost Leonard formation (*Aulosteges* bed): On northwest side of road between road fork and sheep tank near old Word Ranch, about 17–18 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  $\frac{1}{4}$ - $\frac{1}{2}$  mile southwest of road fork near old Word Ranch, 17-18 miles north-northeast of Marathon, Hess Canyon Quadrangle, Texas. Sponge bed. Basal portion dark platy limestone called Word no. 1 by King, just above reefy beds on crest of slope on north side of road,  $\frac{1}{4}$  mile southwest of road fork near old Word Ranch.
- 703d. Word formation (limestone no. 1): In elbow of road at turn of Thomas Ranch, head of canyon near old Word Ranch.
- 705a. Leonard formation, Hess limestone member: 0.7 mile (airline) north, 13° west, of the Hess ranch house, 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 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.
- 706o. Word formation (top of limestone no. 3): Same as U.S.N.M. 706e.
- 707a. Hess (*Scacchinella* bed) of King: 0.5 mile south of Hill 5300 and 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 of limestone no. 1): Dip slope of hill, 3.85 miles (airline) due north of Decie ranch house, 1 mile northwest of entrance to Sullivan Ranch Canyon, Altuda Quadrangle, Texas.
- 707d. Wolfcamp formation (top): Knob on west side of entrance to Sullivan Ranch Canyon, 3 $\frac{1}{2}$  miles north, 7° east, of Decie ranch house, Altuda Quadrangle, Texas.
- 707e. Word formation (limestone no. 1): 5.3 miles (airline) north, 5° west, of Decie ranch house, 0.9 mile (airline) south, 25° east, of Sullivan Peak, Altuda Quadrangle, Texas.
- 707m. Wolfcamp formation (top 10 feet of conglomerate): About 95 feet vertically below Hess at contour 4650 feet in ravine  $\frac{1}{2}$  mile southeast of Hill 5300, north of Decie Ranch, Altuda Quadrangle, Texas.
708. Leonard formation (lower part of King's original Leonard), upper part: 1.55 miles by road east-northeast of Hess gate, 1.75 miles (airline) north, 49° east, of Hess ranch house, Hess Canyon Quadrangle, Texas.
- 708u. Wolfcamp formation (upper portion): Wolfcamp Hills, Hess Canyon Quadrangle, Texas.
712. Hueco limestone: From an isolated hill 0.7 mile south of railroad 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-porphry, Orogrande Quadrangle, New Mexico.
- 712a. Hueco limestone (25 feet below siltstone, 200 feet below "cephalopod bed"): North center of sect. 24 near crest of hill in southeast and south of monument and pin at quarter corner at sects. 13 and 24, T. 33 S., R. 8 E., Orogrande Quadrangle, New Mexico.
- 712b. Hueco limestone: About 700 feet above Powow conglomerate and probably below "Cephalopod beds," NE  $\frac{1}{2}$ , SW  $\frac{1}{2}$  of sect. 25, T. 23 S., R. 8 E., Orogrande Quadrangle, New Mexico.
- 712c. Hueco limestone (about 200 feet below "cephalopod bed"): In the SE  $\frac{1}{2}$ , sect. 8, T. 22 S., R. 10 E., Otero County, New Mexico.
- 712d. Hueco limestone (basal middle portion): 0.5 mile north-northeast of Hueco Inn, east of highway, Hueco Mountains, Texas.
- 712f. Middle Hueco limestone: Hill 1 mile north of Ruddy Tanks, west of road 4.5 miles southeast of Hueco Inn, Hueco Mountains, Texas.

- 716. Bone Spring limestone (lower 100 feet): Nose of Victorio Peak above Figure 2 ranch headquarters, Van Horn Quadrangle, Texas.
- 721. Hueco limestone (basal marly beds): East end of Eagle Butte, a butte directly west of Eagle Flat station on Texas and Pacific Railroad, just west of Van Horn, Texas.
- 728. Cherry Canyon formation, Getaway limestone member: Same as A.M.N.H. 512.

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- 27. Word formation (limestone no. 2): Same as U.S.N.M. 706c.

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- 3. Word formation (limestone no. 1): Same as U.S.N.M. 703.
- 4. Word formation (limestone no. 3): Same as U.S.N.M. 706e.

## REFERENCES CITED

- BATTEN, ROGER LYMAN  
1956. Some new pleurotomarian gastropods from the Permian of west Texas. Jour. Washington Acad. Sci., vol. 46, no. 2, pp. 42-44.
- CHRONIC, HALKA  
1952. Molluscan fauna from the Permian Kaibab formation, Walnut Canyon, Arizona. Bull. Geol. Soc. Amer., vol. 63, pp. 95-166.
- COOPER, G. ARTHUR  
1953. The Wolfcamp formation. Guide for spring field trip to Chinati Mountains, Presidio County, Texas. Midland, Texas, West Texas Geological Society.
- DICE, LEE RICHARD  
1937. Additional data on variation in the prairie deer mouse *Peromyscus maniculatus bairdii*. Occas. Papers Mus. Zool., Univ. Michigan, no. 239.
- GEMMELLARO, G. G.  
1889. La fauna dei calcari con Fusulina della valle del fiume Sosio nella provincia di Palermo. Palermo, fasc. 2, Nautiloidea-Gastropoda.
- GIRTY, GEORGE H.  
1909. The Guadalupian fauna. Prof. Paper U. S. Geol. Surv., no. 58, pp. 1-651.  
1912. On some new genera and species of Pennsylvanian fossils from the Wewoka formation of Oklahoma. Ann. New York Acad. Sci., vol. 21, pp. 119-156.  
1915. Fauna of the Wewoka formation. Bull. U. S. Geol. Surv., no. 544.  
1934. New Carboniferous invertebrates. 4. Jour. Washington Acad. Sci., vol. 24, no. 6.  
1939. Certain pleurotomarid gastropods from the Carboniferous of New Mexico and Texas. *Ibid.*, vol. 29, pp. 21-36.
- GRABAU, A. W.  
1936. Early Permian fossils from China. Part 2. Fauna of the Maping limestone of Kwangsi and Kweichow. Paleont. Sinica, ser. B, vol. 8, fasc. 4.
- GRECO, B.  
1937. La fauna Permiana del Sosio conservata nei Musei di Pisa, di Firenze e di Padova. Paleont. Italica, vol. 37, pt. 2, Gastropoda-Lamellibranchiata, pp. 57-114.
- HAAS, OTTO  
1953. Mesozoic invertebrate faunas of Peru. Part 1. General introduction. Part 2. Late Triassic gastropods from central Peru. Bull. Amer. Mus. Nat. Hist., vol. 101, pp. i-xii, 1-328, pls. 1-18.
- HUXLEY, JULIAN S.  
1932. Problems of relative growth. London, Methuen, 276 pp.
- IDA, KAZUYOSHI  
1952. A study of fossil *Turritella* in Japan. Rept. Japan Geol. Surv., no. 150, pp. 2-62.
- IMBRIE, JOHN  
1956. Biometric methods in the study of invertebrate fossils. Bull. Amer. Mus. Nat. Hist., vol. 108, pp. 211-252.
- KAY, MARSHALL  
1951. North American geosynclines. Mem. Geol. Soc. Amer., no. 48.
- KERMACK, K. A.  
1954. A biometrical study of *Micraster coranguinum* and *M. (Isomicraster) senonensis*. Phil. Trans. Roy. Soc. London, ser. B, vol. 237, pp. 375-428.
- KERMACK, K. A., AND J. B. S. HALDANE  
1950. Organic correlation and allometry. Biometrika, vol. 37, no. 30.
- KING, PHILIP BURKE  
1930. The geology of the Glass Mountains, Texas, Part 1. Descriptive geology. Bull. Univ. Texas, no. 3038, pp. 1-167.  
1942. The Permian of West Texas and southeastern New Mexico. Bull. Amer. Assoc. Petrol. Geol., vol. 26, pt. 1, pp. 555-763.
- KING, PHILIP BURKE, AND J. BROOKES KNIGHT  
1945. Geology of Hueco Mountains, El Paso and Hudspeth Counties, Texas. Prelim. Map Oil and Gas Invest., U. S. Geol. Surv., no. 36 (in two sheets), sheet 2.
- KITTL, E.  
1891-1894. Die Gastropoden der Schichten von St. Cassian der süd-alpinen Trias. Pt. 1. Ann. K. K. Naturhist. Hofsmus., Vienna, vol. 6 (1891), pp. 166-262, 11 figs., pls. 1-7; pt. 2, *ibid.*, vol. 7 (1892), pp. 35-97, pls. 5-9; pt. 3, *ibid.*, vol. 9 (1894), pp. 143-277, pls. 4-12.  
1895. Die triadischen Gastropoden der Marmolata und verwandter Fundstellen in dem weissen Riffkalken Südtirols. Jahrb. K. K. Geol. Reichsanst., vol. 44 (1894), pp. 99-182, 12 figs., 6 pls.  
1899. Die Gastropoden der Esinokalken, nebst einer Revision der Gastropoden der Marmolatakalken. Ann. K. K. Naturhist. Hofsmus., Vienna, vol. 14, pp. 1-237, 112 text figs., 18 pls.
- KNIGHT, J. BROOKES  
1941. Paleozoic gastropod genotypes. Special Papers Geol. Soc. Amer., no. 32, pp. 1-510.  
1945. Some new genera of Paleozoic Gastro-



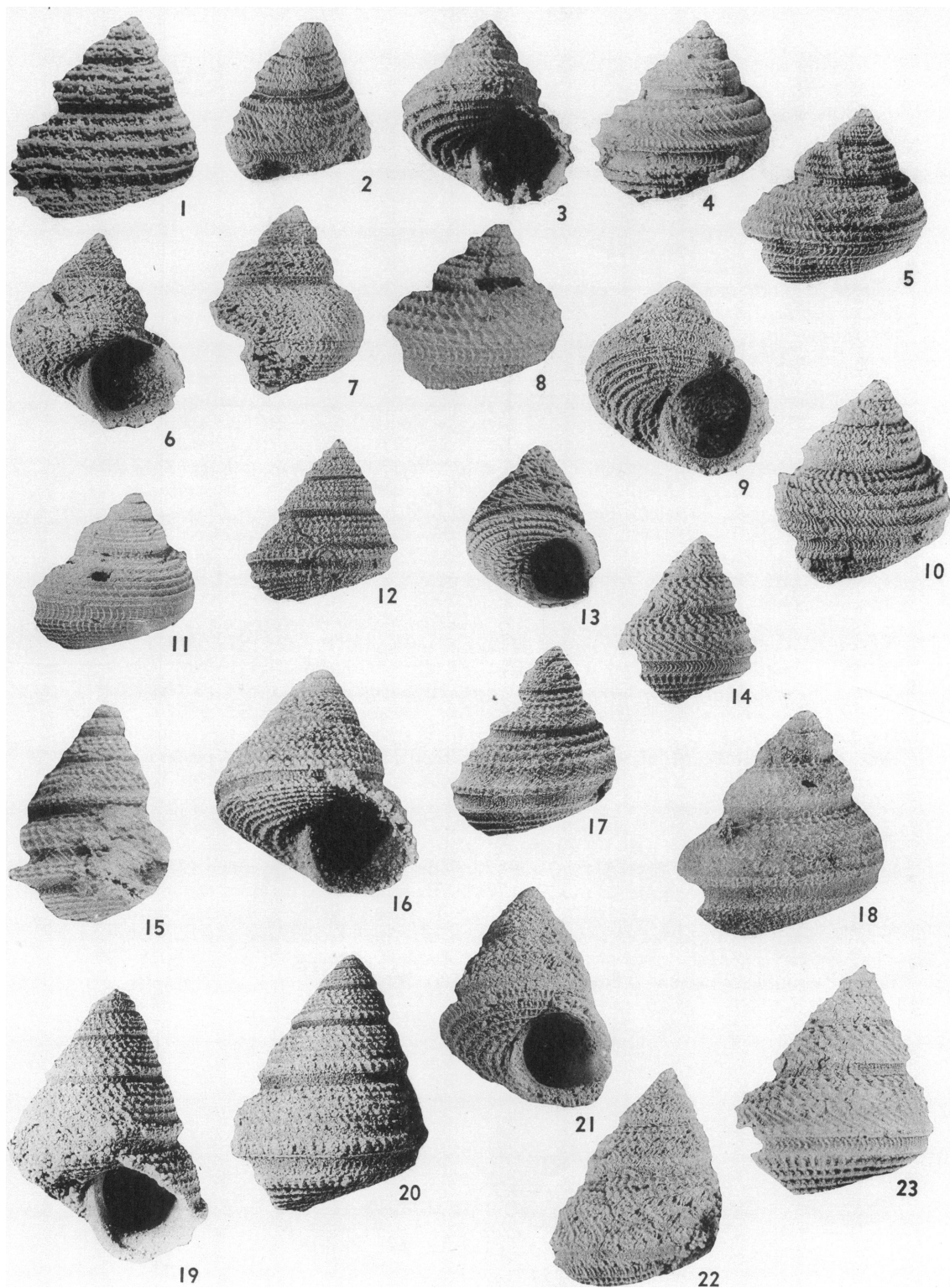
- poda. Jour. Paleont., vol. 19, no. 6, pp. 573-587.
- KONINCK, L. G. DE  
1881. Faune du calcaire carbonifère de la Belgique. Troisième partie, gastropodes. Ann. Mus. Roy. d'Hist. Nat. Belgique, ser. paleont., vol. 6, 170 pp., 21 pls.
- LISON, LUCIEN  
1949. Recherches sur la forme et la mécanique de développement des coquilles des lamelibranches. Mem. Inst. Roy. Sci. Nat. de Belgique, ser. 2, fasc. 34, pp. 1-87.
- MAYR, ERNST, E. GORTON LINSLEY, AND ROBERT L. USINGER  
1953. Methods and principles of systematic zoology. New York, McGraw-Hill Book Co., Inc., pp. 1-328.
- MEEK, F. B., AND A. H. WORTHEN  
1861. Descriptions of new Carboniferous fossils from Illinois and other western states. Proc. Acad. Nat. Sci. Philadelphia, pp. 447-472.
- NELSON, L. A.  
1947. Two new genera of Paleozoic Gastropoda. Jour. Paleont., vol. 21, no. 5, pp. 460-465.
- NEWELL, N. D.  
1940. Invertebrate fauna of the late Permian Whitehorse sandstone. Bull. Geol. Soc. Amer., vol. 51, no. 2, pp. 261-335.
- NEWELL, N. D., B. J. CHRONIC, AND T. G. ROBERTS  
1953. Upper Paleozoic of Peru. Mem. Geol. Soc. Amer., no. 68.
- NEWELL, N. D., J. K. RIGBY, A. G. FISCHER, A. J. WHITEMAN, J. E. HICKOX, AND J. S. BRADLEY  
1953. The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico. San Francisco, W. H. Freeman and Co., 236 pp., 32 pls.
- SHIMER, H. W., AND R. R. SHROCK  
1944. Index fossils of North America. New York, John Wiley and Sons, Inc., 838 pp.
- SHUMARD, BENJAMIN FRANKLIN  
1860. Descriptions of five new species of Gastropoda from the Coal Measures and a brachiopod from the Potsdam sandstone of Texas. Trans. Acad. Sci. St. Louis, vol. 1, pp. 624-627.
- SIMPSON, GEORGE GAYLORD  
1953. Major features of evolution. New York, Columbia University Press.
- SIMPSON, GEORGE GAYLORD, AND ANNE ROE  
1939. Quantitative zoology. Numerical concepts and methods in the study of recent and fossil animals. New York, McGraw-Hill Book Co., Inc., 406 pp.
- SLOAN, ROBERT EVAN  
1951. An instrument for measuring snails. Jour. Paleont., vol. 25, no. 4, pp. 525-526.  
1955. Paleoecology of the Pennsylvanian marine shales of Palo Pinto County, Texas. Jour. Geol., vol. 63, pp. 412-428.
- STEHLI, FRANCIS GREENOUGH  
1954. Lower Leonardian Brachiopoda of the Sierra Diablo. Bull. Amer. Mus. Nat. Hist., vol. 105, pp. 263-358, pls. 17-27.
- THOMAS, EIRLYS GREY  
1940. Revision of the Scottish Carboniferous Pleurotomariidae. Trans. Geol. Soc. Glasgow, vol. 20, pt. 1, pp. 30-72.
- THOMPSON, D'ARCY  
1952. Growth and form. Reprinted edition. London, Cambridge University Press, vol. 2.
- ULRICH, F. O., AND SCOFIELD, W. H.  
1897. The lower Silurian Gastropoda of Minnesota. Final Rept., Minnesota Geol. Surv., vol. 3, pt. 2, pp. 813-1081.
- WANNER, C.  
1942. Neue Beiträge zur Gastropoden-Fauna des Perm von Timor. In Brouwer, H. A., Geological expedition of the University of Amsterdam to the Lesser Sunda Islands. Amsterdam, vol. 4, pp. 137-201.
- YIN, T. H.  
1932. Gastropods of the Penchi and Taiyuan series of North China. Paleont. Sinica, ser. B, vol. 8, fasc. 2, pp. 1-53.
- YOCHELSON, ELLIS L.  
1954. Some problems concerning the distribution of the late Paleozoic gastropod *Omphalotrochus*. Science, new ser., vol. 120, no. 3110, pp. 233-234.  
1956. Permian Gastropoda of the southwestern United States. 1. Euomphalacea, Trochonematacea, Pseudophoracea, Anomphalacea, Craspedostomatacea, and Platyceratacea. Bull. Amer. Mus. Nat. Hist., vol. 110, art. 3, pp. 177-275, pls. 9-24.
- YOUNG, KEITH  
1952. Redescription of two gastropods named by Cragin. Jour. Paleont., vol. 26, no. 5, pp. 818-828.

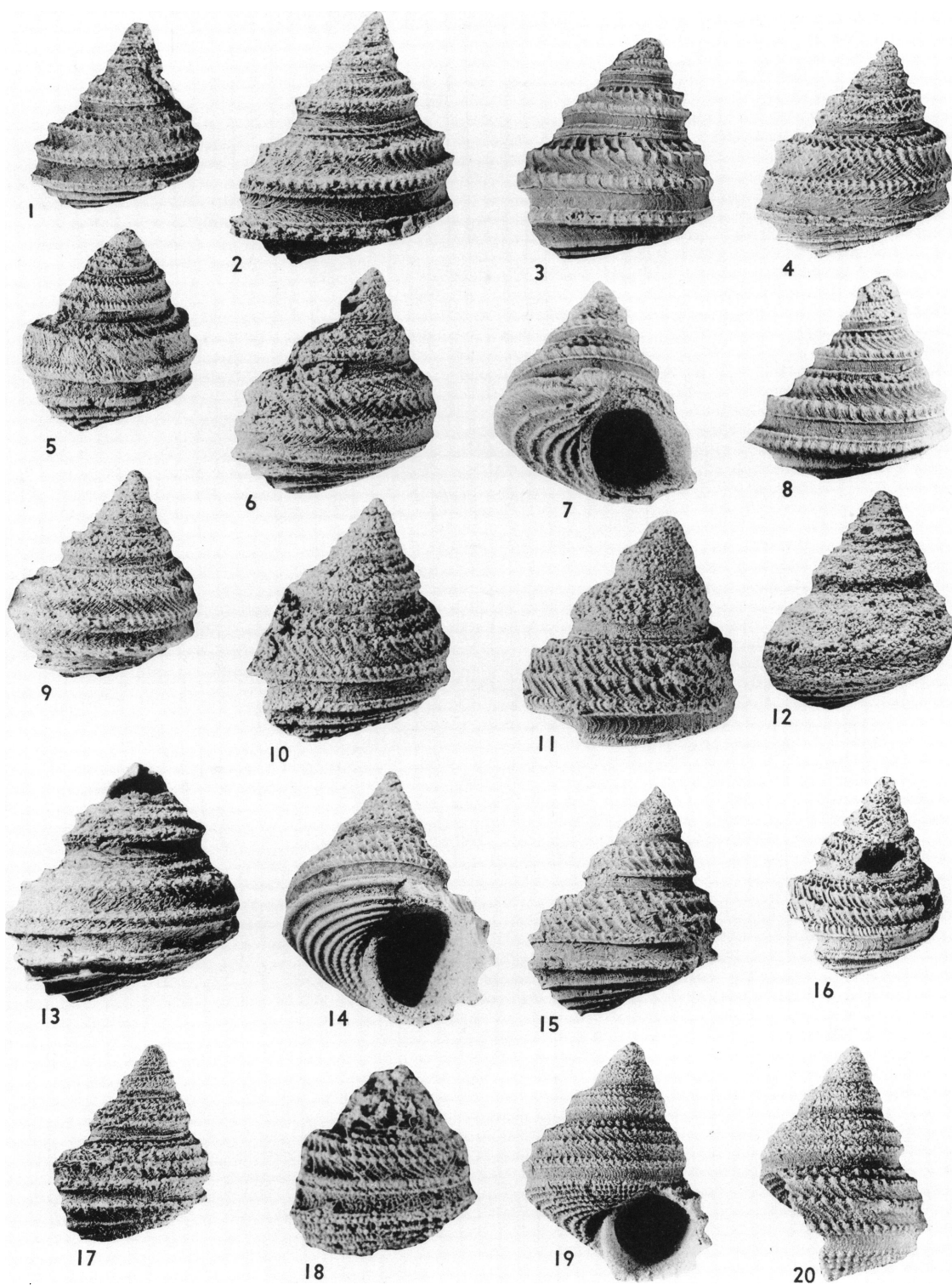
**PLATES 32-42**

## PLATE 32

1-11. *Tapinotomaria globosa* Batten, new species. 1. Side view, paratype, from U.S.N.M. 712f, middle Hueco formation, U.S.N.M. No. 133274,  $\times 8$ . 2. Oblique side view, paratype, from U.S.N.M. 702t, Wolfcamp formation, U.S.N.M. No. 133275,  $\times 5$ . 3. Oblique apertural view, paratype, from U.S.N.M. 703b, lower part of upper Leonard formation, U.S.N.M. No. 133276,  $\times 4$ . 4. Oblique side view, same specimen. 5. Oblique side view of paratype showing median thread on selenizone forming nodes at intersections with collabral ornament, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133277a,  $\times 4$ . 6. Apertural view of paratype showing numerous fine spiral threads on whorl surface above selenizone, from U.S.N.M. 703a, uppermost Leonard formation (*Aulosteges* beds), U.S.N.M. No. 133278a,  $\times 6$ . 7. Side view, same specimen. 8. Oblique side view of paratype showing heavy collabral ornament above the selenizone and also the weakly developed selenizone margins, from A.M.N.H. 512b, lower Getaway formation, A.M.N.H. No. 28047:1,  $\times 7$ . 9. Oblique apertural view, holotype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133277b,  $\times 4$ . 10. Oblique side view, same specimen. 11. Oblique side view, paratype, from U.S.N.M. 703a, upper Leonard formation, U.S.N.M. No. 133278b,  $\times 5$ .

12-23. *Tapinotomaria rugosa* Batten, 1956. 12. Side view of paratype showing heavy and wide first major cord composed of secondary spiral threads, from P.U.3, Bone Spring formation, U.S.N.M. No. 133348a,  $\times 4$ . 13. Oblique apertural view, holotype, from U.S.N.M. 702d, lower Leonard formation (Hess sponge bed), U.S.N.M. No. 125281,  $\times 4$ . 14. Side view, same specimen. 15. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133280,  $\times 8$ . 16. Apertural view of paratype showing fine, beaded, spiral cords above the selenizone, from U.S.N.M. 703a, uppermost Leonard formation, U.S.N.M. No. 133281,  $\times 4$ . 17. Oblique side view, paratype, from U.S.N.M. 702e, Hess limestone member of the Leonard formation, U.S.N.M. No. 133282a,  $\times 4$ . 18. Oblique side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133283,  $\times 6$ . 19. Apertural view, paratype, from P.U.3, Bone Spring limestone, U.S.N.M. No. 133348b,  $\times 4$ . 20. Side view, same specimen. 21. Oblique apertural view, paratype, from U.S.N.M. 702e, Hess limestone member of the Leonard formation, U.S.N.M. No. 133282b,  $\times 4$ . 22. Side view of same specimen showing the gap between the upper selenizone margin and first major cord and the gap between the first major cord and that next above. 23. Side view, paratype, from U.S.N.M. 702d, lower Leonard formation, U.S.N.M. No. 133279b,  $\times 6$ .





### PLATE 33

1-10. *Tapinotomaria crassa* Batten, new species, group 1. 1. Oblique side view of paratype showing fine thread near suture, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284a,  $\times 6$ . 2. Oblique side view of paratype showing most of the outer shell layer missing (note in particular the shape of the crystal structure in the selenizone), from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284b,  $\times 4$ . 3. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133285a,  $\times 4$ . 4. Oblique side view, paratype showing a very large gap between first major cord and that next above, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133285b,  $\times 4$ . 5. Oblique side view, paratype showing weak development of collabral ornament, from A.M.N.H. 624, Bone Spring Limestone, A.M.N.H. No. 28048:1,  $\times 3$ . 6. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284d,  $\times 4$ . 7. Oblique apertural view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133285c,  $\times 6$ . 8. Side view of same specimen showing the well-developed first major cord. 9. Oblique side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284e,  $\times 4$ . 10. Oblique side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284f,  $\times 6$ .

11. *Tapinotomaria crassa* Batten, new species, group 2. Oblique side view showing the increased number of collabral nodes on first major cord compared to the next cord above, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284h,  $\times 4$ .

12, 13. *Tapinotomaria crassa* Batten, new species, group 1. 12. Oblique side view of paratype showing more globose whorls from U.S.N.M. 707d, lower Leonard formation, U.S.N.M. No. 133286,  $\times 4$ . 13. Side view of paratype which shows gap between selenizone margin and first major cord, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284g,  $\times 4$ .

14-18. *Tapinotomaria crassa* Batten, new species, group 2. 14. Oblique apertural view, holotype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284i,  $\times 4$ . 15. Oblique side view of same specimen,  $\times 3$ . 16. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284j,  $\times 4$ . 17. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284k,  $\times 3$ . 18. Oblique side view of a fragment showing very close spacing of first and second cords above the first major cord (this type of variant may have been close to origin of *T. costata*), from A.M.N.H. 592, Bone Spring limestone, A.M.N.H. No. 28049:1,  $\times 10$ .

19, 20. *Tapinotomaria crassa* Batten, new species, group 3. 19. Apertural view of paratype showing reticulate base, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133284L,  $\times 4$ . 20. Side view of same specimen showing rounded nodes on cords above the selenizone.

## PLATE 34

1-3. *Tapinotomaria costata* Batten, new species, group 1. 1. Oblique side view of paratype showing the flat upper whorl surface, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133287a,  $\times 6$ . 2. Oblique side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133287b,  $\times 6$ . 3. Side view of paratype showing most of the outer shell layer missing, from U.S.N.M. 702f, lower Leonard formation (Hess fossil bed), U.S.N.M. No. 133288,  $\times 5$ .

4, 5. *Tapinotomaria costata* Batten, new species, group 2. 4. Oblique side view, paratype, from U.S.N.M. 707e, Word formation (limestone no. 1), U.S.N.M. No. 133289,  $\times 5$ . 5. Side view, paratype, from A.M.N.H. 678, Bone Spring limestone (Cutoff member), A.M.N.H. No. 28060:1,  $\times 5$ .

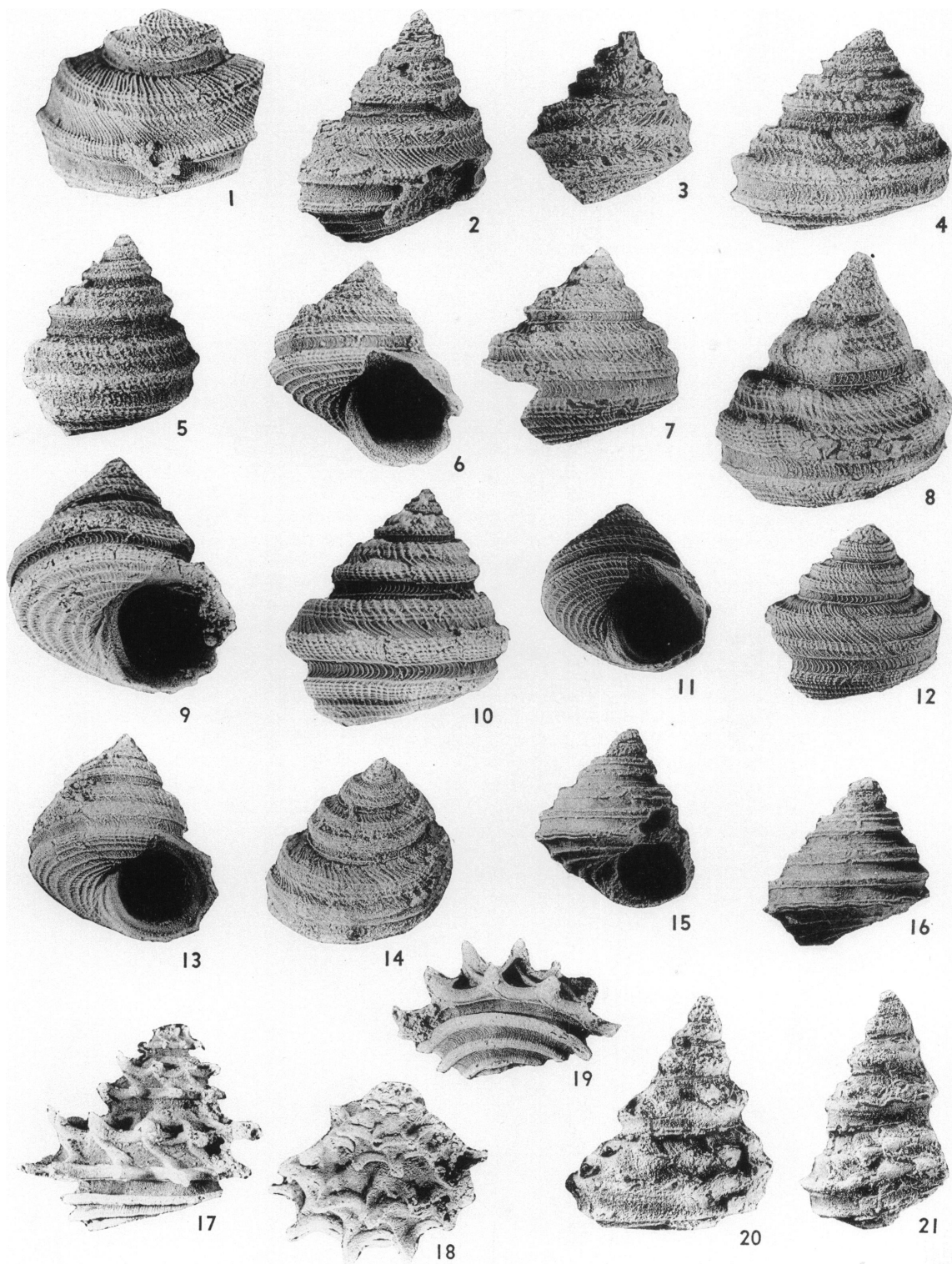
6-14. *Tapinotomaria costata* Batten, new species, group 3. 6. Apertural view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. 28050:1,  $\times 6$ . 7. Side view of same specimen showing weakly developed first major cord. 8. Oblique side view of paratype showing the heavily developed and flattened first major cord, from A.M.N.H. 512b, lower Getaway formation, A.M.N.H. No. 28050:2,  $\times 6$ . 9. Oblique apertural view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28050:3,  $\times 6$ . 10. Side view of same specimen,  $\times 6$ . 11. Oblique apertural view, holotype, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133290a,  $\times 4$ . 12. Oblique side view of same specimen,  $\times 4$ . 13. Oblique apertural view of paratype showing groove or trough around aperture, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133290b,  $\times 3$ . 14. Oblique side view of same specimen,  $\times 3$ .

15, 16. *Tapinotomaria duplicostata* Batten, new species. 15. Apertural view, holotype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133291,  $\times 6$ . 16. Side view of same specimen,  $\times 6$ .

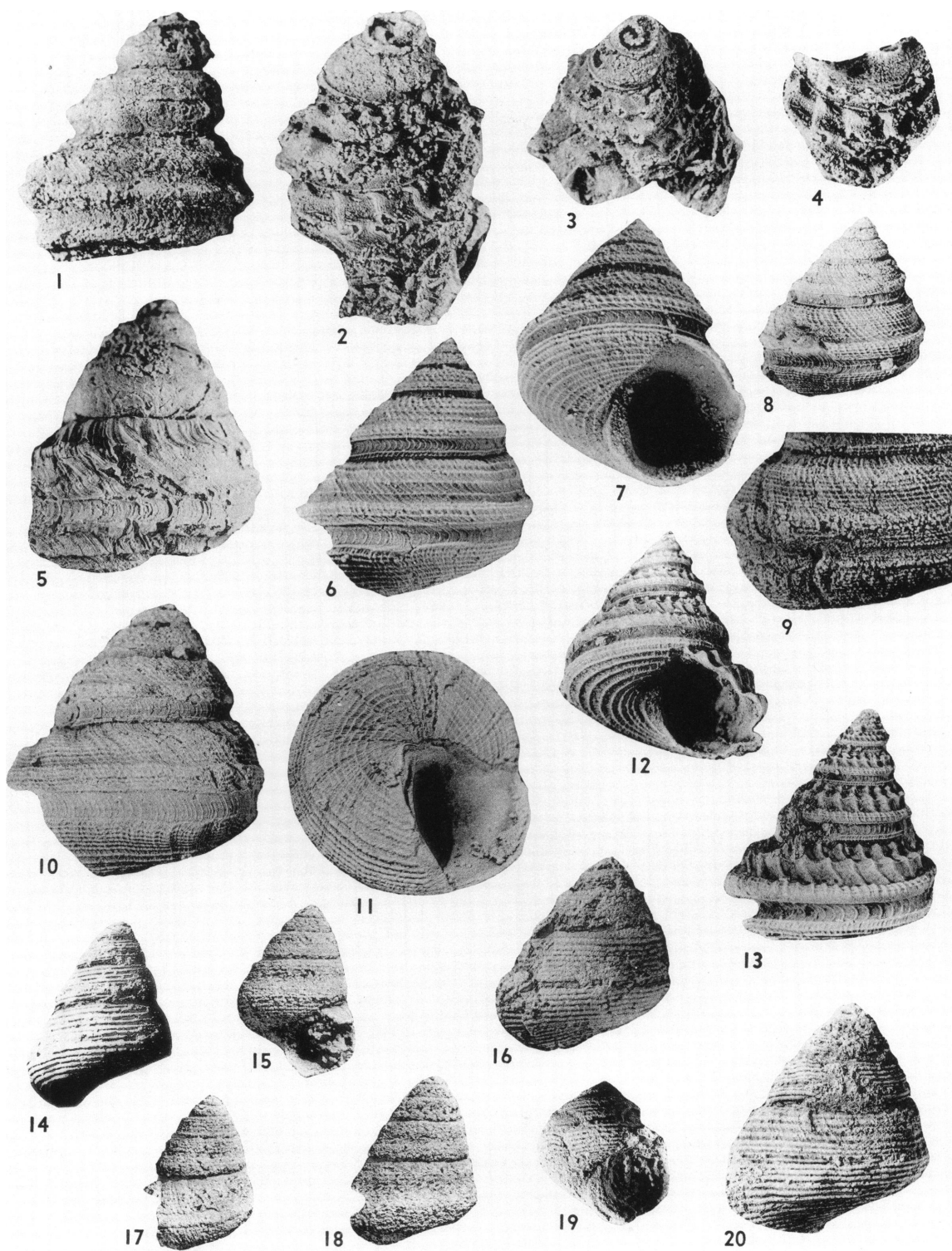
17-19. *Tapinotomaria mirabilis* Batten, new species. 17. Side view, holotype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133292,  $\times 4$ . 18. Oblique side view of same specimen,  $\times 4$ . 19. Oblique basal view of same specimen,  $\times 4$ .

20, 21. *Tapinotomaria submirabilis* Batten, new species. 20. Side view, holotype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133293a,  $\times 5$ . 21. Different side view of same specimen showing that it has been crushed,  $\times 5$ .









## PLATE 35

1-5. *Tapinotomaria submirabilis* Batten, new species. 1. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133293b,  $\times 6$ . 2. Oblique side view of paratype showing the cup-like nodes and hollow spines, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. 133293c,  $\times 4$ . 3. Oblique top view of same specimen showing hollow spines,  $\times 4$ . 4. Detail of same specimen,  $\times 4$ . 5. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133293d,  $\times 4$ .

6-11. *Tapinotomaria pyramidalis* Batten, new species. 6. Side view of holotype showing lack of well-defined lower selenizone margin or lower major cord, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133294,  $\times 5$ . 7. Oblique apertural view of same specimen showing the lack of a trough around aperture,  $\times 5$ . 8. Oblique side view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28051:1,  $\times 4$ . 9. Detail of side view of paratype showing very narrow selenizone and wide selenizone margins, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28051:2,  $\times 4$ . 10. Side view of paratype showing exceptionally wide selenizone and margins, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28051:3,  $\times 8$ . 11. Basal view of same specimen showing the trough around the apertural margin and the resorbed parietal lip,  $\times 8$ .

12, 13. *Tapinotomaria coronata* Batten, new species. 12. Oblique apertural view, holotype, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133295,  $\times 4$ . 13. Oblique side view of same specimen showing the prominent nodes on the cords,  $\times 4$ .

14, 15. *Shansiella conica* Batten, new species. 14. Side view, paratype, from U.S.G.S. 9861, Talpa formation, U.S.N.M. No. 133296,  $\times 4$ . 15. Apertural view, holotype, from U.S.N.M. 712f, middle Hueco formation, U.S.N.M. No. 133297a,  $\times 4$ .

16. *Shansiella tabulata* Batten, new species. Side view, holotype, from U.S.G.S. 9802, Admiral formation, U.S.N.M. No. 133298,  $\times 4$ .

17, 18. *Shansiella conica* Batten, new species. 17. Oblique side view of paratype showing outer shell layer removed, causing the selenizone to appear convex, from U.S.N.M. 712f, middle Hueco formation, U.S.N.M. No. 133297b,  $\times 4$ . 18. Side view of same specimen.

19, 20. *Shansiella tabulata* Batten, new species. 19. Apertural view of holotype, from U.S.G.S. 9802, Admiral formation, U.S.N.M. No. 133298,  $\times 4$ . 20. Side view of paratype showing strong spiral ornament, from U.S.G.S. 9848, Talpa formation, U.S.N.M. No. 133299,  $\times 6$ .

## PLATE 36

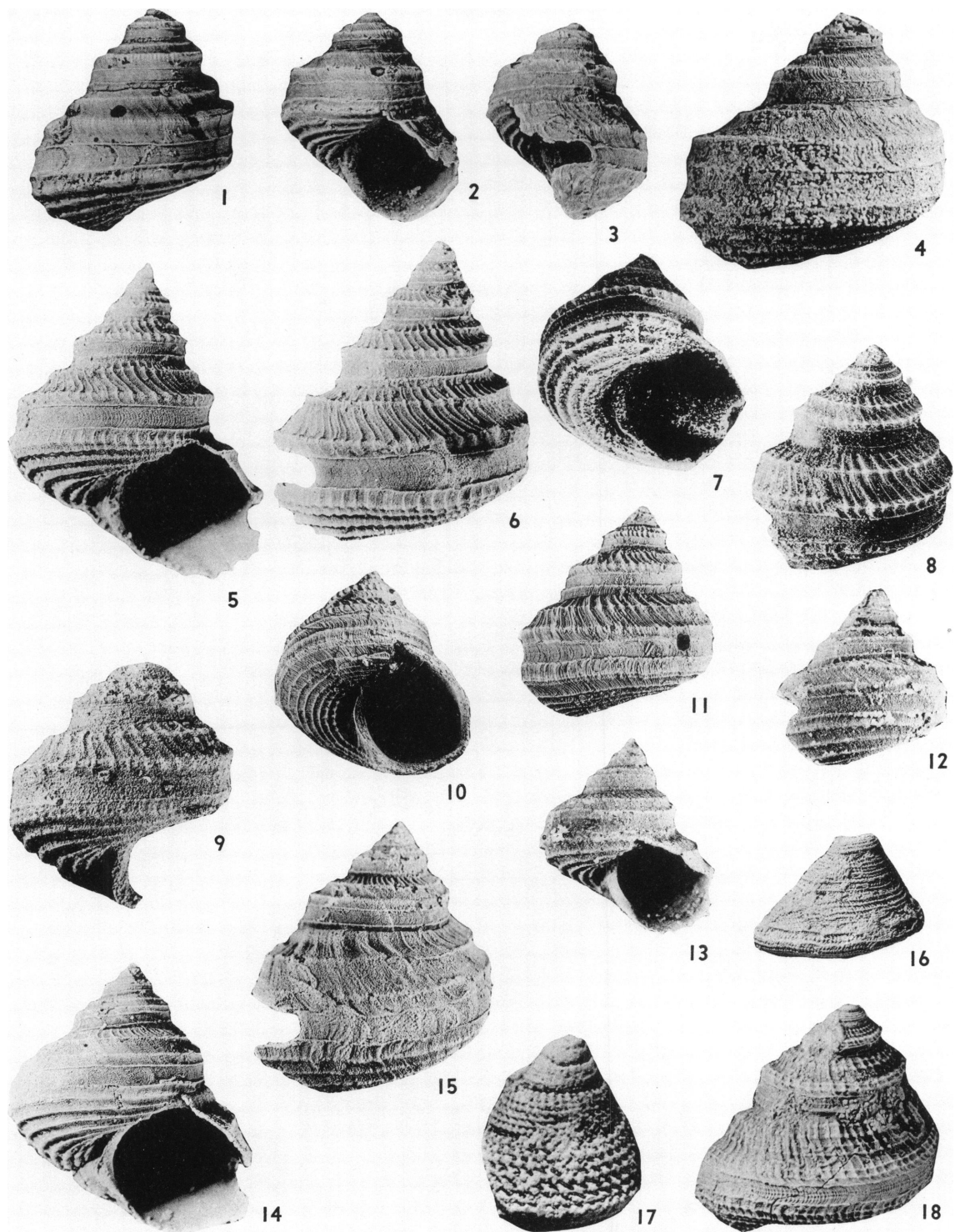
1-4. *Callitomaria magna* Batten, new species. 1. Side view of paratype showing more pronounced ornament on the penultimate whorl, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133300a,  $\times 2$ . 2. Apertural view, holotype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133300b,  $\times 2$ . 3. Side view of same specimen showing relative depth of the slit,  $\times 2$ . 4. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133300c,  $\times 4$ .

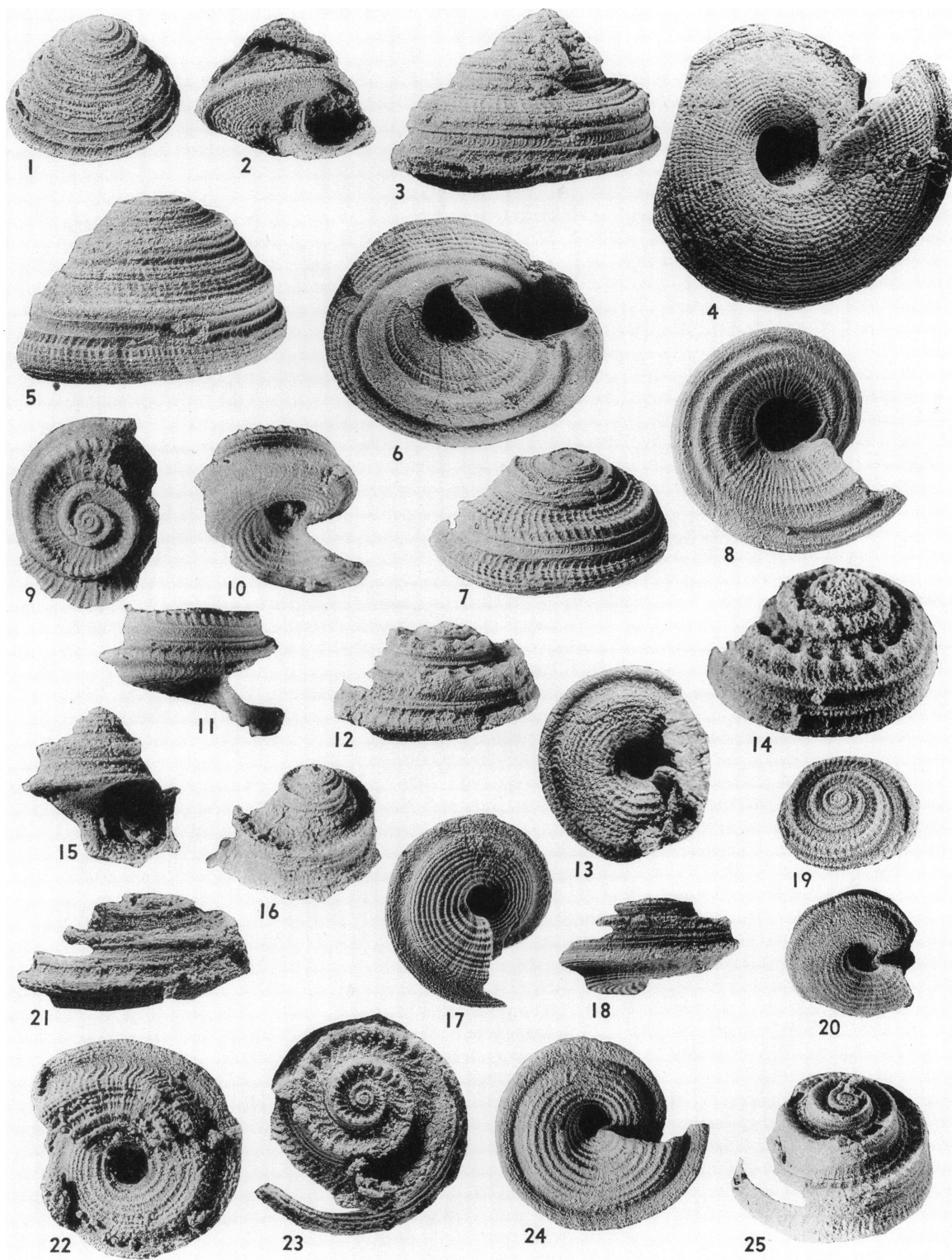
5-15. *Callitomaria stanislavi* Batten, 1956. 5. Apertural view, paratype, from P.U. 3, lower Bone Spring limestone, U.S.N.M. No. 133301a,  $\times 4$ . 6. Oblique side view of same specimen showing maximum development of ornament known within the species,  $\times 4$ . 7. Oblique apertural view, paratype, from A.M.N.H. 433, lower Bone Spring limestone, A.M.N.H. No. 28052:1,  $\times 4$ . 8. Oblique side view of same specimen showing weaker development of ornament than in 6,  $\times 4$ . 9. Side view of paratype showing strong basal ornament, from P.U. 3, lower Bone Spring limestone, U.S.N.M. No. 133301b,  $\times 3$ . 10. Oblique apertural view, holotype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 27953,  $\times 3$ . 11. Side view of same specimen,  $\times 3$ . 12. Side view, paratype, from P.U. 3, lower Bone Spring limestone, U.S.N.M. No. 133301c,  $\times 4$ . 13. Apertural view of same specimen showing weakly developed collabral ornament,  $\times 4$ . 14. Apertural view, paratype, from P.U. 3, lower Bone Spring limestone, U.S.N.M. No. 133301d,  $\times 4$ . 15. Oblique side view of same specimen showing heavy collabral ornament restricted to early whorls,  $\times 4$ .

16. *Phymatopleura brazoensis* Girty, 1939. Oblique side view, hypotype, from U.S.N.M. 702t, Wolfcamp formation, U.S.N.M. No. 133302,  $\times 4$ .

17. *Paragoniozona* cf. *P. nodilirata* Nelson, 1947. Oblique side view, hypotype, from U.S.N.M. 702t, Wolfcamp formation, U.S.N.M. No. 133303,  $\times 4$ .

18. *Phymatopleura* sp. Oblique side view, hypotype, from U.S.N.M. locality near Copan, Oklahoma, Wann shale, upper Pennsylvanian, U.S.N.M. No. 133304,  $\times 6$ .





### PLATE 37

1-4. *Glyptotomaria (Glyptotomaria) marginata* Batten, new species. 1. Oblique side view, paratype, from U.S.N.M. 712f, middle Hueco formation, U.S.N.M. No. 133305,  $\times 4$ . 2. Oblique basal view of same specimen showing the spiral ornament on callus,  $\times 4$ . 3. Side view, holotype, from U.S.N.M. 702d, Leonard formation (Hess limestone member, eastern facies), U.S.N.M. No. 133306a,  $\times 4$ . 4. Basal view of paratype with similar base to that of holotype, from U.S.N.M. 702d, Leonard formation (Hess limestone member, eastern facies), U.S.N.M. No. 133306b,  $\times 4$ .

5-8. *Glyptotomaria (Glyptotomaria) pistra* Batten, new species. 5. Side view, holotype, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133307,  $\times 5$ . 6. Oblique basal view, same specimen,  $\times 5$ . 7. Oblique side view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28053:1,  $\times 4$ . 8. Basal view of same specimen showing columellar and basal sinuses,  $\times 4$ .

9-11. *Discotomaria basisulcata* Batten, 1956. 9. Top view of paratype showing concave upper whorl surface, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133308,  $\times 6$ . 10. Oblique basal view of same specimen showing basal sinus,  $\times 6$ . 11. Apertural view, same specimen,  $\times 6$ .

12-14. *Discotomaria nodosa* Batten, new species. 12. Side view, holotype, from U.S.N.M. 702d, Leonard formation (Hess limestone member, eastern facies), U.S.N.M. No. 133311,  $\times 5$ . 13. Basal view of same specimen showing basal sinus confined to trough,  $\times 5$ . 14. Oblique side view, paratype, from U.S.N.M. 707d, Leonard formation (top of limestone no. 1), U.S.N.M. No. 133312,  $\times 8$ .

15, 16. *Discotomaria dubia* Batten, new species. 15. Apertural view, holotype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133313,  $\times 6$ . 16. Oblique side view of same specimen showing the frill-like extension of the lower edge of outer whorl face,  $\times 6$ .

17, 18. *Discotomaria basisulcata* Batten, 1956. 17. Basal view, paratype, from U.S.N.M. 703b, upper Leonard formation, U.S.N.M. No. 133309,  $\times 4$ . 18. Side view, same specimen.

19, 20. *Discotomaria nodosa* Batten, new species. 19. Oblique top view, paratype, from U.S.N.M. 712b, Hueco formation, U.S.N.M. No. 133310,  $\times 4$ . 20. Oblique basal view, same specimen,  $\times 4$ .

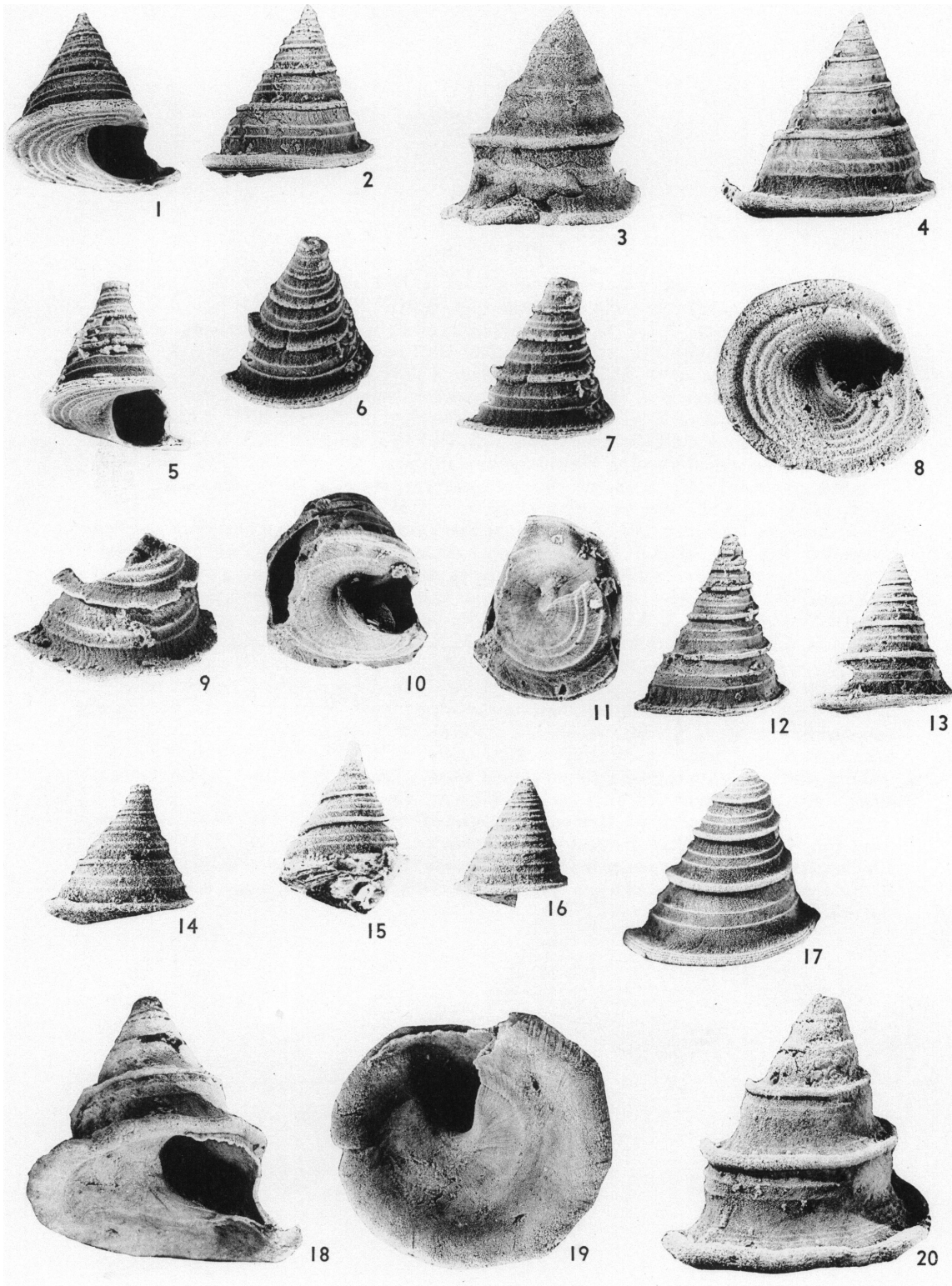
21-23. *Discotomaria basisulcata* Batten, 1956. 21. Side view, holotype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 125280,  $\times 4$ . 22. Basal view of same specimen showing basal sinus confined to basal trough,  $\times 4$ . 23. Top view, same specimen,  $\times 5$ .



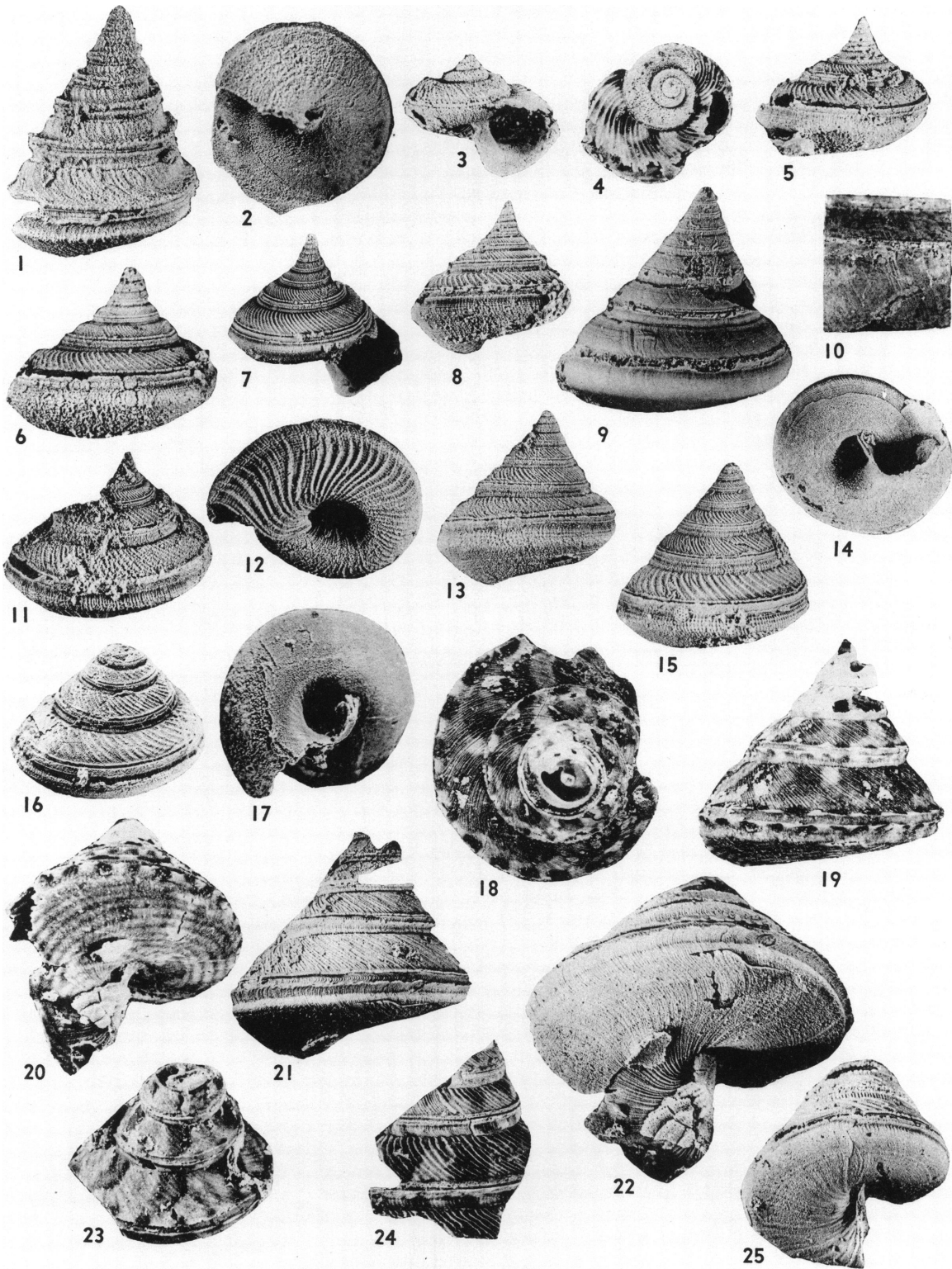
## PLATE 38

1-17. *Lamellospira conica* Batten, new species. 1. Oblique apertural view, holotype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28054:5,  $\times 2$ . 2. Side view of same specimen,  $\times 2$ . 3. Side view of paratype showing lack of overhanging flange in early whorls and also the repaired break of shell in selenizone area of body whorl, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133333a,  $\times 2$ . 4. Side view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28054:1,  $\times 2$ . 5. Oblique apertural view of paratype showing planispiral early whorls, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133333b,  $\times 5$ . 6. Oblique side view of same specimen showing the enlarged, planispiral early whorls,  $\times 5$ . 7. Side view of same specimen,  $\times 5$ . 8. Basal view of paratype showing basal ornament, from U.S.N.M. 707d, Wolfcamp formation (top), U.S.N.M. No. 133334,  $\times 3.5$ . 9. Oblique side view, same specimen,  $\times 3.5$ . 10. Oblique apertural view showing nature of reflexed columellar lip, from U.S.N.M. 703a, upper Leonard formation (*Aulosteges* beds), U.S.N.M. No. 133335a,  $\times 3.5$ . 11. Basal view of same specimen showing type of basal ornament,  $\times 3.5$ . 12. Side view, paratype, from U.S.N.M. 703a, upper Leonard formation (*Aulosteges* beds), U.S.N.M. No. 133335b,  $\times 3.5$ . 13. Side view, paratype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28054:2,  $\times 2$ . 14. Side view of paratype showing convex shell profile, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28054:3,  $\times 3$ . 15. Side view of paratype showing sutural contact on edge of basal cord under flange, rather than on the flange itself, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133336,  $\times 2$ . 16. Side view, paratype, from A.M.N.H. 678, Bone Spring limestone (Cutoff shell member), A.M.N.H. No. 28055:1,  $\times 3.5$ . 17. Oblique side view of paratype showing almost vertical growth lines, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28054:4,  $\times 5$ .

18-20. *Lamellospira cincta* Batten, new species. 18. Oblique side view, holotype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133337,  $\times 3.5$ . 19. Basal view of same specimen (note invaginated base and basal ornament),  $\times 3.5$ . 20. Side view of same specimen showing the relatively high position of the selenizone on the whorl,  $\times 3.5$ .







## PLATE 39

1, 2. *Spiroscala pulchra* Batten, new species. 1. Oblique side view, holotype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133315,  $\times 2$ . 2. Basal view of same specimen,  $\times 2$ .

3–8. *Shwedagonia elegans* Batten, 1956. 3. Apertural view, paratype, from U.S.N.M. 701L, Wolfcamp formation, U.S.N.M. No. 133316,  $\times 2$ . 4. Top view of same specimen (note color pattern),  $\times 2$ . 5. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133317a,  $\times 2$ . 6. Side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133317b,  $\times 4$ . 7. Oblique apertural view of paratype showing deep slit almost a whorl in depth, from U.S.N.M. 703a, upper Leonard formation, U.S.N.M. No. 133318,  $\times 2$ . 8. Side view of same specimen,  $\times 2$ .

9, 10. *Shwedagonia mariana* (Gemmellaro), 1885. 9. Oblique side view of hypotype showing lack of collabral ornament other than growth lines, Permian, Pallaggio, Rocca di Salamone, Fiume, Sosio, Italy, U.S.N.M. No. 133322a,  $\times 3$ . 10. Detail of side view of hypotype showing part of lower selenizone margin formed by outer shell layer which has been removed, exposing narrow selenizone, from same locality as 9, U.S.N.M. No. 133322b,  $\times 4$ .

11–17. *Shwedagonia elegans* Batten, 1956. 11. Oblique side view, holotype, from U.S.N.M. 703b, upper Leonard formation, U.S.N.M. No. 125279,  $\times 2$ . 12. Oblique basal view of same specimen showing extreme development of basal collabral ornament,  $\times 2$ . 13. Side view of paratype showing almost straight shell profile (compare with 5, 6, 7, and 8, which show concave shell profile), from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28056:1,  $\times 2$ . 14. Oblique basal view of same specimen showing smooth base,  $\times 2$ . 15. Oblique side view of paratype showing straight shell profile, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133319a,  $\times 2$ . 16. Oblique side view, paratype, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133319b,  $\times 2$ . 17. Basal view of same specimen showing collabral ornament restricted to margin of umbilicus,  $\times 2$ .

18–23. *Euconospira varizona* Batten, new species. 18. Top view of holotype, showing color pattern, from U.S.N.M. 701g, Wolfcamp formation, U.S.N.M. No. 133320a,  $\times 3$ . 19. Side view of same specimen,  $\times 3$ . 20. Oblique basal view of same specimen showing color bands which spiral in opposite direction to direction of coiling,  $\times 3$ . 21. Side view of same specimen, whitened, and showing flange-like selenizone margins,  $\times 3$ . 22. Oblique basal view of same specimen, whitened, showing an increased intensity of collabral ornament near umbilicus,  $\times 4$ . 23. Oblique side view of paratype showing different color pattern in same species, from U.S.N.M. 701g, Wolfcamp formation, U.S.N.M. No. 133320b,  $\times 2$ .

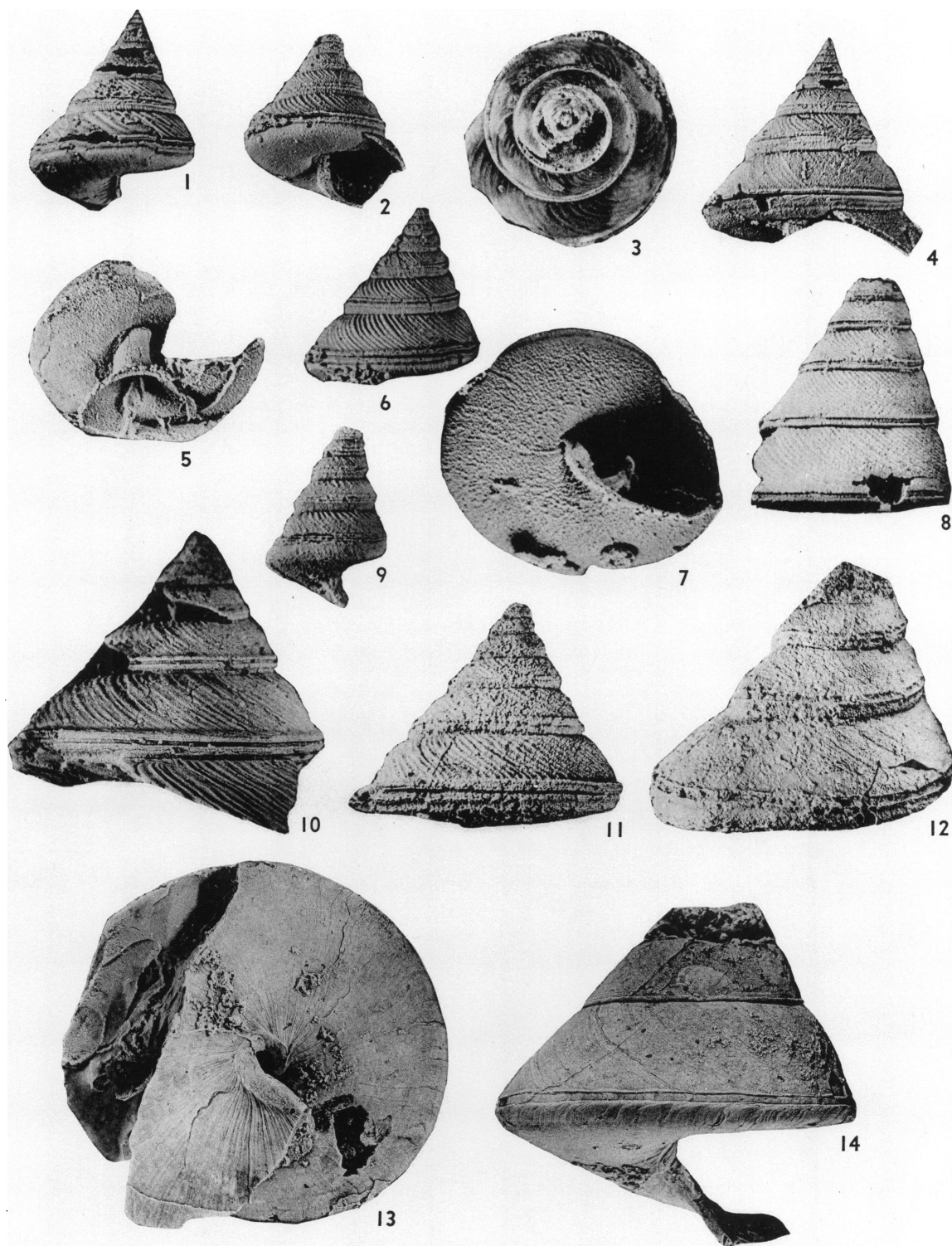
24, 25. *Euconospira pulchra* Batten, new species. 24. Side view of paratype showing heavy collabral ornament which is intense near suture, from U.S.N.M. 702c, upper Leonard formation, U.S.N.M. No. 133321a,  $\times 3$ . 25. Oblique basal view, holotype, from U.S.N.M. 702c, upper Leonard formation, U.S.N.M. No. 133321b,  $\times 2$ .

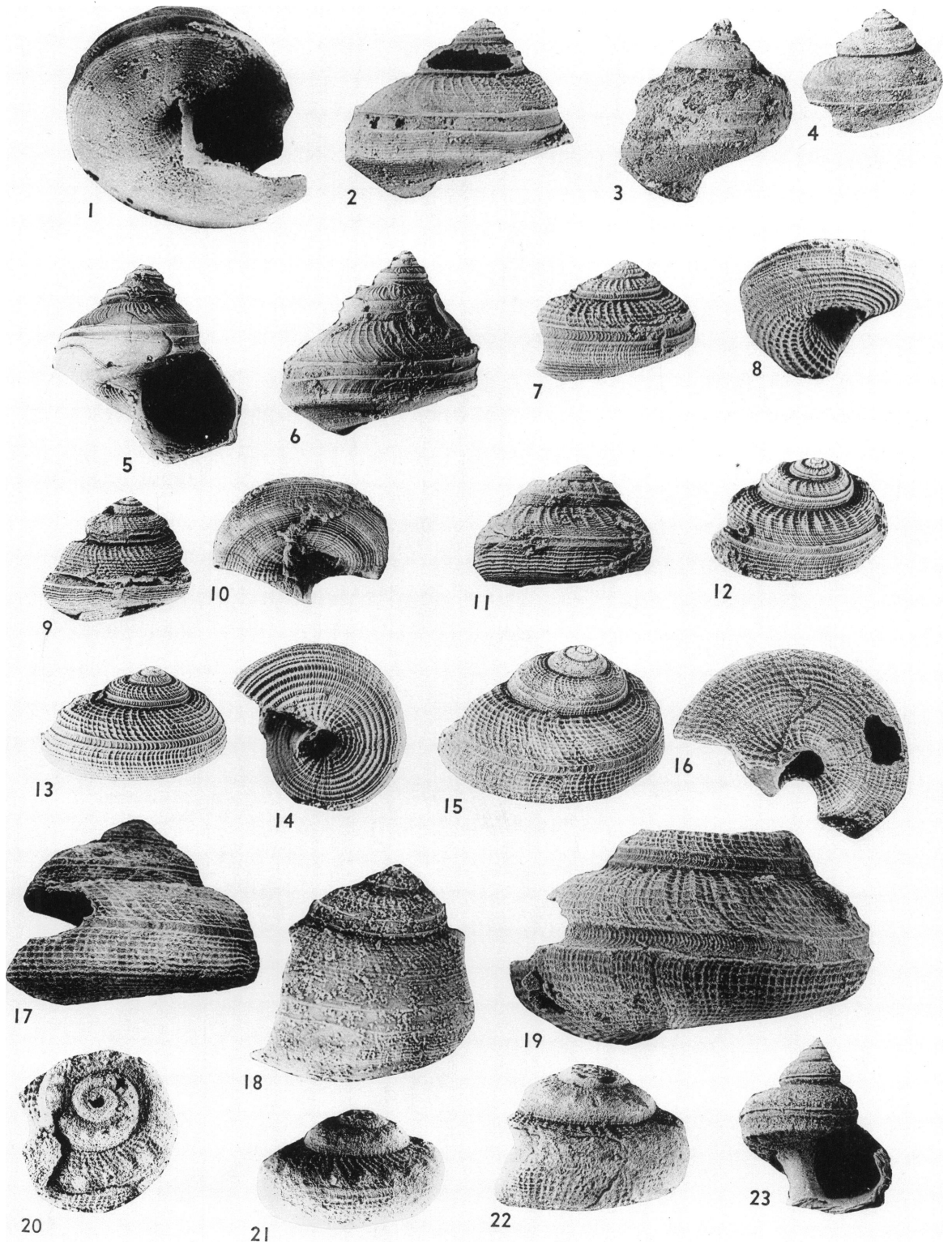
## PLATE 40

1-9. *Euconospira pulchra* Batten, new species. 1. Side view of holotype showing the complex nature of the selenizone and heavy collabral ornament above the selenizone,  $\times 3$ . 2. Apertural view, paratype, from U.S.N.M. 702c, upper Leonard formation, U.S.N.M. No. 133323,  $\times 3$ . 3. Top view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133324a,  $\times 3$ . 4. Side view of paratype showing deep slit, from U.S.N.M. 703a, upper Leonard formation (*Aulosteges* beds), U.S.N.M. No. 133325a,  $\times 3$ . 5. Oblique basal view of a broken paratype showing open umbilicus and a ridge forming upper portion of columellar lip, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133326,  $\times 3$ . 6. Side view of paratype showing the flattened, wide selenizone margins caused by attrition of the tapering margins, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133324b,  $\times 2$ . 7. Oblique basal view of paratype showing the slight groove on the reflexed columellar lip, from U.S.N.M. 703a, uppermost Leonard formation (*Aulosteges* beds), U.S.N.M. No. 133325b,  $\times 2$ . 8. Side view of paratype showing flat base and well-developed selenizone margins, from U.S.N.M. 716, lower Bone Spring limestone, U.S.N.M. No. 133327,  $\times 2$ . 9. Side view of paratype showing heavy collabral ornament near selenizone and the high position of the selenizone on the whorl, from U.S.N.M. 728, lower Getaway formation, U.S.N.M. No. 133328,  $\times 2$ .

10-11. *Euconospira varizona* Batten, new species. 10. Side view of broken paratype showing nature of selenizone margins, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133329,  $\times 3$ . 11. Side view of paratype showing flat base, from U.S.N.M. 703b, upper Leonard formation, U.S.N.M. No. 133330,  $\times 3$ .

12-14. *Euconospira spiroperforata* Batten, new species. 12. Oblique side view, paratype, from U.S.N.M. 707a, Leonard formation (Hess limestone member, western facies), U.S.N.M. No. 133331,  $\times 2$ . 13. Basal view of holotype showing thickened callus around umbilicus, from U.S.N.M. 701f, Wolfcamp formation, U.S.N.M. No. 133332,  $\times \frac{1}{2}$ . 14. Apertural view of same specimen showing weakly developed selenizone margins,  $\times \frac{1}{2}$ .







# PLATE 41

1-6. *Eirlysia exquisita* Batten, 1956. 1. Oblique apertural view, holotype, from P.U. 3, Bone Spring limestone, U.S.N.M. No. 125282,  $\times 3.5$ . 2. Side view of same specimen,  $\times 3.5$ . 3. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133338,  $\times 2$ . 4. Oblique side view of paratype showing intermediate nature of the shell compared to shells shown in 2 and 3, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133339,  $\times 2$ . 5. Apertural view of paratype showing strong reflection of upper columellar lip, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28057:1,  $\times 2$ . 6. Side view of same specimen showing pronounced collabral ornament above the selenizone and the relatively high spire,  $\times 2$ .

7-17. *Eirlysia reticulata* Batten, new species. 7. Oblique side view, holotype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058,  $\times 4$ . 8. Oblique basal view of same specimen,  $\times 4$ . 9. Side view of paratype showing that it is relatively high-spired, from U.S.N.M. 707d, Wolfcamp formation (top), U.S.N.M. No. 133340,  $\times 2$ . 10. Oblique basal view of paratype showing trough around outer edge of base, from U.S.N.M. 703b, upper Leonard formation, U.S.N.M. No. 133341,  $\times 2$ . 11. Side view of same specimen,  $\times 2$ . 12. Oblique side view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133342,  $\times 2$ . 13. Oblique side view of paratype showing weakly developed selenizone margins and nearly equal spiral and collabral ornament, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058:1,  $\times 3$ . 14. Basal view of same specimen showing resorbed collabral ornament,  $\times 3$ . 15. Oblique side view, paratype, A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058:2,  $\times 2$ . 16. Basal view of same specimen showing lack of basal trough,  $\times 2$ . 17. Side view of paratype showing flat base from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058:3,  $\times 2$ .

18. *Eirlysia exquisita* Batten, 1956. Oblique side view, paratype, from U.S.G.S. 14439, Bone Spring limestone, U.S.N.M. No. 133343,  $\times 4$ .

19. *Eirlysia reticulata* Batten, new species. Side view of paratype showing median thread on selenizone and undulating surface above selenizone, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058:4,  $\times 5$ .

20-22. *Eirlysia nodosa* Batten, new species. 20. Oblique top view of holotype showing nodes on outer margin of upper whorl surface, from U.S.N.M. 706c, Word formation (middle of limestone no. 2), U.S.N.M. No. 133344,  $\times 2$ . 21. Oblique side view of paratype with southeast lighting to show nodes, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28058:1,  $\times 2$ . 22. Side view of paratype showing reticulate ornament, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28059:2,  $\times 2$ .

23. *Lacunospira alta* Batten, new species. Apertural view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133345,  $\times 2$ .

PLATE 42

1. *Lacunospira altsia* Batten, new species. Oblique side view, holotype, from A.M.N.H. 512, lower Getaway formation, A.M.N.H. No. 28061,  $\times 4$ .

2-5. *Lacunospira alta* Batten, new species. 2. Oblique view, paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133346a,  $\times 1$ . 3. Oblique apertural view of holotype showing lacunae, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133346b,  $\times 1$ . 4. Oblique side view of same specimen. 5. Oblique apertural view of paratype showing contact of columellar lip with parietal lip, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133346c,  $\times 2$ .

6. *Lacunospira altsia* Batten, new species. Side view, paratype, from U.S.N.M. 703, Word formation (limestone no. 1), U.S.N.M. No. 133349,  $\times 1$ .

7. *Lacunospira alta* Batten, new species. Side view of paratype, from U.S.N.M. 702, upper Leonard formation, U.S.N.M. No. 133346c,  $\times 2$ .

8. *Lacunospira lirata* Batten, new species. Side view, holotype, from U.S.N.M. 707e, lower Word formation, U.S.N.M. No. 133347,  $\times 1$ .

9. *Glyptotomaria* (*Glyptotomaria*) *marginata* Batten, new species. Showing what appears to be a growth of the heliospongid wall around the specimen in the center of the photograph, from U.S.N.M. 702d, Leonard formation (Hess limestone member, eastern facies),  $\times 1$ . Photograph courtesy of Robert Finks who discovered and photographed this specimen.

