

LOWER LEONARDIAN
BRACHIOPODA
OF THE
SIERRA DIABLO

FRANCIS GREENOUGH STEHLI

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INTRODUCTION

ABSTRACT

THE SIERRA DIABLO MOUNTAINS of western Texas contain an excellent section of Permian rocks ranging in age from Wolfcampian to Guadalupian, which in conjunction with the Permian sequence in the near-by Guadalupe Mountains form the standard section of the North American Permian. Outcrops of Leonardian rocks (Bone Spring formation), poorly exposed in the Guadalupe Mountains, are well exposed in the Sierra Diablo, with excellent three-dimensional control over the complex facies changes which take place at the margin of the Delaware Basin. The sea of early Bone Spring time transgressed an erosion surface of Wolfcampian and older rocks, leaving deposits which reveal many of the environmental conditions. Sediments deposited in the deeper waters of the Delaware Basin, and occasionally on the rim of the marginal shelf, are dark, platy carbonates representing an environment inimical to most

forms of life. Immediately behind the transgressing shore line followed an environment of high organic activity. From these deposits large collections of silicified fossils have been obtained. The excellent preservation and ease of recovery of these fossils have permitted much more complete sampling of the fauna than had previously been possible. The nature of the material and its occurrence are such that many inferences may be made concerning the life requirements of the animals represented. The fauna is composed largely of brachiopods, a systematic study of which constitutes most of this contribution. This study has resulted in the recognition of 54 species, 36 of which are new, distributed among 45 genera, 12 of which are new. These 45 genera are distributed among 14 subfamilies, of which six are new, and among 15 families, of which four are new.

Investigation of the Sierra Diablo was initiated as a part of a broad study of the Permian reefs of west Texas directed by Norman D. Newell. The program was sponsored by the American Museum of Natural History and Columbia University and was financed by a grant from the Humble Oil and Refining Company.

Study of the Permian reefs was concentrated especially in the Guadalupe Mountains because of the excellent development there of well-preserved reef structures. The lower part of the Permian section, however, is not shown there, and important reef structures are limited to the Guadalupian series (Goat Seep and Capitan reefs).

Much of the sequence in the Sierra Diablo comprises sediments deposited during Wolfcampian and Leonardian time on the slopes and margin of the Delaware Basin, at that time a comparatively deep and perhaps stagnant basin of deposition. Organic reefs, both large and small, are scattered throughout much of the Permian sequence. The majority are older than any exposed in the Guadalupe Mountains. Consequently it will be seen that this section supplements that of the Guadalupe Mountains, the two areas providing the outcrops of the American standard section of the Permian system.

Study of the Sierra Diablo was undertaken by me to extend the reef studies to the lower part of the Permian section and to piece together the evolution of the marginal area of the basin during the Leonardian.

The major program of reef studies in west Texas falls into two parts. The first, now completed, consisted of a study of the stratigraphy of the reef areas, with especial reference to the depositional environments. During this phase of the investigation large collections of fossils, mainly silicified, were accumulated. The preparation and study of these vast collections constitute the second phase of the program, on which work is just beginning. Study of these collections in the light of the known sedimentational data will advance our understanding of past environments in general and of the Permian reef environments in particular. The faunal study is complementary to the work of G. A. Cooper and others in the Glass Mountains.

Preparation for this investigation has included study of the modern reefs of Andros Island in the Bahamas. These reefs were studied with the aid of a small boat and diving gear. Appreciation of the exceedingly complex organic community composing the living reefs has greatly aided in the understanding and interpretation of the Permian reefs and

in recognition of the multitude of ecologic niches offered by the reef environment.

Field work in the Sierra Diablo was carried on during July and August of 1951 by the writer, assisted by William Marshall, and was devoted mainly to the collection of tons of limestone containing silicified fossils. Hence the investigation did not include all of the range but was carried only as far south as the region about Victorio Canyon (fig. 2). Brief trips were made, however, farther to the south and also into the adjoining Baylor Mountains. The accumulation of large fossil collections was essential because of the general lack of knowledge of the Leonardian faunas in this region.

Work in the Sierra Diablo was greatly facilitated by investigations of earlier workers, chief among whom have been P. B. King, R. E. King, and J. B. Knight. A geologic map of the range prepared by P. B. King and J. B. Knight was of invaluable aid in the earlier phases of the investigation.

Following completion of the field work the limestone blocks that had been collected were processed in the acid laboratory of the American Museum of Natural History. From the resulting collections those of the lowest Bone Spring formation in the area around Victorio

Canyon were selected for immediate study. This choice was made not only because of the remarkable brachiopod fauna contained in the collections but because at this horizon it was possible to reconstruct the physical conditions during deposition. Study of the prepared faunas was carried out at the American Museum of Natural History and at the United States National Museum.

The writer wishes to acknowledge the assistance of numerous individuals and organizations during the course of this study. The work was made possible by support from the Humble Oil and Refining Company and by a fellowship awarded by the National Science Foundation. Field studies were directed by Dr. Norman D. Newell, who also extended the facilities of the American Museum of Natural History and generously contributed much of his own time and energy. Assistance in the field was rendered without stint by Mr. William Marshall.

A prolonged stay at the United States National Museum was made possible by Dr. G. A. Cooper, who offered not only the facilities of the Museum but his own hospitality and served both as adviser and a source of inspiration.

REGIONAL SETTING

THE PERMIAN SECTION in the west Texas region is of outstanding interest among the principal Permian areas of the world because it exposes up to 12,000 feet of fossiliferous Permian strata which are largely of marine origin. A general understanding of the very complex stratigraphic relations of the region has been gradually obtained through the work of many geologists, particularly the outstanding contributions of P. B. King.

Extensive Permian sections are found in several of the mountain areas of west Texas, the most notable being the Glass Mountains and the combined sections of the Guadalupe Mountains and the Sierra Diablo (fig. 1).

marginal areas of the basins. What at first seem to be completely random changes assume meaning if they are regarded in their relationship to the depositional surfaces. They exhibit a pattern which outlines rapidly subsiding areas (the eastern Midland Basin, the central Delaware Basin, and the western, incompletely known, Marfa Basin) separated by areas of more gradual subsidence (Central Basin Platform and the Diablo Plateau). (See fig. 1.) To the northwest, north, east, and south these basins and their intervening platforms were surrounded by more slowly subsiding shelf areas of great extent.

The most rapid and extreme marine facies

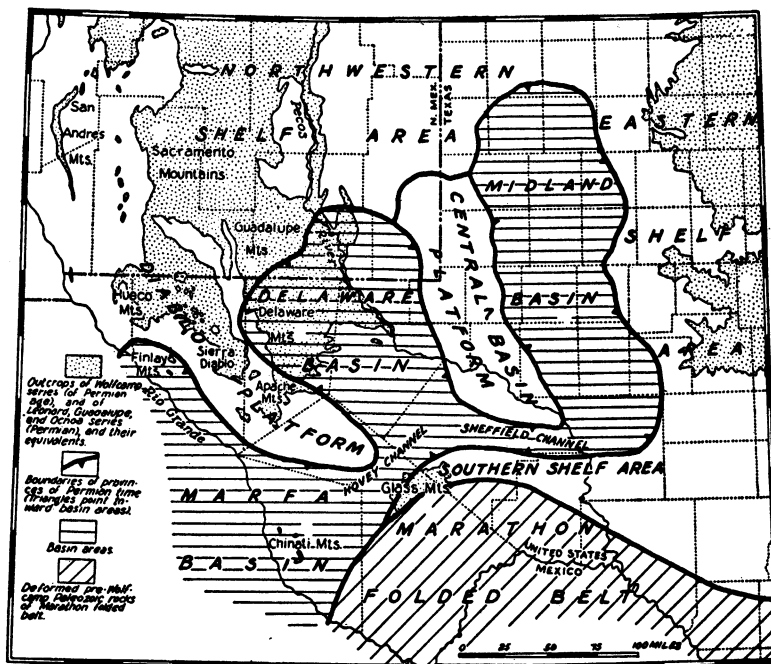


FIG. 1. Generalized map of west Texas and southeastern New Mexico, showing the location of the principal mountain masses and the location of the Permian basins and platforms. Copyright by the American Association of Petroleum Geologists; used by permission.

Numerous less extensive areas have added details, and in some areas much information has been gained from drilling.

The most striking feature of the Permian rocks in west Texas is found in the extreme and rapid facies changes characteristic of the

changes bear definite relations to the basin margins. Localization of the margins was only partly of tectonic origin. It was accentuated through much of Permian time by great reef structures which encircled the basins and acted as both sedimentational barriers and

depositional agents.

The magnitude and character of some of these facies changes are magnificently displayed in the Sierra Diablo where the margin of the Leonardian Delaware Basin is well shown in three dimensions.

The Sierra Diablo is a tilted fault block, bounded on the east by a steep escarpment ranging up to 2000 feet in height. To the west the surface of the range slopes gently away as a nearly flat upland. The range runs northward from the town of Van Horn, Texas (fig. 2), for a distance of about 40 miles, and closely follows the boundary between Hudspeth and Culberson counties. An associated group of fault slivers forms the triangular mass of the Baylor Mountains adjacent to the Sierra Diablo to the southeast.

The Sierra Diablo is dissected by many small canyons and by several major ones which cut completely through the mountains and afford excellent exposures. The two most

important canyons are Apache Canyon in the north and Victorio Canyon in the central part of the range (fig. 2).

The present distribution of the Permian outcrops is strongly influenced by two monoclinal flexures which cross the range with a west-northwest trend. These are the Victorio flexure (P. B. King, 1942, p. 624) just south of Victorio Canyon, and the Babb flexure just north of Apache Canyon. Both flexures roughly parallel the margin of the basin, and in each case the rocks were depressed to the northeast. South of Victorio flexure only older Permian formations are preserved, while to the north of the Babb flexure outliers of lower Guadalupian rocks remain.

Access to the mountains is gained by a few ranch roads to windmills in the mouths of the major canyons. Large areas of the range are approached with difficulty, and high cliffs along the base of the escarpment in places impose a formidable barrier to investigation.

STRATIGRAPHY

Much work on the stratigraphy of the Sierra Diablo has been done by P. B. King, and in many respects the conclusions of the present study confirm his interpretations and overlap his work. Many of the ideas presented below have been previously advanced by King (1934, 1942). The motivation behind this study is unlike that of earlier investigators. Here, the stratigraphy has been investigated with the purpose of evaluating the ecology of the various kinds of sedimentational environments represented by the rocks and fossils. In this respect the work is independent of that of previous investigators, and considerable new information has been added by the study. A summary of the general stratigraphic relations together with certain interpretations as to depositional conditions is presented below.

PRE-PERMIAN SURFACE

The beginning of Permian (Huecoan) deposition witnessed an advance of the sea across an erosional surface in the Sierra Diablo region. The rocks truncated by this surface range in age from Precambrian to

middle Pennsylvanian (King and Knight, 1944). Lithologically they range from varied Precambrian metamorphics to sandstones, shales, and carbonates of the Paleozoics.

This great unconformity beneath the Permian is strikingly exposed in the southern Sierra Diablo between Victorio Canyon and Van Horn (fig. 2). Throughout this area the Permian is seen to lie largely on the Precambrian, though in places it rests on lower Paleozoic rocks.

To the north, between Victorio and Apache canyons, the unconformity is less well exposed, but where the contact is visible the Permian lies on a varied terrane of Ordovician to Pennsylvanian rocks. North of Apache Canyon the base of the Permian is not exposed.

The encroaching Permian seas inundated a surface of considerable local relief. This is indicated by irregular thickness and distribution of the clastic beds in the lower part of the Hueco formation (fig. 3). These beds appear to have collected in low areas; they are absent over former hills. These relations may be strikingly seen in the upper reaches of Vic-

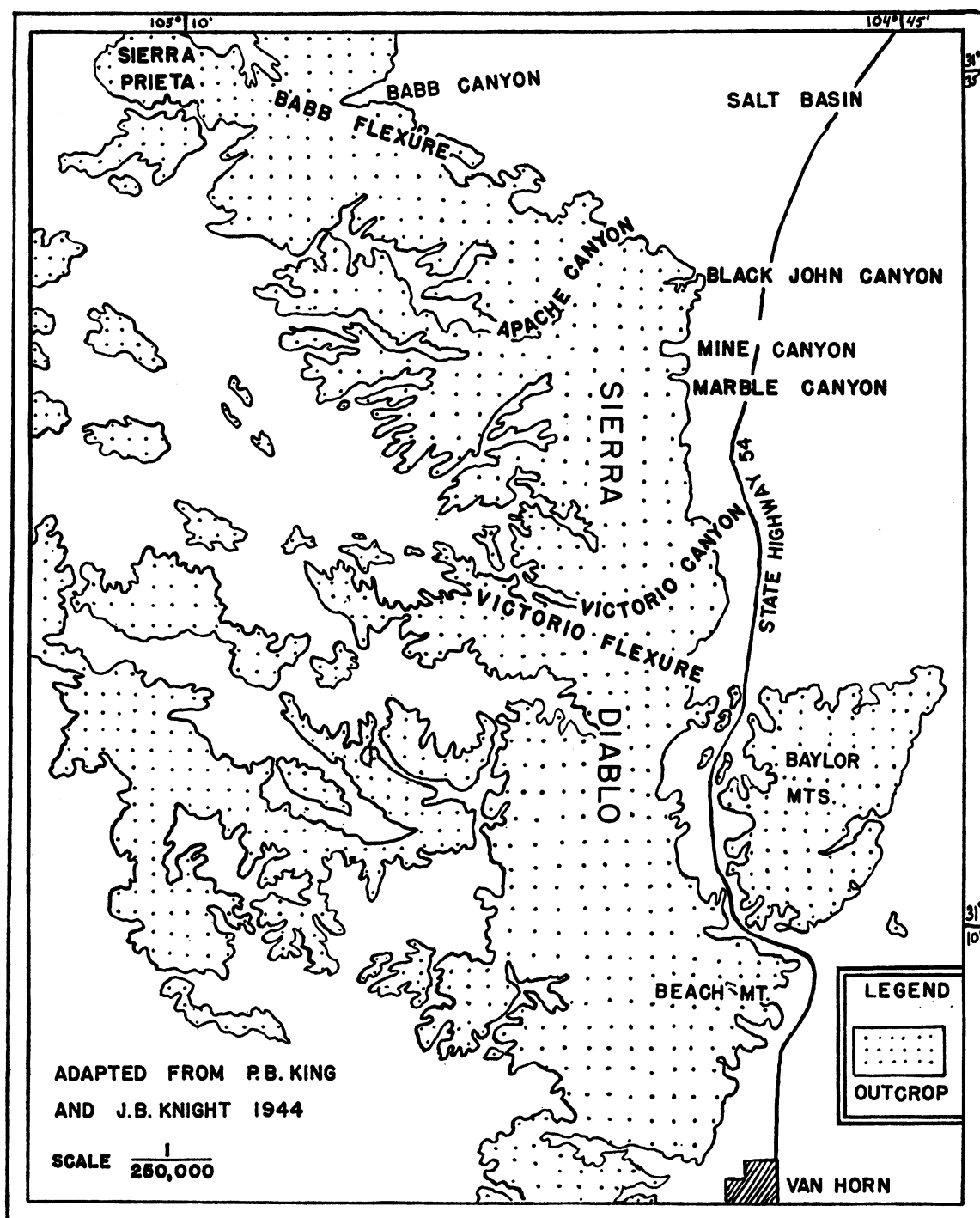


FIG. 2. The Sierra Diablo region.

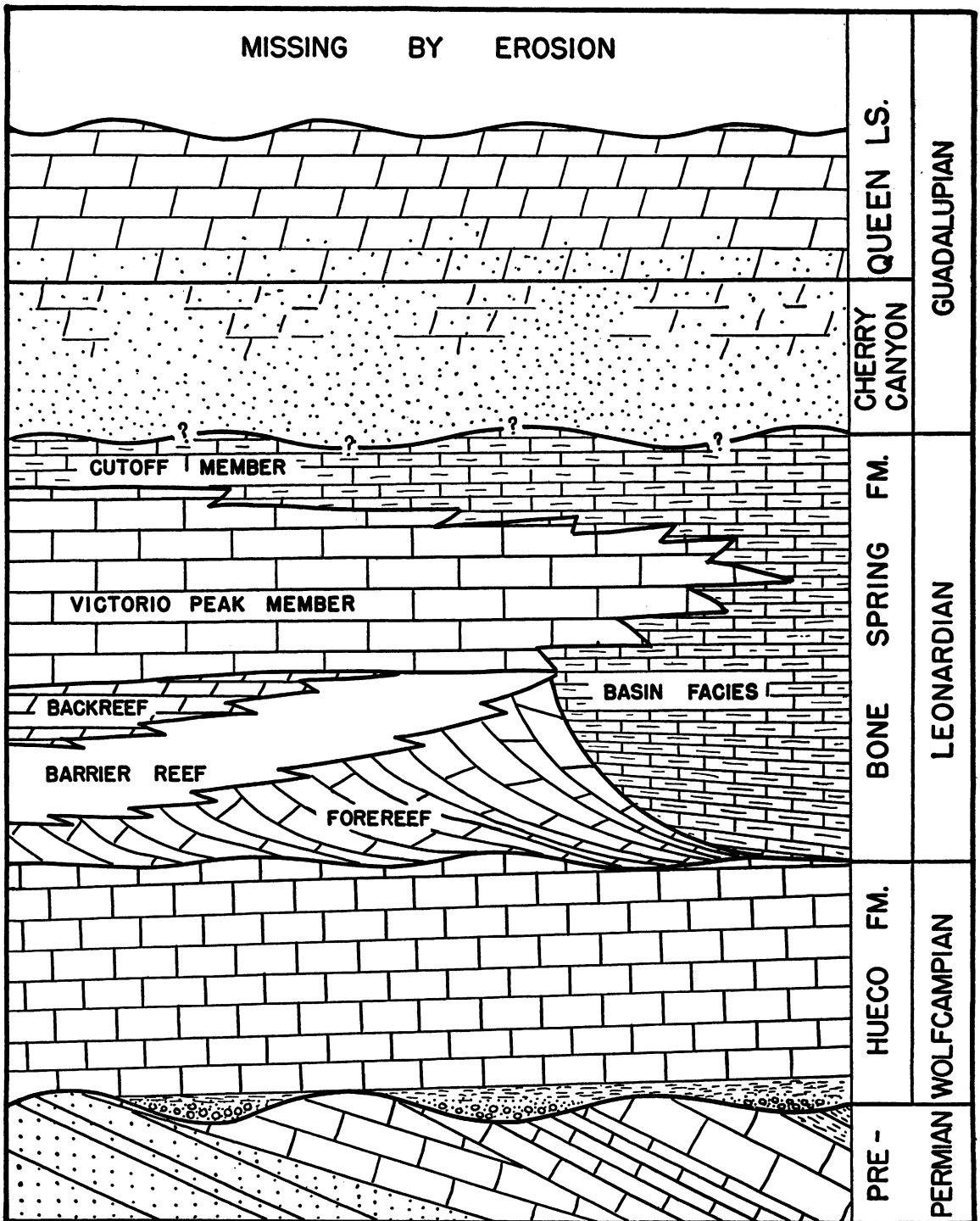


FIG. 3. Diagrammatic composite section of the Permian rocks of the Sierra Diablo.

torio Canyon where the Hueco rests on a hill of steeply dipping Ordovician rocks (King and Knight, 1944). The Hueco dips away from this hill in all directions and contains clastics only locally near its base. Further indications of relief may be seen about one-half of a mile above the mouth of Victorio Canyon where the north wall exposes several small-scale folds and "thrusts." The local nature and small scale of these features are believed to indicate that they are due to slumping following deposition on a slope; however, they could also be explained by Permian movement along the line of the Victorio flexure. Because of the presence of an unconformity above as well as below the Hueco, its thickness distribution as a whole offers little evidence relative to initial relief.

THE HUECO FORMATION

The oldest Permian deposits in the Sierra Diablo are represented by the Hueco formation of Wolfcampian age which lies on the unconformity noted above. The initial Hueco deposits are clastics of varied nature and perhaps represent reworked soils and stream deposits of the inundated surface. In the southern part of the range, where this basal sequence is best developed, it begins with the deposition of conglomeratic materials and grades upward into sandstones, siltstones, and marls. The conglomerates, commonly lying on or near the unconformity, are reddish, buff, or gray and contain numerous rounded fragments of diverse character up to one inch in diameter. All of the Paleozoic rock types of the area seem to be represented, and there are also quartz pebbles presumably derived from the Precambrian metamorphics. These quartz pebbles often occur at some distance from known Precambrian outcrops and were probably moved to their present position by streams during the pre-Hueco erosion interval. The pebbles are contained in a fine-grained matrix, indicating that the sediment has not been significantly sorted.

In general the higher part of the clastic section becomes finer grained, and there is a concomitant increase in megafossils. Fusulinids, productid brachiopods, and gastropods are common in the upper marly beds and commonly weather out in profusion.

The basal Hueco beds are best developed and most accessible at the mouth of Victorio Canyon and farther to the north at the mouths of Marble and Mine canyons. In the intervening area these beds are not exposed. South of Victorio Canyon they are moderately developed but are located high on the escarpment and are wholly inaccessible. North of Mine Canyon the beds are thinner and less strikingly developed. In Black John Canyon (fig. 2) they are thin and consist of fusulinid-packed marls, while coarser deposits are lacking. At the mouth of Apache Canyon, the northernmost exposure of the base of the Permian, the clastic beds are completely absent, and the dolomites characteristic of so much of the Hueco lie on older Paleozoic rocks.

Above the clastic beds, the Hueco consists of a series of carbonate rocks of rather uniform character. They are well stratified, but the beds are of irregular thickness and vary from a few inches to 6 feet or more. In general the formation consists of a monotonous series of reddish to gray, largely dolomitic and considerably unfossiliferous rocks.

In the southern part of the range the Hueco forms a prominent cliff capping a scarp composed of Precambrian and Paleozoic rocks. Just to the south of Victorio Canyon the Victorio flexure brings the formation to a position at the base of the scarp where it forms low cliffs. Between Victorio Canyon and Mine Canyon the formation is not well exposed. From Mine Canyon north to Apache Canyon the Hueco is well developed and forms a series of outstanding cliffs surmounted by a broad bench. North of Apache Canyon the formation is not exposed.

In addition to the exposures along the eastern scarp, several excellent sections are to be found in canyons which have cut deeply into the range. These canyons furnish excellent three-dimensional control on many aspects of the stratigraphy. Apache Canyon cuts entirely through the range and affords exceptionally good exposures of the Hueco and Bone Spring formations (fig. 4A).

At the mouth of Apache Canyon the Hueco is very thin. It lies unconformably on the Fusselman (Silurian) limestone (King and Knight, 1944) and is overlain unconformably

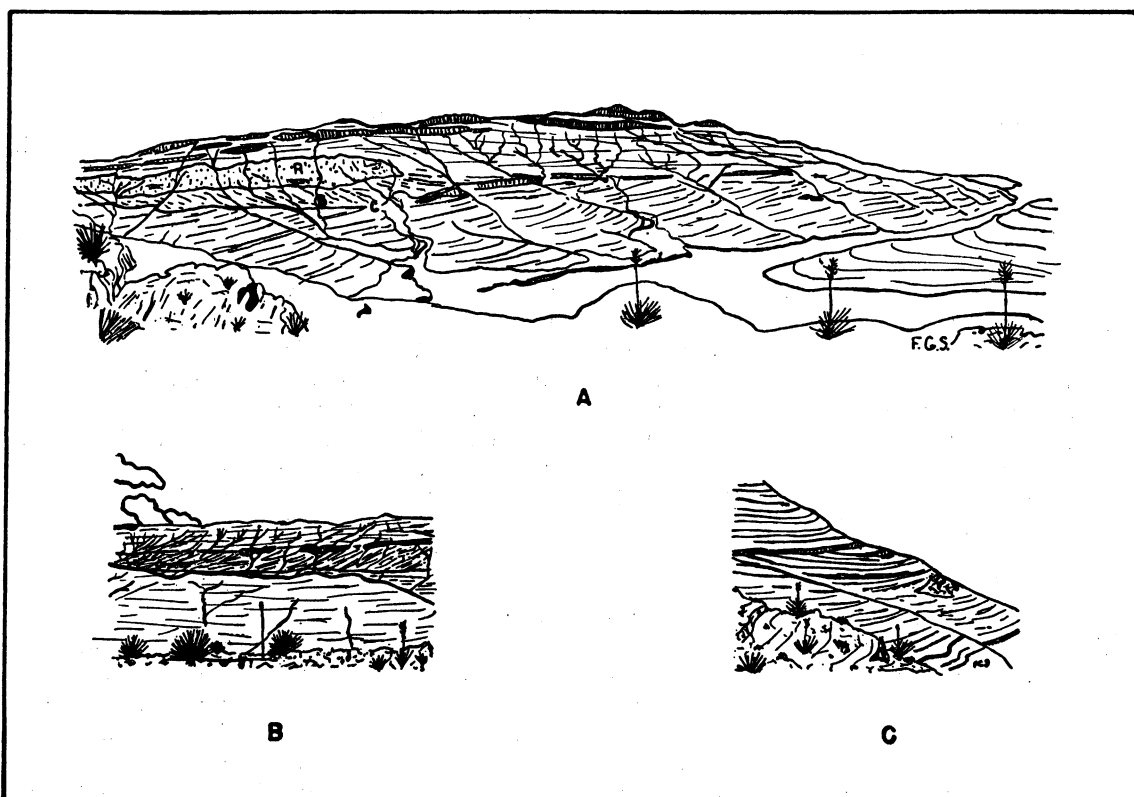


FIG. 4. Sketches of Apache Canyon and the Victor flexure. A. North side of Apache Canyon. The lower part of the canyon wall is composed of the Hueco formation dipping gently up the canyon. It is overlain above unconformity (C) by the Bone Spring formation. The Barrier reef (A) has migrated basinward over its own forereef beds (B), and both give way to rocks of basin facies towards the canyon mouth. Above the reef (A) the massive beds of the Victorio Peak member replace the rocks of basin facies beyond the limit of former reef growth. B. Longitudinal section of the barrier reef as seen in a tributary of Apache Canyon. Dipping forereef beds unconformably overlie the Hueco formation. Above the forereef beds is the massive reef, which is in turn overlain by the Victorio Peak member. C. Unconformable relations between the Hueco and Bone Spring formations along the Victorio flexure.

by the Bone Spring formation. Despite the great erosional unconformity between the Fusselman and the Hueco there is little apparent discordance and the contact is difficult to recognize. Exposures are poor, but the basal clastic phase of the Hueco seems to be absent here. The exact thickness of the Hueco was not determined. Certainly it does not exceed a few hundred feet and quite probably is little more than 100 feet.

The thinness of the formation at this place is the result of several factors. The absence of the basal clastics suggests that the area may have been a topographic high on the surface transgressed by the Wolfcampian sea. A sec-

ond and far greater effect has been exercised by post-Hueco to pre-Bone Spring erosion. The Hueco was flexed at the close of the Wolfcampian along or parallel to the present Babb flexure. In Apache Canyon the formation is seen to dip 4 to 5 degrees to the southwest. The actual flexure, together with its eastern limb, is to be sought in the down-dropped block that floors the Salt Basin to the east. This flexure exposed a great thickness of Hueco beds to erosion. The magnitude of the erosional interval is especially impressive as one proceeds up the canyon, for younger beds of the Hueco continue to come in below the overlapping Bone Spring until

the thickness of the formation probably exceeds 1000 feet, though the entire thickness is not exposed at any one place.

In Victorio Canyon the Hueco exhibits a considerable thinning. Though the base of the formation is not exposed in the canyon, there is a good section of the basal clastics and it is probable that the base is not far below the lowest beds exposed. The formation has a thickness of only about 150 feet (P. B. King, 1942, p. 561) at this point. The abundance and conglomeratic nature of the clastics indicate that this was not an elevated area on the Prepermian surface though there are local highs near by. The thinning seems to be due to extensive erosion which in some places along the general trend of the Victorio flexure (fig. 4C) cut deeply into the Hueco or even allowed the Bone Spring to be deposited on exhumed hills of Ordovician rocks. There seems to have been post-Hueco movement along the Victorio flexure, though it was less sharply defined than on the Babb flexure.

THE BONE SPRING FORMATION

Lying unconformably on the Hueco and older rocks is the Bone Spring formation of Leonardian age, characterized by extreme and rapid changes in facies which make it the most interesting of the Permian units in the Sierra Diablo.

Along the eastern scarp of the range its distribution is considerably different from that of the Hueco, but in both formations the distribution is largely influenced by the two monoclinical flexures which cross the range. Along the Victorio flexure the Bone Spring is strongly uplifted on the southern side so that beyond this point it is quickly lost by erosion. The situation is not simple. A pre-Cretaceous surface likewise cuts off the Bone Spring at approximately the same place. Still other considerations such as the rapid facies changes of the Bone Spring into round-pebble conglomerates suggest that the sea may have lapped against a shore only slightly south of the Victorio flexure. Thus the lower part of the formation (below the Victorio Peak member; fig. 3) may never have been deposited far beyond its present limit.

Between Victorio and Apache canyons the Bone Spring forms the upper part of the east-

ern escarpment, rising high above the broad bench of the Hueco. From Apache Canyon to the north, as far as the Babb flexure, it constitutes the entire escarpment. North of the Babb flexure the formation soon disappears underground, and younger Permian rocks form the bulk of the northern outliers of the range.

Erosion between the end of Hueco deposition and the initiation of Bone Spring sedimentation was evidently severe in many localities, while other areas were relatively little affected. Great erosion took place along the general trends of the two flexures and indicates their activity at this time. The unconformity between the two formations, however, is often obscure and difficult to place.

The extreme facies variation of the Bone Spring makes discussion of the formation difficult, and the facies are treated separately. In order to grasp the rather complex relationships it is necessary to keep in mind that we are actually dealing with a single formation which in the Delaware Basin was deposited as one facies under rather uniform conditions. In contrast, the lateral equivalents of this basin facies were deposited under the fluctuating environmental conditions of the marginal shelf and are highly variable.

BONE SPRING REEFS: It appears from drilling (P. B. King, 1942, p. 563) that sedimentation was uninterrupted in the Delaware Basin during the erosional interval between the Wolfcampian and the Leonardian, which was so important on the surrounding shelf. Following the erosional period the shelf began a renewed subsidence which gradually brought much of it again below sea level. The initial Bone Spring sediments on the shelf were deposited along the margin of the basin. Gradually the depositional environment moved shelfward across the eroded Hueco. As this happened a zone highly favorable to a rich assemblage of organisms followed the advancing shore. The record of the advance of this favorable environment is found in the abundant small reefs and shell banks of the lower part of the Bone Spring.

Erosion of the Hueco along the flexure in Apache Canyon had left linear ridges of the

more resistant rocks and as they were gradually drowned they at first formed elongate shoals. This produced conditions well suited to reef growth, and they were soon occupied by reef-building organisms that had followed the advancing shore shelfward.

A large reef resulted from this organic activity and is well exposed in cross section in Apache Canyon (fig. 4A). Longitudinal sec-

badly dolomitized, and original textures as well as organic structures have been destroyed. It is still a striking structure and was of paramount importance in controlling facies distribution during the period of its growth.

This large reef seems to have been of the barrier type, although there are indications that often it was not so much a continuous barrier as a coalescing group of patch reefs

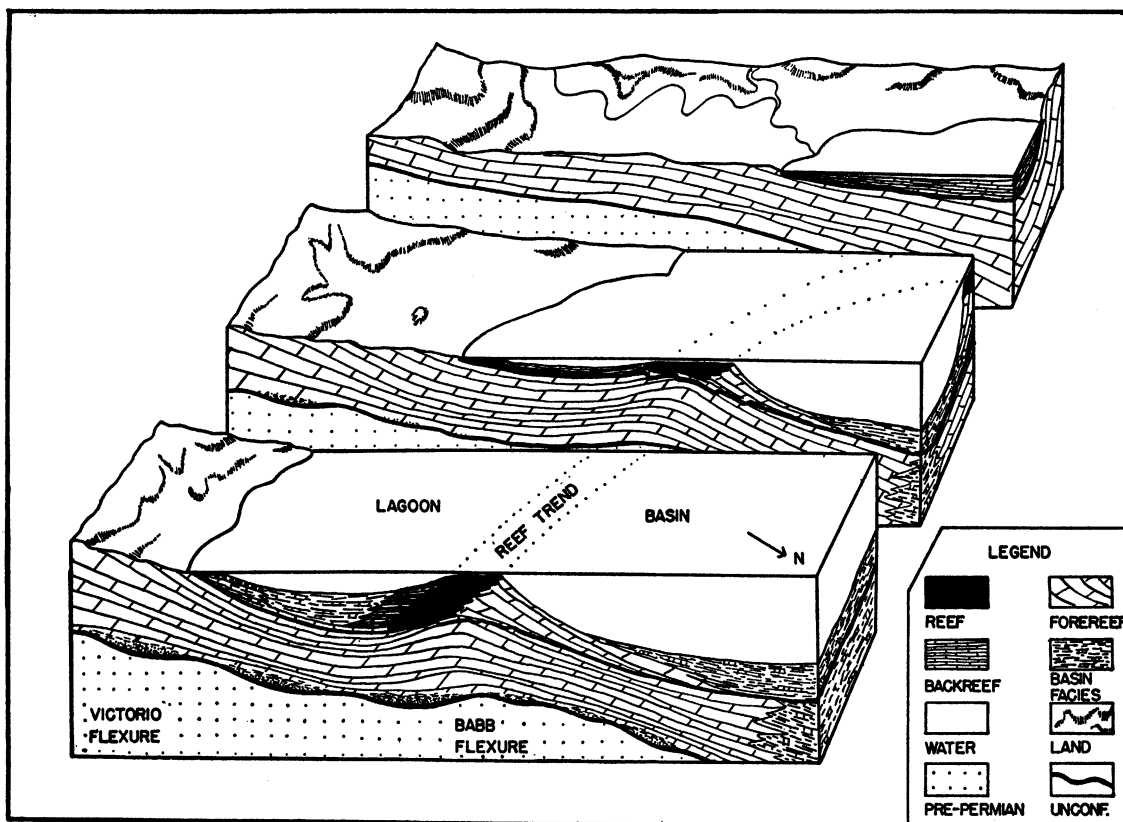


FIG. 5. Schematic diagram of conditions in the Sierra Diablo at the climax of barrier reef growth in the lower part of the Bone Spring formation.

tions are to be seen in one of the larger tributary canyons of Apache Canyon (fig. 4B) as well as in the headwall behind Black John Canyon. In all the reef is exposed for a distance of nearly 6 miles.

The gross form of the reef is very well displayed. Forereef beds dip steeply (up to 20°) away from the reef which has extended itself basinward across its own detritus for some distance. Behind the reef are extensive backreef deposits. Unfortunately the reef has been

growing along a well-defined trend. The situation seems to have been closely analogous to that along the eastern shore of the present-day island of Andros in the Bahamas.

The northeasternmost exposure of the reef is in Apache Canyon, and its relations beyond that point can only be inferred. To the west in the Sierra Prieta (a volcanic dome along the trend of the Babb flexure around which rocks as old as Hueco are exposed) a member of the Bone Spring entirely younger than the

barrier reef (Victorio Peak member) lies on the Hueco (fig. 3). The area about the Sierra Prieta seems, then, to have been a low land during the growth of the barrier reef. The exposed trend of the reef is towards this land. It must therefore either have died out in this direction or, if suitable substrata and water depth were available, swung to the east along the edge of the Delaware Basin. This possibility is considered likely in view of the known distribution of the Permian reefs.

To the southeast the reef is intersected by the edge of the range, so that relations are again not certainly known. Some evidence exists that suggests that the reef never extended far beyond its present truncation at the eastern fault scarp (see below, this page).

The small patch reefs of the lowest Bone Spring deposits on the basin margin migrated shoreward with the advance of the sea, maintaining themselves only in a position near the shore. The barrier reef probably developed from the coalescence of the smaller reefs and because of its favorable position on the flexure was able to maintain itself against the deepening seas and even advance seaward. The smaller patch reefs were unable to offset the deepening water by upward growth and were soon buried by deposits of basin facies.

BACKREEF FACIES: The backreef facies is exposed in Apache Canyon. It is a thin sequence of dolomitic beds between the Hueco below and the Victorio Peak member of the Bone Spring above (fig. 4A). The beds were flat-lying as deposited but now participate in the general westerly dip of the range. As traced away from the barrier reef they become thinner but still persist far up the canyon and finally go underground above Apache Tank. They are absent to the northwest in the Sierra Prieta. These beds represent sediments shed from the reef and accumulated in a wide but shallow lagoon between reef and shore. There was also some contribution of sediment from the shore, as evidenced by the presence of rounded chert pebbles in several places.

The only other exposure of the backreef facies is along the east scarp in the upper part of Mine and Marble canyons. Here again the reef gives way to a series of dolomitic beds, but in many respects they contrast strongly

with those of Apache Canyon. The beds dip gently away from the reef in what seems to be at least partially a primary dip, but the situation is complicated by a large intrusion which has imparted additional dip to the beds. At some distance behind the reef these beds are laterally replaced by black, platy carbonates characteristic of the basin facies. The lagoon behind the reef there seems to have been far deeper than in Apache Canyon, and it probably communicated directly with the basin by some sort of deep-water connection. The evidence seems to indicate that the shoal waters, in which the reef initiated its growth, deepened towards the basin and that the reef terminated in deep water at this end.

This differs from the interpretation of King and Knight (1944) who believed that the reef swung to the southwest until it reached the Victorio flexure and then followed this feature to the east-southeast.

BASIN FACIES: All the facies of the Bone Spring on the shelf area grade basinward into a thick series of laminated, platy, bituminous limestones and dolomites. Within the Sierra Diablo are shown basin facies equivalents of both the reefs and the succeeding Victorio Peak member (fig. 4A). During the deposition of the Cutoff member (fig. 3), rocks of basin facies lapped far onto the shelf.

The rocks of the basin evidently were deposited under conditions unfavorable to most forms of life. The presence of the organic material causing the dark color of the sediment, together with the undisturbed laminations of much of the rock, suggests a scarcity of scavengers on the bottom. Possibly these waters lacked oxygen below an aerated surface layer as in the Black Sea.

Fossils are found very sparingly in this facies. They are usually found singly and represent pelecypods of types generally preferring muddy bottoms, such as nuculoids, or nektonic ammonoids. Only rarely, as when both valves of the nuculoids are found together, can the benthonic forms be shown to have lived essentially where they are found.

If it is assumed that the tops of the reefs represented sea level during their growth, then most of these dark, platy rocks were deposited in deep water. This is suggested by the differences in elevation between the reef

tops and equivalent basin facies deposits as they are reconstructed for the lower Leonardian. It is further indicated by the general confinement of these rocks to the Delaware Basin, in which deeper water is shown to have existed by the continuous deposition there during the erosion of the Hueco formation on the shelf. The presence of rocks of basin facies cannot, however, be used alone as a criterion for deep water, because sediments of this facies occasionally spread beyond the basin and were deposited on the shelf. The initial deposits of the Bone Spring formation in Apache and in Black John canyons consisted of rocks of basin facies interspersed with small reefs. Both the reefs and the proximity of the underlying erosional surface suggest that on occasion sediments of basin facies were deposited in shallow marginal waters.

NEAR-SHORE FACIES: The basin facies rocks lying in the broad, deep lagoon behind the reef at its southeastern end undergo changes in the area of the Victorio flexure. As is the case farther north, the initial deposits of the Bone Spring consist of reefy masses and shell banks overlain by and in part intercalated with rocks of basin facies. As the sea transgressed the surface this zone of reefs and organic debris retreated to the south, followed by the environment of the basin facies. This retreating environment was not sufficiently stable for the construction of large reefs. Deposits mapped as representing a continuation of the barrier reef (King and Knight, 1944) are not here so interpreted. It is true that the deposits are largely made up of organic debris, but there is little evidence of more than occasional wave resistant structures.

Along the flexure the rocks of basin facies are replaced in striking fashion by great interfingering tongues of detrital limestones and dolomites and by conglomerates. The pebbles in the conglomerates are highly rounded. Probably they were shaped on the shore. At one point along the top of the flexure, beds of conglomerate and interbedded dolomites are seen to dip steeply and are thought to represent the foreset beds of a delta. It is believed that the seas of the lower Bone Spring episode of Permian history in this area ended against the near-by shore. This interpretation is supported by the absence of deposits of this

age to the northwest in the Sierra Prieta.

The change in facies from basin rocks to conglomeratic limestones which takes place on the Victorio flexure might be interpreted as an effect of sudden change in water depth at this point. This is not the case, however, and the dip of the beds is due to much later deformation which produced the Victorio flexure. The conditions in this area seem to be those that would prevail on a coast gradually sloping into deep water.

VICTORIO PEAK MEMBER: Long before the close of the Leonardian, and for unknown causes, the Bone Spring barrier reef died, and a new sedimentary regime was initiated. The new conditions resulted in the deposition of the Victorio Peak member which blankets backreef, reef, and forereef deposits of earlier times. This change was accompanied by eustatic or isostatic changes affecting sea level, for, as noted above, the Victorio Peak member was deposited on what had been a land surface during the time of barrier reef growth. In addition the Victorio Peak progressively extends farther basinward, so that its younger beds replace the black carbonates of the basin facies at an increasing distance beyond the limit of former reef growth. These relations could indicate a minor westward tilting of the area at this time, or that the subsidence of the shelf continued unabated while the subsidence of the basin was temporarily retarded.

Seen from a distance the Victorio Peak member seems unbedded or very massively bedded. Closer inspection shows it to be regularly and often thinly bedded. The rock is pink to gray and varies from limestone to dolomite, is largely composed of shell sands and coarser organic debris, and is believed to represent an extensive bank deposit. Near its basinward margin it occasionally contains small reef masses.

Along the east scarp of the range the Victorio Peak member makes its southernmost appearance near Victorio Peak. To the north it forms the upper cliffs of the escarpment as far as the Babb flexure where it goes underground. In the upper part of the member there is a thin sandstone along the Babb flexure. It occurs at about the same horizon and is believed to be equivalent to a similar sand-

stone in the Guadalupe Mountain section.

CUTOFF MEMBER: The Cutoff member is exposed only in the extreme northern part of the Sierra Diablo where it overlies the Victorio Peak member north of the Babb flexure. The Cutoff is several hundred feet thick and consists of thin-bedded to platy, buff, gray, or black limestones, interbedded with buff silty shales and gypsum. The rocks are mostly of basin facies, and the unit seems to indicate a considerable expansion of basin conditions over the shelf area.

The exposures of the member are insufficient to yield much information as to facies distributions. The gypsum seems, however, to increase northward towards the Dos Alamos Hills. Probably the gypsum also is more important to the west, as facies changes in this part of the section generally bear a direct relation to the margin of the basin.

THE CHERRY CANYON SANDSTONE TONGUE

Above the Cutoff member of the Bone

Spring lies a series of sandstones and sandy dolomites. These rocks are probably unconformable on the Bone Spring, but this was not demonstrated. The sandstone unit is believed by King and Knight (1944) to represent the basal Cherry Canyon sandstone tongue of the Guadalupe Mountains.

THE QUEEN LIMESTONE

Lying on the sandstones and somewhat gradational into them is a considerable thickness of sandy and silty dolomites. These are massive, yellow-weathering, brown rocks crowded with fusulinid molds. They also contain some poorly preserved brachiopods. The fossils are not diagnostic. The rocks are thought to represent a backreef facies of the Goat Seep reef exposed in the Guadalupe Mountains. The reef itself is concealed in the down-dropped fault block to the east of the Sierra Diablo. These rocks are the youngest Permian rocks exposed in the Sierra Diablo.

PERIODS OF TECTONIC ACTIVITY

There is evidence of three periods of tectonic activity in the Sierra Diablo since the beginning of the Permian. In addition, beds older than Permian show the effects of the late Pennsylvanian orogeny to the south, as well as of earlier movements.

The oldest Permian activity seems to have occurred at the close of the Wolfcampian when there was movement along the zones now followed by the Victorio and Babb flexures. Permian movement is indicated by the unconformable relations between the Bone Spring and Hueco formations.

A second period of activity occurred along the same zones at some time between the deposition of the youngest preserved Permian deposits and the lower Cretaceous (Trinity). This is indicated by the remnants of a blanket of Cretaceous rocks on the Victorio flexure and in Red Tank Canyon in the Baylor Mountains (King and Knight, 1944). The Cretaceous deposits do not participate in the

flexure.

Finally at some time in the late Cenozoic there was widespread and intense normal faulting. At this time the major fault along the eastern edge of the range was formed, giving the mountains their present relief. Lesser faults are frequent throughout the Sierra Diablo. Considerable igneous activity was apparently associated with this faulting, which is indicated by frequent dikes and sills and by such major features as the large intrusive at the mouths of Marble and Mine canyons. The volcanic dome forming the Sierra Prieta in the northwest part of the Sierra Diablo is probably also of this age. The recency of the faulting is indicated by the present relief of the range, the steepness of the eastern scarp, and the relatively minor dissection of the range. A fault in the alluvium mapped by King and Knight (1944) indicates recurrent movement and suggests multiple periods of faultings.

CORRELATION

WITH THE GUADALUPE MOUNTAINS

While physical continuity of outcrop is lacking between the Sierra Diablo and the Guadalupe Mountains, the two sections are relatively close geographically. Both sections cut across abrupt facies changes at the edge of the Delaware Basin, and the two are lithologically very similar and had the same history. The base of the Bone Spring formation is not exposed in the Guadalupe Mountains, but most of the formation is well exposed. On the basis of lithologic similarity and sequence it correlates well with the section in the Sierra Diablo.

Unfortunately this physical correlation is based largely on rocks of basin facies which are sparsely fossiliferous. For this reason adequate paleontological documentation of the correlation is lacking. Fusulinid zones are present, and there seem to be brachiopod zones in the Victorio Peak and Cutoff members of the Bone Spring, but in an area of such abrupt facies changes there is a strong suspicion that such zones indicate similarity of environment rather than chronologic identity.

WITH THE GLASS MOUNTAINS

Correlation of the section in the Sierra Diablo with that of the Glass Mountains because of wide geographic separation rests solely on a paleontologic basis. Fortunately the lower part of the Bone Spring is abundantly fossiliferous. The brachiopods have been better studied than other groups and are the main basis of correlation, though the fusulinids add corroborating evidence. A number of brachiopod genera and species considered by R. E. King (1930) to be reliable guide fossils are present in the section.

Robert E. King (1930) correlated with the Hess formation those rocks in the Sierra Diablo now considered to be Hueco, exclusive of the basal clastics which he considered to be Wolfcampian. Important parts of his collections of Sierra Diablo brachiopods came from the area about Victorio Peak where the basal, highly fossiliferous limestones of the

Bone Spring rest with obscure disconformity on the Hueco and are overlain by Bone Spring of basin facies. It is believed that he may have collected from these beds and considered them to be part of the underlying sequence. If this were the case his correlation of Sierra Diablo rocks with the Hess was more nearly correct than it at first seems, for his fossils were not actually from the Hueco but from the Bone Spring.

At the time that this correlation was made, the Hess in the Glass Mountains was considered to be older than the Leonard. Subsequent work by P. B. King (1942, p. 651) has led him to the conclusion that the Hess is actually equivalent to the Leonard in age. That this is indeed the case is suggested by the distribution of faunal elements in the Sierra Diablo allied both to the Hess and to the Leonard faunas. The faunas from the vicinity of Victorio Canyon are of Hess aspect, yet collections farther north in Black John Canyon overlying the basal unconformity of the Bone Spring, and therefore of about the same age, contain what R. E. King believed to be diagnostic Leonard fossils. This is taken to indicate that some aspect of the environment, as yet unknown, preserved these two faunal associations with a minimum of intermixing, but on occasion allowed them to flourish in close proximity.

The Bone Spring of the Sierra Diablo and the Guadalupe Mountains is here considered as approximately correlative of the Leonardian of the Glass Mountains. This conclusion reinforces the earlier view of P. B. King (1942).

It must be noted 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. These fossils are:

Orthotetella wolfcampensis

Orthotichia hueconiana (= *O. kozlowskii* King)

Limbella sp. (= *Aulosteges*, in part, of King)

Kozlowskia sp. (= *Marginifera*, in part, of King)

Planispina sp.

COMPARISON OF PERMIAN WITH MODERN REEFS

There is a strong dissimilarity in geographic distribution between modern and Permian reefs. Reefs of modern seas are in general restricted to a belt lying within 30 degrees of the Equator; exceptions to this pattern are explained by the presence of warm currents (e.g., Bermuda). Accurate distributional data on fossil reefs are difficult to gather because of the broad usage given the word "reef." Permian reefs seem, however, to have had a much wider distribution than do those of the present and have been reported from areas as distant from the Equator as Greenland (Maync, 1942).

While latitudinal distribution has varied through time there seems to be a rather sharply defined reef environment. Reefs seem to be localized along the interface between deep and shallow waters, and they generally exaggerate the contrast across this interface by their own growth.

The growth of reefs in shallow water may be in part an expression of the importance of algal contributions to reef formation. The preference for the margins of deep-water areas is probably related to the food supply of the microphagous reef-building animals and perhaps the nutrient salt supply of the algae.

The basic pattern of reef development seems to be the same for Permian as for modern reefs. Both show the development of a wave-resistant core which is flanked on the seaward side by a forereef talus slope and on the lea side by backreef deposits of finer reef debris. This is to be expected, for the gross form of the reef is due to the constructional activity of organisms acting within the close-

ly controlled limits permitted by the destructive force of the sea. Thus as reefs of the Permian and the recent both grew at the margins of deep water, both were subject to similar shaping forces.

One striking difference between modern reefs and many fossil reefs of the later Paleozoic and early Mesozoic is the association of these reefs with what appear to have been stagnant basins of deposition (Newell and others, 1953). Modern reefs are generally found in well-aerated environments, quite different from those in which the deposits associated with the earlier reefs are presumed to have been formed. No explanation for this situation has been found.

The greatest contrasts between Permian and modern reefs are seen in a comparison of the reef-building organisms responsible for their construction. Modern reefs are built principally by corals (*Scleractinia*) and by algae, with minor contributions by many other groups. The Permian reefs of west Texas, though usually diagenetically altered, seem to have been constructed mainly by sponges and algae, with some contribution by *Bryozoa*.

Brachiopods were present in considerable numbers in the Permian reefs but did not contribute materially to their construction, though some of the cemented forms may have played a small part in building the framework. In modern reefs brachiopods play a very insignificant role. This paucity of brachiopods is a feature of the general post-Paleozoic decline of the group rather than a change peculiar to the reef environment.

FACIES

LITHOFACIES

The general distribution and character of the lithofacies of the lower part of the Bone Spring formation are closely related to the distribution of the faunas and must therefore be briefly considered. In the area which produced the fossils treated in this report (vicinity of Victorio Canyon) the lower Bone Spring exhibits two major lithofacies. These

are the basin facies, which maintains considerable lithic unity throughout, and a near-shore facies of considerable lithic diversity.

BASIN FACIES: Rocks of basin facies seem to have been deposited almost continuously within the Delaware Basin from the beginning of the Permian to the end of the Guadalupian. Confinement of these rocks to the basin is the general rule, but on rare occasions

they lapped briefly onto the shelf areas at the immediate margin of the basin. Such an interlude occurred in early Bone Spring time shortly following the resurgence of the sea after the post-Hueco erosional interval.

The major portion of the lower Bone Spring in the vicinity of Victorio Canyon consists of rocks of basin facies deposited during this incursion of the sea. They are generally of dark color and are conspicuously banded in many areas. The banding is the result of alternating light and dark layers, between which there is considerable compositional difference, with the light layers high in silica and the dark layers high in calcium.¹ The color differences are, however, principally due to variation in the content of bituminous matter, mainly contributed by plant spores. The bulk of the rock consists of finely crystalline carbonates with rare larger, detrital carbonate grains. The rock is largely dolomitic, though there is variation from place to place. Detrital quartz grains are present in surprising quantity and indicate that terrigenous detritus was being continuously, if very slowly, introduced.

In outcrop the rocks of basin facies may be black or gray or weather to various browns or yellows which suggest shales or siltstones rather than carbonate rocks. On fresh surfaces they are invariably dark in color. Bedding in these rocks is thin to platy, and individual beds do not commonly exceed a few inches. Despite their thinness individual beds frequently have considerable lateral extent.

These rocks, by their low topographic position relative to the reef tops and typical confinement to the basin, can usually be shown to have been deposited in deep water. Occasionally along the margins of the basin, however, they are associated with small reef masses and shell banks containing shallow-water organisms in position of growth. The rocks in this association are physically very similar to those of deeper water but usually do not display significant lamination. Even when closely associated with rich organic assemblages the rocks are generally poor in fos-

sils. There is an exception, however, in a very persistent deposit following a single horizon in the Apache Canyon area. This horizon is rich in molluscan remains and contains pelecypods, gastropods, nautiloids, ammonoids, scaphopods, and chitons. Brachiopods are exceedingly rare. The fossils of this zone are all forms found sparingly in rocks of basin facies in the area. They are often somewhat worn and broken. The bed in which they occur is unusually high in quartz grains, and it is believed that the deposits are concentrates left at this horizon as the result of reworking of an indeterminate thickness of basin facies rocks.

Near Victorio Canyon the basin facies closely follows the advancing shore line as it transgresses to the south. It was not deposited directly on the Hueco surface, however, but is always separated from it by a variable thickness of rocks of different (near-shore) facies.

NEAR-SHORE FACIES: The migrating shore, as it gradually advanced over the unconformity at the top of the Hueco, produced an environment favorable for a rich assemblage of organisms. The hard parts of marine invertebrates contributed largely to the formation of the rock in this depositional environment. In addition to its physical contributions to the sediment the abundant life had a distributional effect on sedimentation, for it built small outlying reefs. Concentration of the softer sediments occurred in the deeper, quieter, inter-reef areas.

The general character of these initial beds is radically different from that of the basin facies. The rock is massively bedded, with some beds as much as 4 to 6 feet thick. Individual beds are irregular both in thickness and distribution. They occasionally swell into reef or shell bank lenses or thin into silty, somewhat conglomeratic inter-reef areas. The rocks in general consist of light-colored, non-dolomitic limestones.

In the small reefs and shell banks many of the fossils are in position of growth and have aided in the formation of the rocks by their own growth and by their action as sediment traps. In the inter-reef areas they have contributed heavily to the sediments but mainly as detrital fragments rather than entire shells.

¹ These rocks have been studied by William Marshall, to whom the writer is indebted for the information presented here. For a more detailed summary of his findings, see Newell and others (1953).

Individual beds can seldom be traced over an appreciable area. They pinch out against the shore, and basinward they are replaced by rocks of the basin facies. The environment in which the near-shore facies was deposited was very limited in extent. With the advance of the shore the depositional area moved also. Because of this the deposits are thin and are replaced above by the basin facies.

BIOFACIES

Two major biofacies compare very closely in distribution with the two lithofacies. In rocks of the basin facies fossils are extremely rare, as is noted above, and those found can seldom be shown to be in place. It is evident that the conditions represented by the black rocks of basin facies were inimical to most forms of life, but an explanation for this situation has not been found.

The sediments deposited in close proximity to the shore and in shallow water generally

give abundant evidence of crowded organic communities. Two minor biofacies can be distinguished in this environment. One is represented by reefs and areas of hard bottom such as rocky shores or shell banks. These areas supported an abundance of attached forms of distinctive aspect. The other is found in the quieter and somewhat deeper waters between the densely populated hard bottom areas. In these locations many of the faunal elements were free living, and the general aspect is reminiscent of the Permian deposits of the mid-continent region of the United States.

In an examination of the faunas in general one is struck by the virtual mutual exclusion of brachiopods and mollusks. The reason for this is not surely known but there is some evidence in distribution that the mollusks preferred to live near the transition of basin to near-shore facies, while the brachiopods preferred the shallower, better-aerated waters of the near-shore facies.

ENVIRONMENTAL RECONSTRUCTION AT COLLECTING LOCALITIES

GENERAL RELATIONS

The deposits from which collections were made during this investigation all lie within a short distance above the eroded surface of the Hueco formation and represent the initial deposits of the Bone Spring seas on the shelf area following their earlier confinement within the Delaware Basin. The deposits are those left immediately behind an advancing shore line and consist of rather massive limestone beds often containing considerable silt and abundant pebbles of both organic and inorganic origin. These deposits are succeeded by platy, bituminous limestones and dolomites characteristic of the basin facies of the Bone Spring formation, deposited in somewhat deeper water at a greater distance from shore.

While the physical nature of the deposits allows considerable assurance in the determination of approximate water depth (discussed below), distance from shore, and sequence of events, other factors of the environment which were probably of as great or greater importance are less certainly defined.

Water temperatures of the lower Permian seas in the west Texas area were doubtless

important in determining the distribution of organisms at this time, as in the present seas. It is probable that the relatively shallow waters of the marginal shelf as well as the surface waters of the Delaware Basin were warm. The reefs which are so well developed in the Permian strata around the margins of the Delaware Basin were probably similar to modern reefs in their requirements in spite of the difference in the organisms responsible for their construction. Where the conditions required for growth can be determined they are those of modern reefs. This is especially evident in the localization of the reefs at the edge of a shelf bordering deep waters, as is shown by the relative topographic position of the reef tops and equivalent beds of basin facies. It seems probable, though it cannot yet be proved, that temperature requirements were likewise similar.

Further indications of warm Permian climate are furnished by extensive evaporite deposits found in Permian strata throughout much of the southwestern United States. Evaporation sufficiently rapid to have produced these deposits suggests aridity and relatively high temperatures.

Large, poikilothermic, terrestrial tetrapods are characteristic of the Leonardian (Wichita and Clear Fork) red beds of north central Texas. Certainly these animals required equable to warm climates for their existence.

The present climate of areas of the latitude of west Texas is generally warm in spite of the fact that this seems to be a time of unusual emergence. During the lower Permian much of the area was covered by shallow seas which generally have a moderating influence on the climate, and the climate may have been considerably warmer and more uniform than it is at present.

The salinity of sea water is another important factor in the distribution of marine life, but is one which for past seas is difficult to determine. The circulation of normal marine waters within the Delaware Basin seems to have been rather restricted, although the exact form and dimensions of the connection with the open sea are not known. This restriction, initially slight, became more severe towards the end of the Permian and seems virtually to have isolated the basin from circulation, allowing it to fill with evaporites. During the lower part of Bone Spring deposition evaporites did not occur in the Sierra Diablo area. The surface waters of the basin as well as the shallower waters of the shelf were of normal salinity for the time. The deep waters of the Delaware Basin may have been toxic owing to lack of oxygen, dissolved salts, or low pH. The general absence of fossils in the basin facies of this time suggests inimical conditions. Such conditions would result if the waters of the basin joined the open sea across a shallow threshold.

SPECIFIC CONDITIONS

LOCALITY 625: This locality is on the south wall of Victorio Canyon near the mouth. The collections were made from a 2-foot bed of limestone which lies 220 feet above the top of the clastic beds of the Hueco, exposed in the base of the canyon wall, and 10 feet above the massive limestone bed believed to mark here the top of the Hueco formation. The rock in which the fossils are found is a gray limestone relatively free of silt but containing some small silicified limestone pebbles and a large quantity of much worn and rounded,

silicified shell sand. Constituents of this shell detritus range in size from grains less than 1 mm. in diameter to cobbles several inches across formed from worn clumps of the coral *Heritschia* and massive bryozoans. The bottom seems to have consisted of lime mud in which were embedded worn and broken shells and scattered patches of shell sand. The deposit was not a reef but an area of somewhat quieter water marginal to a reef or shoal area offering a solid bottom.

It is apparent that the deposit was formed in shallow water, but the exact depth cannot be determined. The worn shell debris and the position of the deposit only 10 to 12 feet above an overlapped surface all point to deposition in very shallow water.

It is difficult to place the shore exactly during formation of this deposit, for the sea was advancing across a surface of generally low relief and the situation is secondarily complicated by post-Permian warping along the Victorio flexure. The shore seems to have been within a few miles, and probably islands dotted the inundated surface.

An interesting feature of this and many other collecting localities is the complete imbalance of the organic assemblage. There are 10 times as many brachiopod individuals as all others combined. Second in importance are the bryozoans which occur in large numbers and include both stony forms and delicate fenestellids. Pelecypods are next in variety but are very low in numbers of individuals. Crinoid debris is abundant. Corals are present in moderate numbers. Gastropods are of limited variety but there are moderate numbers of individuals. Cephalopods are very rare. Sponges and arthropods are represented by rare fragmentary material. Fusulinids are abundant.

The following list indicates the dominance of brachiopods in the fauna at a generic level:

GASTROPODS

Platyceras
Euomphalus
Straparollus

PELECYPODS

Pseudomonotis
Streblochondria
Myalinidae, 1 sp.
Aviculopectenidae, 1 sp.

CORALS

Cladochonus
Heritschia
Lophophylidium

CEPHALOPODS

Cooperoceras

BRYOZOA

Goniocladia
Rhombopora
Septopora
Polypora
Meekopora
Fistuliporinae

BRACHIOPODS

Rhipidomella
Orthotichia
Enteleles
Diplanus, new genus
Derbyia
Meekella
Lessochonetes
Quadrochonetes, new genus
Chonetinella
Antiquatonia
Nudauris, new genus
Spinifrons, new genus
Linoproductus
Cancrinella
Kozłowska
Pylonotus, new genus
Ramavectus, new genus
Overtonia
Scacchinella
Alexenia
Planispina, new genus
Teguliferina?
Prorichthofenia
Leptodus?
Poikilosakos
Neospirifer
Spiriferellina
Crenispirifer, new genus
Altipecus, new genus
Hustedia
Wellerella
Composita
Dielasma

The pattern exhibited in the make-up of this fauna is generally characteristic for collecting localities in this (near-shore) facies.

LOCALITY 629: This locality is about one-quarter of a mile south of Victorio Canyon along the frontal escarpment of the range. Collections were made from an 18-inch bed of very silty, brownish limestone, containing numerous rounded, flat pebbles of yellowish

clay and occasional worn shells, which lies 30 feet above the massive bed at the top of the Hueco. The bottom during deposition seems to have consisted of silty lime mud in which were embedded pebbles of what apparently were poorly consolidated yellow clay, and a few worn shells. The shells are less worn and fragmental than those of other localities, and it is believed that locality 629 represents somewhat deeper and quieter water.

The depth of the water is not certainly known but was relatively slight. The water was deeper here than at any of the other localities collected, for locality 629 represents a position farther behind the advancing shore line. The water was probably less than 100 feet deep. The collecting locality may have been several miles from shore but may have been close to offshore islands or shoals.

The fauna of locality 629, like that of locality 625, is heavily overbalanced with brachiopods. The list of genera outlines the general faunal composition:

GASTROPODS

Platyceras
Peruvipsira

BRYOZOA

Septopora
Polypora
Acanthocladia
Fenestrellina?

PELECYPIDS

Pseudomonotis
Streblochondria
Streblopteria
Girtypecten

BRACHIOPODS

Rhipidomella
Orthotichia
Enteleles
Schuchertella
Derbyia
Meekella
Orthotetella
Quadrochonetes, new genus
Dyoros, new genus
Heteralosia
Limbella, new genus
Scacchinella
Teguliferina?
Prorichthofenia
Leptodus?
Neospirifer
Crurithyris
Attenuatella, new genus

Heterelasma
Glossothyropsis
Dielasma
Chonetinella
Antiquatonia
Nudauris, new genus
Linoproductus
Cancrinella
Kozlowskia
Psilonotus, new genus
Ramavectus, new genus
Spiriferellina
Punctospirifer?
Crenispirifer, new genus
Hustedia
Stenosisma
Wellerella
Terebratuloides?
Composita

LOCALITIES 628 AND 631: These two localities are of minor importance and produced

the animals represented can be shown to have lived here. The fragmentation of the material must have taken place in highly agitated water though the material probably reached locality 628 after having been broken up, because this locality represents relatively deep water. The near-shore limestones are replaced immediately above the collecting locality by basin facies.

Locality 631 (fig. 6) is immediately above the Hueco bioherm behind the Figure 2 ranch house, 2 miles south of Victorio Canyon. The beds are believed to represent the very base of the Bone Spring formation on the shelf in this area. The fossils are found in a relatively pure limestone, almost free of silt but containing abundant pebbles and great quantities of shell detritus which is badly worn and broken. The bottom at the time of deposition was probably a coquina of broken



FIG. 6. Small reef masses along the eastern escarpment of the Sierra Diablo near the Figure 2 ranch house. Locality 631 in the Bone Spring formation immediately overlies the Huecoan reef (A). Reef B is in the Bone Spring formation. Drawn by N. D. Newell from a telephoto by H. N. Fisk.

little material of value. Locality 628 is at the same place as locality 625 but is 40 feet higher in the section. Almost all the organic remains found are fragmentary. Very few, if any, of

shells in a lime matrix. The deposit was formed in very shallow water for it was the initial deposit above an unconformity. The water was probably less than 25 feet deep.

BRACHIOPOD ADAPTATIONS

During the course of this study certain observations have been possible which seem best treated under the title of adaptations. Most of the information presented was derived

from a study of the fauna with which this paper is primarily concerned, that of the lower Bone Spring formation in the Sierra Diablo. Observations have also been made in

the field in the Guadalupe, Delaware, and Apache Mountains. Material from all these areas as well as additional collections from the Glass Mountains was observed during acid etching and has yielded information on associations and inferred life habits.

Despite pioneer studies of Girty (1908) and R. E. King (1930) on Permian brachiopods of the west Texas area, the state of knowledge of these fossils is inadequate and has severely hampered paleoecological work. If the present study may be taken as indicative of what is known of the west Texas Permian brachiopods, about 25 per cent of the genera and a much higher proportion of the species have not been described. This is unfortunate because it hampers the assembling of distributional data for the lower taxonomic units. Data at the generic level are fairly satisfactory for many groups, but the genus is only a collection of species most of which are mutually exclusive, and therefore it is not the most refined tool for paleoecologic studies. In view of the vastness of the area of Permian outcrops and the still imperfect knowledge of the stratigraphy the use of generic and even larger categories is quite consistent with the level of accuracy attainable.

Other difficulties have been introduced into the study as a result of the collecting methods employed. In order to obtain the best possible collections in the time available great reliance was placed on silicified material. Good preservation by silicification is erratic in distribution. As a result large areas between the collecting localities are poorly known. To this are added the inevitable spotty nature of collection in so vast an area, and the difficulty of comparison between silicified and non-silicified materials.

When the west Texas Permian brachiopods are dealt with in a general way, certain conclusions can be reached. Particularly revealing are contrasts between the deposits of shallow and those of deep waters. While these contrasts obtain in several of the outcrop areas, the problem may be best illustrated in the Guadalupe Mountains for the period in which the Capitan reef flourished. If we accept the basic premise that in the Permian, as at present, reefs grew upward to, or nearly to, sea level then we can determine with un-

usual accuracy the depth of water in the Delaware Basin immediately in front of the reef.

The structural relationships of the back-reef, reef, and basin areas seem not to have been significantly altered since the Permian. Compaction of the basin sediments may have increased somewhat the apparent water depth, for the massive reef presumably underwent little compaction, but the error thus introduced is probably not very important within the limits of accuracy involved (see Newell and others, 1953).

The water depth only a short distance basinward of the Capitan reef late in its growth was in excess of 1500 feet and thus far exceeded the limit of light penetration. The profile of the bottom between the reef top and the basin depths was initially precipitous, but the slope gradually flattened with depth and finally merged with the nearly flat floor of the Delaware Basin.

In the great expanse of the basin itself brachiopods are rare fossils and seem to be consistently represented only by *Leiorhynchoides* (formerly *Leiorhynchus*) which has been long suspected of tolerating foul bottoms. The only associates of this brachiopod are forms which appear to have been nektonic, such as ammonoids, and a few mud-loving pelecypods (nuculoids). The hardy rhynchonellid was able to survive in the deep lightless waters of the basin, but it is also found in association with the normal faunas of very shallow waters, as in the small reef masses of the lower Getaway of the Guadalupe Mountains. Evidently it had wide tolerances. It is possible, but considered unlikely, that *Leiorhynchoides* may have attached to floating objects and thus reached the deep-water bottoms upon death as did the ammonites. The abundance of these shells at certain localities of the basin facies and the presence of complete ontogenetic sequences cast doubt on the floating habit.

Occasional limestone beds in the basin contain an abundant fauna, including brachiopods. The fossils are usually badly worn and broken and are not believed to represent life associations. Abundant evidence of transfer of sediment from shallow waters into the basin by turbidity currents and submarine

slides (see Newell and others, 1953) points to the origin of these faunas in the shallower waters of the reef and forereef slopes. The apparent paucity of life in the basin is difficult to explain. Were it not for the presence of *Leiorhynchoides* and nuculoids, the waters might be considered to have been toxic in the lower part of the basin throughout the Permian.

In the shallowest waters represented in the Guadalupe Mountains, on top of the Capitan reef, brachiopods were abundant. They were of little importance in the construction of the reef and simply utilized it as a convenient place to live. Their distribution in the reef is erratic, and they occur in small pockets here and there. Because of the absence of silicification in the reef, adequate comparisons between it and other environments cannot be readily made.

If allowances are made for the different mode of preservation in the reef and forereef deposits, the brachiopods still appear to have attained their acme of development, not in the reef, but along the upper part of the forereef talus. Most species seem to have had considerable depth range and to have been present in both areas. However, in numbers of individuals the forereef far outstrips the reef. To what extent this is a feature of the inevitable showering of reef dwellers down into the deeper water is impossible to determine.

In the deposits formed behind the reef, along the edge of the lagoon, brachiopods become increasingly rare with increasing distance from the reef. During the later Permian, waters in the backreef areas were frequently hypersaline and evidently inimical to brachiopod existence. Most of the shells that are found here were probably swept off the reef and belong to pediculate groups. Two notable exceptions are the Orthotetacea, which are not uncommon near the reef, and occasional specimens of *Prorichthofenia*. The Orthotetacea apparently were somewhat more tolerant of increased salinity than most groups, for they have been found in the Ochoan dolomites in what may have been a highly saline environment (Walters, MS). The presence of *Prorichthofenia* is surprising. The specimens perhaps represent individuals torn

loose and washed over a reef. The general paucity of brachiopods in these backreef deposits indicates that most of those that lived in the reef were concentrated on the seaward side.

The final impression gained from this area is very much what might be expected from the extrapolation of distributional data on modern brachiopods, except that in the Permian deep-water forms seem to have been even less common than they are today. The brachiopods were concentrated in shallow water and in areas of free and active circulation and adequate food supply for microphagous animals, and lived in reefs for the most part only as incidental members of the reef community, though some cemented forms may have contributed slightly to reef formation.

BRACHIOPOD ATTACHMENT

The nature and permanence of the attachment of brachiopod shells are most important considerations in the evaluation of distributional evidence. Three principal modes of attachment of the shell to the substratum can be discerned among Permian brachiopods. Of foremost interest and importance is the rigid, cemented attachment of the shell to the substratum, for it is in this group of brachiopods that distributional evidence is most reliable. A second group of shells were attached only in earliest ontogeny, becoming free in later life. Finally a large group of brachiopods retained the primitive pediculate condition.

Among the shells in which there is rigid attachment, fixation is accomplished in several ways. Most of these forms are members of the Productacea and make use of their spines which may or may not be augmented by a direct cementation of the umbo. In forms lacking spines, such as the Oldhaminidae and the Orthotetacea, attachment was effected by direct cementation of all or part of the anterior slope of the pedicle valve. In shells of each type subordinate variations in shape were superimposed on the basic plan and equipped the possessor for some particular mode of life.

Among the Productacea an interesting development follows an essentially parallel course in two families, the Richthofenidae

and the Scacchinellidae. In both groups there has been a modification of the pedicle valve into a more or less deep cone, while the brachial valve has become operculiform. This seems to result, in many groups of fixed animals, from intense competition and has the advantage of placing the animal above its surroundings.

The Richthofenidae are known from a considerable series of genera, and several progressive trends can be followed through their development. Of these the basic one is the increasing development, through time, of the conical pedicle valve. Early genera such as *Teguliferina* and *Planispina* are relatively small forms, in which the conical shape is still rudimentary. In the terminal genera, *Richthofenia* and *Prorichthofenia*, the cone has become very deep. Inevitably associated with the deepening of the cone is the development of an increasingly high internal "area" formed by the upward migration of the brachial valve in the cone. Finally there is a tendency towards the reduction of spines which in the early genera are borne by the entire surface of the pedicle valve, while in the younger forms they are increasingly limited to the lower part of the cone. There is a strong element of ecological selection as well as evolutionary trend in all these developments, for in the lower Bone Spring formation in the Sierra Diablo the genus *Prorichthofenia* coexisted with the primitive genera *Teguliferina*? and *Planispina*. While it is clear that both types lived at the same time, it is equally clear that both did not occupy the same ecological niche, for at localities 625 and 629 *Teguliferina*? and *Planispina* are abundant and beautifully preserved, while *Prorichthofenia* is represented only by much battered fragmentary material which has quite evidently been introduced from another site following death of the animal.

It seems probable that the smaller, primitive genera were able to attach themselves effectively to small bits of shell and other detrital fragments on the bottom which did not offer sufficient support for the larger, higher *Prorichthofenia*. The geographic distribution of forms currently placed in the genus *Teguliferina* is far wider than that of the larger and more specialized genera, and

extends into the deposits of Kansas, Oklahoma, and Nebraska where the bottom seems to have consisted generally of soft mud and sand. *Prorichthofenia* seems to be limited, on the other hand, to the vicinity of reefs, rocky shoals, and rocky shores, which offer firm attachment sites.

The Scacchinellidae are not so well represented as the Richthofenidae, being known at present from a single genus, *Scacchinella*. Here, too, there has been development of the conical form, though in this group intermediate steps are absent and we see only the end member of the trend. *Scacchinella*, like the larger Richthofenidae, does not occur in the Permian of the mid-continent region. It seems to prefer sandy and gravelly sediments, apparently in accordance with the form of the animal, for in *Scacchinella* the brachial valve caps the cone of the pedicle valve, and is thus well adapted to shed sediment. Quite to the contrary *Prorichthofenia* bears the brachial valve deep within the pedicle cone and thus would seem to have been very vulnerable to sediment accumulations unless the soft mantle parts of the animal were in some way adapted for its removal. *Scacchinella* does not occur in reef deposits in the Sierra Diablo, but seems to live in softer sediment by virtue of its gregarious nature which enables it to form solid clumps. It is interesting to note that, in west Texas at any rate, *Scacchinella* is limited to the low Permian and disappears shortly after the Richthofenidae make the transition from low to high cones. Whether or not there is truly a relationship is uncertain but the coincidence is suggestive.

Another adaptive trend among the Productacea is found among the Strophalosiidae. Here the valves retained a more or less normal productid shape and were attached by cementation of the pedicle umbo and by extensive development of anchoring spines along the cardinal margin, ears, and posterior slope. Many of the smaller genera exhibiting this habit are ubiquitous and seem to have attached to any available solid object. Large types such as "*Aulosteges*" *beedei* King seem to have been able to attach almost anywhere initially, but in later development sent out long root-like spines the function of which seems to have been to entangle sufficient for-

eign material to afford firm attachment. Brachiopods having this general mode of attachment seem to be abundant in the vicinity of reefs and shoals but are rare or absent elsewhere. Specimens of *Limbella* from locality 629, an interreef area, did not live where they are found. The valves are dissociated and the spines, especially the attachment spines, are mostly broken away. Abrasion has not been severe, however, and they probably lived on one of the near-by small reefs.

A very interesting trend, not concerned with attachment, occurs among several lineages of the Productacea. This is the development of complex straining devices. Many, in fact most, articulate brachiopods have developed some sort of straining device. In some of the Permian Productacea, however, the trend went to extremes which suggest that the adaptations were aimed at protection of the animal from parasitic or carnivorous forms. A series of developmental stages in the attainment of a straining device may be seen in the Richthofenidae. Early forms possessed a row of spines around the anterior margin of the pedicle valve and a few spines on the interior of the brachial valve towards the front. When the brachial valve opened the two sets of spines meshed, forming a protecting screen. A second stage is seen in *Prorichthofenia ud-den* King in which the marginal spines of the pedicle valve anastomose to form a crude hood over the top of the pedicle cone. Finally in a form from the Guadalupian rocks of the Guadalupe Mountains a complete, tightly meshed hood of anastomosed spines covers the pedicle cone, and the brachial valve is protected within.

An adaptation having a similar effect is found in *Strophalosiina*. Here the shell is modified in such a way that water is taken in through specialized spines without necessitating the gape of the valves.

Rigid attachment by the outer part of the pedicle valve was practiced by some spineless groups, especially the Orthotetacea and the Oldhaminidae.

Among the Orthotetacea attachment by the umbo of the pedicle valve became widespread among the late Paleozoic representatives. It appears to be associated with a deepening of the conical pedicle valve. Such at-

tachment produces considerable asymmetry of the shell, and the latter is often a clue to the mode of life even when the scar of attachment is difficult to discern. The degree to which this type of attachment was carried varied widely in different genera. *Diplanus* was often cemented by much of the pedicle valve. It appears to have lived habitually in reef masses and may have needed extra support. Many of the larger genera, such as *Derbyia* and *Orthotetella*, seem to have been attached only by the tip of the valve, as a general rule, though there is ample evidence that on occasion they were more firmly attached. In view of their large size and relatively weak attachment it is believed that these genera preferred areas of relatively quiet water, where they attached to other shells and to pebbles. This is borne out by the abundance of *Derbyia* in the non-reefy deposits of the mid-continent area of the United States, and by its presence in the backreef immediately behind the Capitan reef.

Genera such as *Meekella* and *Geyerella* are also widespread and probably inhabited an environment similar to that of *Derbyia*, though in some of the more extremely modified species such as *Meekella attenuata* life may have been spent in more strongly agitated waters.

The second great group of shells exhibiting the solid attachment of the pedicle exterior is the Oldhaminidae. These brachiopods seem to have occupied the niche among their fellows that was occupied by *Ostrea* among pelecypods. There is great variation in the group, with some forms developing a conical shape and attaching only at the umbo, while others were cemented by the entire surface of the valve. The animals evidently settled at random on any firm surface and began growth, but in the case of the larger species they soon became so large that only those fortunate enough to have attached to sizable objects survived. Most species were successful on reefs, rocky shoals, and rocky shores. Some species solved the problem of attachment by habitual attachment to the stems of crinoids. *Poikilosakos* is an exception to the general distributional rule for this group and seems to have succeeded equally well in the reefs of west Texas and on the soft bottoms of north

central Texas. In the latter area it is found attached to shell fragments which evidently represented firm attachment sites on the otherwise soft bottom, and the genus owes its success here to its small size. The Eurasian genus *Oldhamina* was exceptional among the Oldhaminidae in that it was seemingly attached only in early ontogeny and in adult life became free living. It is not known to occur in North America, and its life habits are otherwise unknown, but it may be assumed that it lived in areas of soft bottom.

Studies of silicified material have revealed an important aspect of brachiopod ecology during the Permian which has not previously been fully appreciated. Crinoid stems furnished firm support for a large number of brachiopods which were otherwise limited to reefs or areas of firm bottom. Several species seem to have habitually utilized the crinoid stems for attachment, and a number of other species seem to have taken advantage of them on occasion. *Leptodus catenatus* and *Oldhaminella philocrina* from the Permian of Timor seem habitually to have sought attachment on crinoids (Wanner and Sieverts, 1935). *Leptodus ? marshalli* of the west Texas Permian had similar habits. In two instances it was found to be attached to a small platyceroid snail. These snails seem to have habitually if not invariably lived attached to crinoids and therefore this association furnishes further evidence that both animals preferred this niche. The deflection of the attachment callus of the brachiopod away from the aperture of the snail indicates that the snail was alive at the time of the attachment.

One species of *Linoproductus* (*L. philocrinus*, new species) lived attached to crinoids. This mode of life represents an extreme specialization for the genus. Attachment was effected by cementation of the umbo and then by the encircling of the stem by the first pair of cardinal spines. As additional spines were developed along the cardinal margin they were also medially directed and entangled the stem. Only one specimen in the present collection actually shows the crinoid stem still in place, but every specimen in which the pedicle beak is preserved shows an attachment scar of a shape that could be made only by a cylindrical object.

The two genera of small Richthofenidae present in the collection have both been found attached to crinoid stems. In these animals this was not the habitual mode of attachment and was adopted only in rare instances.

A large proportion of the Productacea and the Chonetacea seem to have been free-living forms during the greater part of their lives. Among the Productacea the animal was attached in the earliest growth stages by a circle formed of the first two cardinal spines. This feature has been observed in many genera, though by no means in all. As the individual reached larger size it broke free of this attachment and became a free-living form. There appear to have been two modes of life among these free-living Productacea. The majority of genera developed abundant long spines, often with those of some particular part of the shell greatly enlarged, and it is believed that with these spines the animal held itself in place on the bottom. The spines may have penetrated soft bottoms and thus offered additional stability.

Among the small Productacea are some forms in which the spines are so abundant that the animal is burr-like in appearance. In this group the shell may have been free to roll about the bottom with the currents, and regardless of the position in which the shell might come to rest the brachial valve was able to open and feeding could be resumed.

The Chonetacea were also free living, but evidently lay on the sea floor without support of spines other than those of the cardinal margin which may have functioned to prevent overturning. Many genera seem to have been equally at home in the strata of north central Texas and in the near-reef environments of west Texas. Representatives of the group seem to have been among the rarest brachiopods in the Capitan reef, and it is probable that the animals preferred quieter waters and softer bottoms.

The great majority of the Permian brachiopods were attached to the substratum in the primitive way, by a pedicle. It is among these animals that interpretation is most difficult, for upon death they were released by the disintegration of the pedicle and drifted freely about the sea bottom. It is very difficult to decide whether the shells as they are finally

found as fossils represent a life or death assemblage. That there is significance to the distribution even of these shells is shown by the abundance of rhynchonellids at locality 629 and their virtual absence at near-by locality 625, which produced only one species.

Among recent brachiopods most forms are pediculate, and many prefer to live in protected places such as crevices between rocks or even in hollows beneath them. Such habits characterized some Permian pediculate brachiopods as well, for they are localized in what formerly were sheltered pockets in the Capitan reef. Many of the pediculate groups found in the Permian are completely extinct, and among these there seems little hope of determining the habits of most species. Among those groups that continue to the present we are hampered by the lack of data on the living forms. One feature of brachiopod history which seems to offer hope that the general life habit of some types may be discovered is the frequency of homeomorphy. Continual reappearance of certain shell forms leads one to the conclusion that they must be adaptive to

a particular mode of existence. Where such growth forms occur in modern shells it may be possible, as the recent forms become better understood, to extrapolate into the past on a basis of shell form and make what would at least be reasonable guesses as to life habits.

In summary it may be said that little ecological data can yet be gathered about most groups. Some groups offer little hope that their preferences can be established. This is true of most free-living forms and especially true of those attached by a pedicle in life. Distributional data for attached forms are more reliable than for other groups and indicate that large forms are indicative of shallow water, firm bottom, and, in general, proximity either to rocky shores, shoals, or reefs. Many brachiopods requiring solid attachment lived occasionally or habitually attached to the stems of crinoids. Permian brachiopods preferred shallow water, and it seems that very few lived in deep water. Population densities were highest where water was of normal marine character and freely circulating.

SYSTEMATICS

THE BRACHIOPODS of the west Texas Permian have been studied in some detail by Girty (1908) who concentrated his work on material from the Guadalupe Mountains, and by R. E. King (1930) who worked principally on the fauna of the Glass Mountains. Both men studied some material from the Sierra Diablo, but it is represented in only a minor part of their collections.

In spite of this previous work, the present collection has yielded a large number of new units, partly because of the increasing refinement of recent years, especially among the Productacea, but principally as the result of the collecting methods used.

All the fossils studied in the preparation of this report were preserved as siliceous replacements. This type of preservation is superior to any other for most purposes. Its overwhelming advantage is the ease with which preparation is accomplished. A single block of limestone may produce, within a few days, hundreds of first-rate specimens which would take years to prepare by any other method, and the large collections so easily obtainable supply many shells so rare that ordinary collecting would not reveal them. Good silicified material is of biological importance because of the ease with which details of the interior and the exterior of the shell can be obtained. Under less than optimum conditions, however, silicified material is frequently disappointing because of the loss of surface detail. Occasionally only the exteriors of thick-walled structures may be replaced, and in such cases etching dissolves the unreplaced center, leaving two separate plates. Such plates may sometimes be confused with the original plates of brachiopods, and the possibility must always be considered in doubtful cases.

REMARKS ON TAXONOMY

Taxonomists generally recognize that there is a subjective element in classification. It is a reflection of the philosophy of the individual and stems partly from past experience and partly from a basically progressive or conservative attitude. Because the subjective element cannot be eliminated, the following

remarks are introduced in an effort to make clear the position of the writer.

This paper deals with the fauna of a small area during a short time interval. Under such conditions subspecific variation would not ordinarily be expected and none was noted.

The species is the basic unit of our system of classification and as such is the unit with which the paleontologist most often deals. Specific units encompass considerably more variation than is generally realized and in the writer's opinion should be more broadly interpreted than is usually the case. It is occasionally necessary to erect new species for material that cannot be adequately compared with poorly preserved types.

Subgenera have not been used in this paper because it is felt that most generic complexes are not yet well enough known. Subgenera certainly exist and as evolutionary study of brachiopod lines progresses they will undoubtedly come to play an important role. At the present time, however, they are generally used to express extreme conservatism (e.g., the use of "*Productus*" with a score or more of subgenera).

Genera have here been based to some extent on external ornamentation, but distinctions are usually supplemented by internal characters. No general statement regarding the characters on which genera are based can be made because of the differences in variability between groups.

Subfamilies, families, and superfamilies are used to express increasingly broad relationships. Above the superfamily level brachiopod taxonomy is undergoing a revolution. The long-accepted ordinal units of Beecher are clearly no longer suitable, but as yet no satisfactory replacements have been found. Because of this, classification is here carried only as high as the superfamily.

MEASUREMENT OF VARIATION

An attempt has been made in this paper to present, where possible, indication of the variability of each species described. In most the number of specimens suitable for measurement was small, and the measurements are presented in tables. For a few species larger

samples were available, and up to 30 individuals were measured. Thirty specimens was the maximum number of whole adult individuals available in any species. Where perfect specimens fell slightly short of 30, slightly broken specimens were measured on the assumption that the shells were bilaterally symmetrical. For these larger samples the data are presented as histograms.

It has been shown that in populations of living brachiopods there are many individuals of small size but that larger shells become progressively less abundant (Percival, 1944). A similar distribution should characterize a well-preserved fossil population. This is seldom the case, as the results of sorting are usually evident.

Because of the large size of the blocks etched in the preparation of the material studied many micro-horizons have been sampled. This should have the effect of minimizing the bias of sorting, unless sorting was consistent throughout the time represented by the thickness of the blocks. Bias has been introduced by the picking of the acid residues in which small shells are easily overlooked, and in the elimination of juveniles which could not be specifically identified.

The histograms probably represent samples of essentially adult populations and therefore should indicate important parameters of the species concerned. Skewness of many histograms is believed to be due to sorting.

MATERIAL STUDIED

Study has, for the most part, been limited to the faunas of the four localities treated in this paper, but the writer has been fortunate in having at hand the vast Permian collections of the United States National Museum and the American Museum of Natural History. These collections have not yet been studied and contain many new genera and species which await description. Such new forms, when observed, have sometimes been discussed and compared with the forms treated in this paper, but they have not been named.

TYPES

All types and specimens figured in this report are on deposit in the collections of the American Museum of Natural History.

SUPERFAMILY DALMANELLACEA SCHUCHERT AND COOPER, 1932

DIAGNOSIS: Middle Ordovician to Permian Orthoidea characterized by the possession of an endopunctate test and primitively bilobed cardinal process.

FAMILY RHIPIDOMELLIDAE SCHUCHERT, 1913

DIAGNOSIS: Silurian to Permian Dalmanellacea in which the diductor scars enclose the adductor scars; brachioophores short; fulcral plates absent.

GENUS RHIPIDOMELLA OEHLERT, 1890

DIAGNOSIS: Biconvex, Silurian to Permian Rhipidomellidae without a fold in either valve; hinge narrow; interareas present.

GENOTYPE: *Terebratula michelini* L'Eveillé.

DEFINITION: Small to medium-sized, moderately to strongly biconvex Rhipidomellidae of subcircular to subtrigonal outline. Pedicle valve with or without a sulcus; front rounded, straight or slightly emarginate; beak short, slightly incurved; hinge short; interarea low. Brachial valve with or without a sulcus; beak low and short. Both valves are ornamented by hollow costellae which open to the surface by small pores; concentric growth lines infrequent.

Pedicle interior with the hinge teeth supported by abbreviated dental plates; adduc-

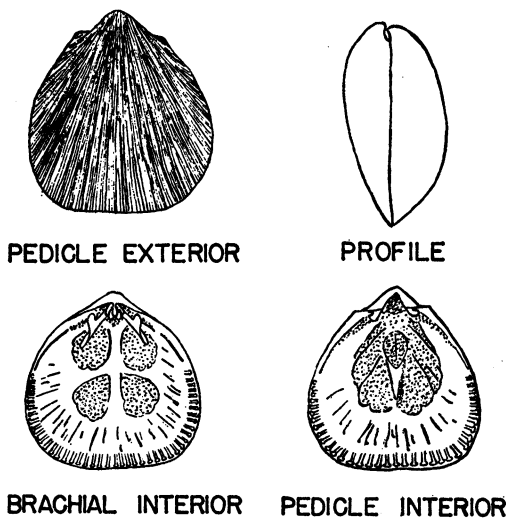


FIG. 7. *Rhipidomella*.

tor scars elongate; diductors large; adjustors outside the diductors. Brachial interior with a large, posteriorly flattened cardinal process from the base of which the long brachiophores arise; brachiophores thin, blade-like, and bearing a posteriorly directed prong which functions as a socket plate; muscle field quadripartite and longitudinally bisected by a low, rounded ridge.

COMPARISONS: *Rhipidomella* is distinguished from *Perditocardinia* Schuchert and Cooper by the presence of interareas and the absence of rostration. It is distinguished from *Reeftonia* Allen by its narrow hinge, and from *Platyorthis* Schuchert and Cooper by its biconvex profile.

DISCUSSION: *Rhipidomella* is probably the only genus of its family to persist into the Permian. *Perditocardinia* has been reported from the Permian of the Indian Salt Range (Reed, 1944, p. 7), but the assignment seems questionable.

It is surprising in a genus having so long a range as *Rhipidomella* that the shell has remained so constant. There have been minor variations in shell shape, and one or two generic stocks have diverged from the main line, but the general character of the shell has been notably unchanging. In view of the external constancy it is not surprising to find that the internal features have remained almost static. Such a singular stability probably means either that there was change which did not affect the shell greatly and has not yet been recognized, or that the genus was exceedingly well adapted to some ever present and relatively unchanging environment.

Rhipidomella seems to have lived attached to the substratum by a pedicle which must have been thread-like, for the cardinal process was so large as to have very nearly closed the delthyrium. The pedicle may have been finely divided at the distal end and adapted for the entangling of enough mud or sand to effect a firm attachment. Certainly the attachment was not a rigid one, and the animal must have swung freely back and forth in the currents. This may account for the signs of wear which are frequently found on the umbones. In the west Texas Permian the genus seems to have preferred a near-shore habitat.

Whether or not this has always been the case is uncertain, but the constant shell form strongly suggests it.

In the faunas of the Sierra Diablo and Guadalupe Mountains *Rhipidomella* seems to be limited to the older Permian strata, and it has not been found higher than the Bone Spring formation. However, in the Glass Mountains the genus has been reported from the Word formation. In parts of Eurasia it seems to extend to the end of the Permian.

Rhipidomella hessensis King

Plate 17, figures 1-6

Rhipidomella hessensis R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 43, pl. 1, figs. 2-4.

DIAGNOSIS: Leonardian *Rhipidomella* in which both valves bear a sulcus or median flattening.

DEFINITION: Shell of medium size for the genus; biconvex; subcircular to subtrigonal in outline; about as wide as long, with the greatest width nearly two-thirds of the length; shell material thick. Pedicle valve convex but frequently with a median flattening near the front; anterior margin straight to somewhat rounded; interarea low; beak short, curved and extending beyond the shorter beak of the brachial valve; lateral slopes with the pore-like openings of the hollow costellae abundant. Brachial valve more strongly convex than the pedicle; often with a median flattening or shallow sulcus; interarea low and nearly in the plane of commissure; median portion of the valve marked by abundant openings of the costellae, while the lateral portions bear them sparingly. Both valves are costellate, with eight to nine costellae in 3 mm.

The interiors of both valves are as described for the genus.

COMPARISONS: *Rhipidomella hessensis* differs from *R. leonardensis* King in being somewhat larger and more finely costellate. It is distinguished from *R. transversa* King by being much narrower, and, in addition, figures given by King (1930, pl. 1, figs. 12-13) suggest that the latter is actually a juvenile shell of *Orthotichia hueconiana*.

DISCUSSION: In the Sierra Diablo *R. hessensis* is ubiquitous in the lower part of the Bone Spring formation and has been found at all the collecting localities. It is present in

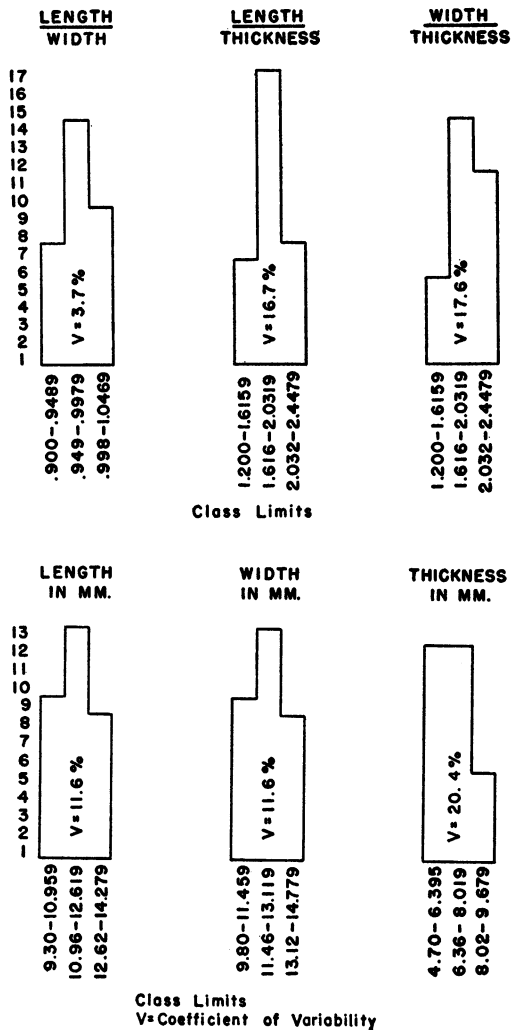


FIG. 8. Individual variation in *Rhipidomella hessensis* King.

faunules of strikingly different general aspect. The shells are usually worn and seem to have undergone noteworthy transportation, though some of the wear may be due to the animals' mode of life. The species was evidently very abundant in the seas of the time and probably inhabited some widespread ecologic niche. The thickness of the shell and the wear of the umbones suggest that the animal lived in areas of strong currents, and in the Sierra Diablo, at least, it is found only in shallow-water deposits.

Rhipidomella hessensis is known from the Hess formation of the Glass Mountains and

from the Bone Spring of the Sierra Diablo. It has not been recognized outside the west Texas Permian.

FAMILY SCHIZOPHORIIDAE SCHUCHERT, 1929

DIAGNOSIS: Lenticular to biconvex, costellate, Ordovician to Permian Dalmanellacea; with or without plications at the front; brachial pallial sinuses consisting of three pairs of trunks.

SUBFAMILY SCHIZOPHORIINAE SCHUCHERT, 1929

DIAGNOSIS: Lenticular to convexo-concave, middle Ordovician to Permian Schizophoriidae; without plications at the anterior margin.

GENUS ORTHOTICHIA HALL AND CLARK, 1892

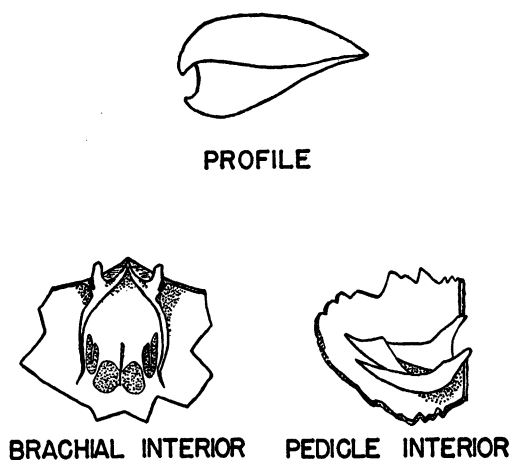
DIAGNOSIS: Pennsylvanian and Permian Schizophoriinae with a uniplicate anterior margin; pedicle interior with dental plates and a strong, anteriorly crested median septum.

GENOTYPE: *Orthis ? morganiana* Derby.

DEFINITION: Pennsylvanian and Permian Schizophoriinae externally similar to *Schizophoria*, but more finely ornamented. Pedicle valve moderately convex; with or without a sulcus; beak short and slightly incurved; interarea well developed. Brachial valve the more convex; interarea low; beak incurved. Both valves are very finely costellate and sometimes bear irregular, concentric growth lines.

Pedicle interior with the hinge teeth supported by dental plates extending far into the valve and bordering the diductor and adductor scars; median septum low, arising in the beak and reaching a crest near the anterior ends of the dental plates where it is abruptly truncated; adductor muscles probably inserted on the septum. Brachial interior with strong, tusk-like brachiophores supported by divergent plates; sockets deep and defined by fulcral plates; cardinal process small; anterior adductor scars oval and separated by a low median ridge; posterior adductors elongate but bifurcating around a low ridge and posterolateral to the anterior pair.

COMPARISONS: *Orthotichia* most nearly resembles *Schizophoria* but differs in having

FIG. 9. *Orthotichia*.

much higher plates in the interior of the pedicle valve. The genus *Enteletoides* Stuckenberg, proposed for atavistically smooth *Enteletinae*, should differ from *Orthotichia* in the possession of much higher plates in the pedicle interior, and is stated to lack an interarea.

DISCUSSION: The genotype of *Orthotichia* is a South American species which differs rather strongly from *O. hueconiana* Girty in its size and general shape. Specimens of the genotype were examined in the course of this study and prove to have the same general internal features found in *O. hueconiana*. On this basis the two species are considered congeneric despite their external differences.

Orthotichia is known from Pennsylvanian and Permian strata in many parts of the world. In the west Texas region the genus ranges only as high as the Leonardian. Elsewhere in the world, however, it persists to the close of the Permian. The Permian deposits of Serbia are remarkable for the fact that they represent a haven in which dalmanellids persisted after they had disappeared over much of their former range.

Orthotichia hueconiana (Girty)

Plate 17, figures 7-12

Schizophoria hueconiana GIRTY, 1929, Jour. Washington Acad. Sci., vol. 19, pp. 406-407, figs. 29-36.

Orthotichia kozlowskii R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 45, pl. 1, figs. 14-15.

DIAGNOSIS: Small Wolfcampian and Leo-

nardian *Orthotichia*; rather globose for the genus; generally with a well-developed sulcus in the pedicle valve.

DEFINITION: Shell small for the genus, uniplicate, somewhat globose; semicircular in outline; usually slightly wider than long. Pedicle valve quite strongly convex; beak very short and somewhat incurved; beak ridges sharp; interarea slightly more than twice as wide as high; delthyrium about one-fourth of width of interarea; sulcus rounded to angular, arising near mid length. Brachial valve the more convex; beak low, slightly incurved; interarea about one-fifth as high as wide; notothyrium about one-fourth of width of interarea; fold absent.

Pedicle interior with the dental plates subparallel or even slightly convergent; median septum high for the genus; muscle scars not well developed but seemingly as in the genotype. Brachial interior with the brachiphore plates short; median septum minute; ridge bisecting the posterior adductor scars poorly developed.

Measurements (in mm.) of isolated valves of *O. hueconiana* are as follows:

Brachial valves

Length	20	18	15	18	18	14	15	16	16	17
Width	21	21	17	19	20	16	17	18	18	17

Pedicle valves

Length	20	16	16	14	16	18	19	17
Width	25	17	18	17	19	22	21	19

COMPARISONS: *Orthotichia hueconiana* seems to be the only valid species of the genus so far described from the Permian of North America. It differs from *O. schucherti* of the Pennsylvanian in being more strongly convex and in having a larger interarea.

DISCUSSION: Unfortunately the types of *O. hueconiana* have been lost, and direct comparison of the present material has not been possible. Girty collected his material in the Sierra Diablo somewhat to the north of the localities from which the present material was derived, but at about the same horizon. The specimens agree very well with those figured by Girty, and there can be little doubt that they belong to his species.

Robert E. King (1930, p. 45) proposed the name *O. kozlowskii* for specimens of what appear to be *O. hueconiana*. King recorded *O. kozlowskii* from the Sierra Diablo close to the

locality at which Girty obtained his types and from a horizon at which *O. hueconiana* is very abundant, so that it appears probable that *O. kozlowskii* should be relegated to synonymy.

King believed that specimens figured by Kozlowski (1914, pl. 3, figs. 11-12) and referred to *O. morganiana* were conspecific with west Texas specimens. This is considered uncertain.

Orthotichia hueconiana has been found at all the collecting localities treated in this paper. With the exception of a few juvenile shells, all specimens consist of disarticulated valves. It is believed that the species did not live where found but in near-by localities offering different conditions. Its ecological preferences are unknown aside from the fact that it seems to have preferred shallow water.

The species has been reported from the Wolfcampian and Leonardian of both the Glass Mountains and the Sierra Diablo, and is questionably present in the Permo-Carboniferous of Bolivia.

SUBFAMILY ENTELETINAE WAAGEN, 1884

DIAGNOSIS: Pennsylvanian and Permian Schizophoriidae of globular or strongly biconvex form; front plicate or (?) atavistically smooth.

DISCUSSION: The Enteletinae form a very compact subfamily in which genera are based on the presence or absence of plication, the sulcate or uniplicate nature of the anterior margin, and the nature and arrangement of the plates in the interior of the pedicle valve. The principal differences between genera of the subfamily are summarized in the following key, which also includes some closely allied brachiopods that might be confused with members of the Enteletinae.

ARTIFICIAL KEY TO THE GENERA OF ENTELETINAE AND CERTAIN ALLIED BRACHIOPODS

- A. Shells with abundant, strong plications at the front
 - B. Shells with a pedicle sulcus and brachial fold
 - C. With nearly parallel dental plates and a high, simple median septum in the pedicle valve *Enteletes*
 - CC. With dental plates joining the median septum to form a spondylium. *Enteletella*
 - BB. Shells with a pedicle fold and a brachial sulcus

- C. With a V-shaped cella under the anterior end of the median septum in adults. *Parenteletes*

- CC. With subparallel dental plates and a high simple median septum *Enteletina*

- AA. Shells without abundant, strong, plications at the front

- B. Shells with interareas

- C. With dental plates extending to the front of the muscle area as a rather high ridge, and with a strong median septum *Orthotichia*

- CC. With dental plates extending about the muscle area as a low ridge and with the median septum absent or forming a low and rounded ridge towards the front of the muscle area *Schizophoria*

- BB. Shells without interareas

- C. With high, *Enteletes*-like plates in the pedicle valve *Enteletoides*

Of the seven genera included in the above key, only *Orthotichia*, *Enteletes*, and *Parenteletes* are known from the west Texas Permian, unless *Enteletes plummeri* King is actually an *Enteletella*.

GENUS ENTELETES FISCHER DE WALDHEIM, 1825

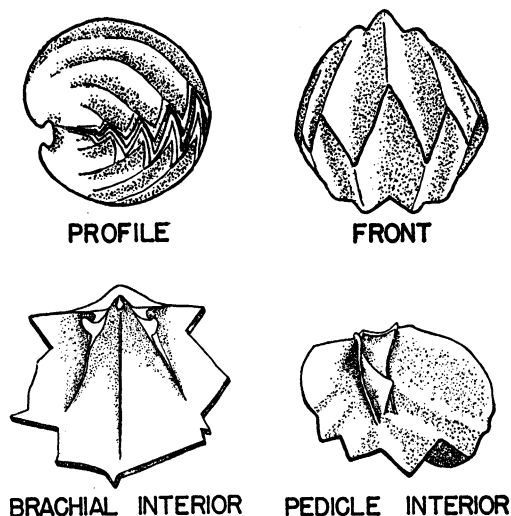
DIAGNOSIS: Pennsylvanian and Permian Enteletinae with a brachial fold and pedicle sulcus; pedicle interior with dental plates and an anteriorly crested median septum.

GENOTYPE: *Enteletes choristites* Fischer de Waldheim.

DEFINITION: Small to large, globular, anteriorly plicate Enteletinae. Pedicle valve strongly convex; sulcus usually somewhat deeper than adjoining plications; interarea well developed. Brachial valve the more convex; fold present. Both valves are finely costellate.

Pedicle interior with strong, nearly parallel dental plates and a simple median septum rising to a crest near the ends of the central plates and then terminating abruptly; diductor and adjustor scars located between the dental plates and the septum; adductor muscles probably inserted on the septum itself. Brachial interior with strong, tusk-like brachiophores supported by diverging plates; posterior adductor scars small and located outside and slightly posterior to the anterior pair; cardinal process small.

DISCUSSION: Within the genus *Enteletes* there is a wide range in size, shape, nature of

FIG. 10. *Enteleles*.

plication, and details of the plates. In spite of this diversity the genus is difficult because there is also a wide range of individual variability. The conclusive determination of species is a matter requiring in most instances a large series of well-preserved specimens.

The shell of *Enteleles* is very thin in comparison to that of such genera as *Orthotichia* and *Rhipidomella*. This may be a feature made possible by the greater strength inherent in the globular, strongly plicate form of the shell, or it may be related to some feature of the animal's preferred habitat. The plicate nature of the anterior margin represents a functional advance over such genera as *Orthotichia* and *Schizophoria* in that it permitted water to enter and leave the shell through a greater area while holding the gape of the valves to a minimum. The ecological preference of the genus is uncertain, but its occurrence both in the reef facies of the Permian and in the non-reef facies suggests that its presence near reefs was coincidental. It seems probable that it lived in the areas of muddy or sandy bottom between reefs in the west Texas area.

Enteleles is of world-wide distribution and is very abundant in many strata of upper Pennsylvanian and Permian age. In west Texas the genus ranges into the Wordian but is not known from younger deposits. In other parts of the world it is reported to persist to the close of the Permian.

Enteleles dumblei Girty

Plate 17, figures 13-18

Enteleles dumblei Girty, 1908, Prof. Papers U. S. Geol. Surv., no. 58, p. 295, pl. 26, figs. 4-4b.

Enteleles angulatus Girty, 1908, *ibid.*, no. 58, pp. 295-296, pl. 26, figs. 3-3a.

Enteleles dumblei R. E. King, 1930, Univ. Texas Bull., no. 3042, p. 45, pl. 2, figs. 4-8.

DIAGNOSIS: Wolfcampian and Leonardian *Enteleles* with strong angular plications; plates of the pedicle valve subparallel, unjoined at the base.

DEFINITION: Shell large, globose, wider than long; highly variable; subcircular to ovate in outline. Pedicle valve convex; sulcus present but not greatly deeper than the three to four angular lateral plications; beak rather short, but strongly incurved; beak ridges strong; interarea about one-third as high as wide; delthyrium about one-fourth of the width of the interarea. Brachial valve very strongly convex, far more so than the pedicle; beak short, inflated, and strongly incurved; interarea one-third to one-half the height of the pedicle valve, and lying initially almost in the plane of commissure; fold not greatly higher than the lateral plications. Both valves are ornamented by very fine costellae numbering 30 to 40 in 10 mm.; sometimes with numerous irregular growth lines, especially near the front; umbones costellate only, with the plications appearing at about one-third of the length.

Pedicle interior with the plates subparallel and reaching the floor of the valve without joining. Brachial interior with the brachio-phores rather variable, especially in gerontic individuals; a very inconspicuous median ridge is sometimes present.

Measurements (in mm.) of *Enteleles dumblei* are as follows:

Length	19	26	18	21	20	19	20
Width	20	32	20	27	24	22	21
Thickness	21	29	16	20	21	16	19

COMPARISONS: This species is so variable that it is difficult to characterize, and understanding of its range of variability can be gained only on the examination of a large series of specimens.

DISCUSSION: Robert E. King (1930, p. 46) has given reasons for considering *E. angulata*

Girty as a synonym of *E. dumblei* Girty. In view of the very imperfect nature of Girty's types, his conclusion is entirely reasonable.

Enteletes dumblei has been reported from the Hess and Word of the Glass Mountains, from the Bone Spring of the Sierra Diablo, and from the Hueco Mountains. Girty's type came from what he called the upper Hueco limestone in the Sierra Diablo, and its close agreement with the present specimens leaves little doubt of their correct assignment to his species.

SUPERFAMILY ORTHOTETACEA WILLIAMS,
1953

DIAGNOSIS: Upper Ordovician to Triassic strophomenids without a functional pedicle; pedicle valve usually modified by cementation to a foreign body; cardinal process bilobed; lophophore probably spirolophous, exceptionally supported by a spirally coiled calcareous ribbon.

DISCUSSION: Williams included in the Orthotetacea the Scacchinellidae which, as is shown below, are members of the Productacea. He also placed here the Gemmellaroidae. This assignment is regarded by the writer as being doubtful because of the very unusual shell structure of the group. The inclusion of the Triassic genus *Thecospira* Zugmayer is tentatively accepted, as specimens have not been available for study.

The Orthotetacea is a long-ranging group in which there was rapid evolution of certain characters despite the relatively unchanging nature of basic patterns. Early forms were lenticular and apparently lived free on the bottom. In many of the later genera, however, there is a tendency towards the development of a strongly conical form in which the pedicle valve becomes deep, while the brachial valve is more or less lid-like. This trend probably parallels the adoption of rigid attachment.

The pedicle interior shows great variation in the nature and development of the dental plates and median septum, and it is on these structures that the taxonomy is largely based. Practically every conceivable condition from the deep, conical spondylium of *Orthotetella* King to the complete absence of either dental plates or a median septum in the Schuchertel-

lidae has been described. There are concomitant changes in the nature of the cardinal process in response to the condition of the plates in the pedicle valve, but on the whole the brachial valve is rather constant.

In the late Paleozoic forms there is a tendency in many genera towards plication. Many of the important structural types are represented by both plicate and non-plicate genera. A study of the group gives the impression that, endowed with certain basic structures, there was continual experimentation in their utilization, until at last practically every possibility had been tried.

Within the group are seen striking examples of parallelism. A particularly interesting one is that between the genera *Meekella* and *Kiangsiella*. Both are rather deeply conical, strongly costate forms of similar appearance. Internally they differ greatly, for *Kiangsiella* is without plates of any kind in the pedicle valve while *Meekella* possesses long, subparallel, dental plates. Thus we see two genera which show by their internal structure that they belong to two different orthotetaceid families yet have evolved almost identical external form.

The function of the dental plates of *Meekella* is unknown, but that they were adaptive can hardly be doubted for they underwent evolution in the subsequent genus *Geyerella* into an elongate, angular spondylium. Their function was evidently not simply the strengthening of the shell, for *Kiangsiella* was successful without them.

The Orthotetacea seem to offer excellent possibilities as a subject for evolutionary studies, if the function of the dental plates could be ascertained. The median septum and spondylium seem to have been used for the insertion of muscles, but simple dental plates have not been noted to bear muscle scars.

The Orthotetacea are of great diversity in the Permian and are second in importance only to the Productacea. Among late Paleozoic representatives cementation of the pedicle beak to the substratum seems to be a frequent if not invariable adaptation. Correlated with this habit is an asymmetry which makes the shell extremely variable. In addition there is a wide range of individual variation in characters not affected by cementation, such as

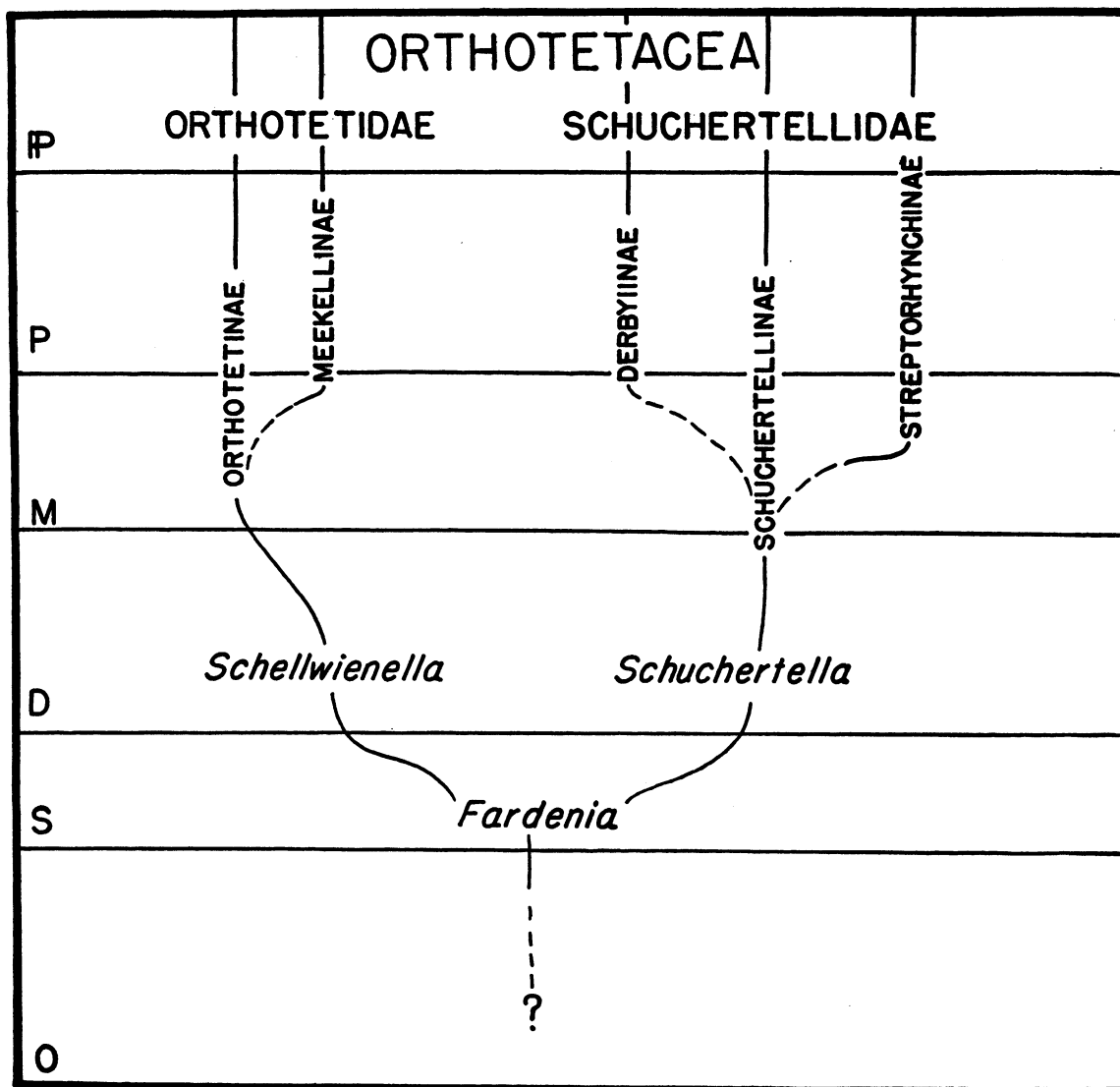


FIG. 11. Phylogeny of the orthotetid and schuchertellid divisions of the Orthotetacea.

costellation and costation. Variability makes most species exceedingly difficult to work with unless large series of specimens are available. When such are studied a growth pattern peculiar to the species generally becomes apparent. Solitary specimens of most species rarely can be identified with confidence.

SCHUCHERTELLIDAE STEHLI, NEW FAMILY

DIAGNOSIS: Orthotetacea without dental plates.

DISCUSSION: The Schuchertellidae repre-

sent one of the major structural types found in the Orthotetacea. They appear early in the history of the group. During the early and middle Paleozoic, the family is represented only by the members of the subfamily Schuchertellinae, but in the upper Paleozoic the Derbyiinae and Streptorhynchinae appear. These groups were derived from the Schuchertellinae, but though somewhat intermediate forms are known, no particular species can yet be assigned to ancestral positions.

SUBFAMILY **SCHUCHERTELLINAE** WIL-
LIAMS, 1953, EMEND.

DIAGNOSIS: Schuchertellidae in which the pedicle valve is a low cone, or in which the shell is biconvex; brachial valve with a low cardinal process, crural plates recurved and joined to the posterior margin of the shell.

DISCUSSION: The Schuchertellinae have not received as much study as some other groups within the Orthotetacea, and consequently their classification into generic units is not considered adequate. It is apparent that the genus *Schuchertella* as generally used is heterogeneous. Much of the evolution within the group seems to have been concerned with a trend away from the ancestral biconvex condition and towards the development of a slightly conical pedicle valve capped by a nearly flat brachial valve. This appears to be related to a trend towards the adoption of the attached habit.

The only described genus now placed here is *Schuchertella*, although material generically distinct is known from the Traverse group (Devonian) of Michigan.

GENUS **SCHUCHERTELLA** Girty, 1904

DIAGNOSIS: Silurian to Permian Schuchertellinae in which costellae are added by intercalation towards the front.

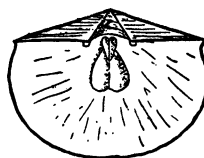
GENOTYPE: *Streptorhynchus lens* White.

DEFINITION: Small to rather large, plano-convex or biconvex Schuchertellinae; subsemicircular to transversely suboval in outline; hinge relatively long, but seldom the greatest width. Pedicle valve a shallow to moderately deep cone, flattened along one side by the interarea; beak with or without a cicatrix of attachment. Brachial valve nearly flat to somewhat convex; interarea linear. Both valves are ornamented by radiating costellae which increase by intercalation; concentric growth lines present.

Pedicle interior with the hinge teeth supported by their thickened traces along the margin of the delthyrium; adductor scars elongate, located in the beak; diductor scars large, flabellate, and located at the sides, and in front, of the adductor scars. Brachial interior with a low, bifid cardinal process supported by crural plates which are recurved and joined to the posterior margin of the shell



GROWTH POSITION



PEDICLE INTERIOR



BRACHIAL INTERIOR

FIG. 12. *Schuchertella*.

enclosing deep sockets; adductor scars oval, large, and located just in front of the cardinal process; a low, short, crested median septum is sometimes present, bisecting the muscle area anteriorly.

COMPARISONS: *Schuchertella* is distinguished from an undescribed Devonian genus by its abundant, fine costellation and the increase of the costellae by intercalation. Some species of *Streptorhynchus* resemble late Paleozoic species of *Schuchertella* externally, but the two genera can be distinguished by the high cardinal process and deep, conical pedicle valve of the former and the low process and shallow pedicle valve of the latter.

DISCUSSION: That *Schuchertella* as now constituted contains several units which might be given separate generic recognition can hardly be doubted. The problem is sufficiently complex that a critical restudy of the whole group will be necessary in order to give it satisfactory standing.

Schuchertella ranges from the Silurian to the Permian, but is not common above the Mississippian. It has been reported from strata of Permian age in several Eurasian localities, but in so far as the writer is aware this is its first recognition in the North American Permian.

Schuchertella permiana Stehli, new species

Plate 17, figures 19-23

DIAGNOSIS: Leonardian *Schuchertella* with

the pedicle deep and attached; brachial valve almost flat; ornamented with fine costellae.

Types: A.M.N.H. No. 27285; from locality 629.

DEFINITION: Shell small for the genus, plano-convex, rectimarginate; subsemicircular in outline; hinge equal to or only slightly less than the greatest width. Pedicle valve attached at the umbo, but the shell is usually rather symmetrical; valve with the shape of a shallow half cone; interarea very high for the genus; pseudodeltidium strongly convex. Brachial valve flat to very slightly convex; interarea linear; chilidium small but convex. Both valves are ornamented with radial costellae which increase by intercalation, and near the front number 12 to 14 in 5 mm.; concentric growth lines infrequent.

Pedicle interior characteristic of the genus. Brachial interior with the socket plates unusually long; a low, short, median septum is usually present, bisecting the muscle area anteriorly.

Measurements (in mm.) of *Schuchertella permiana* are as follows:

Width	13	12	16	13	13
Length from hinge					
to front	9	8	11	9	9
Depth	6	5	5	4	5

COMPARISONS: *Schuchertella permiana* differs from *S. pratteni* (McChesney) in its finer costellation. It may be distinguished from *S. affine* (Girty) by its generally larger size and coarser costellation.

DISCUSSION: While most specimens of this species are of uniform size, a few are very much larger and more coarsely costellate. These shells may belong to a different species or may indicate that the material studied was sorted before preservation and that the average size of the species is larger than most of the material indicates. Until more and better specimens of the larger shell are discovered it will be impossible to determine its proper placement, and it is therefore included in *S. permiana*.

This species was attached to the substratum by the umbo of the pedicle valve but is surprisingly symmetrical. This is thought to indicate that the shell did not habitually grow where there was excessive competition for space with other organisms, such as might be

expected in a reef. Its attached mode of life probably means, however, that it could withstand considerable current and lived in rather agitated waters. It is believed that the species may have lived near reefs but not in the zones of strongest wave action. The streptorhynchid genus *Diplanus*, on the contrary, is often strongly distorted and shows many signs of intense crowding. It is often very abundant in small reefs.

STREPTORHYNCHINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Schuchertellidae in which the pedicle valve is a deep cone; brachial valve convex, cardinal process high, crural plates recurved and joined to the posterior margin of the shell.

DISCUSSION: The Streptorhynchinae seem to have arisen from some ancestor among the Schuchertellinae during the Mississippian. Attachment by the pedicle beak was apparently developed early, and evolution proceeded in the direction of increasing the depth of the pedicle valve and the height of the cardinal process. There were also experiments with ornamentation which culminated in the costation seen in the Permian genus *Kiangsiella*.

Genera included in the subfamily are *Streptorhynchus*, *Diplanus*, and *Kiangsiella*. There are, in addition, one or more as yet undescribed genera in the Permian of the Glass Mountains which belong to the group.

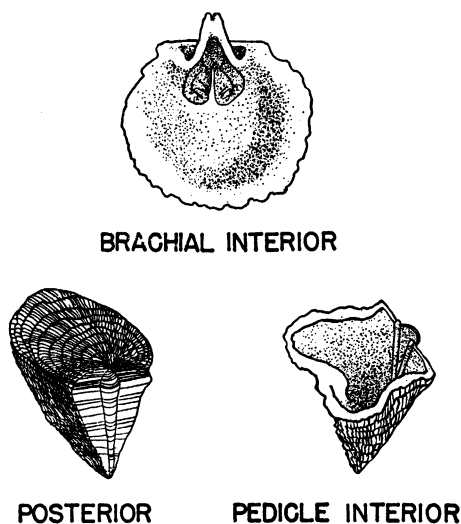
DIPLANUS STEHLI, NEW GENUS

DIAGNOSIS: Upper Pennsylvanian and Permian Streptorhynchinae with a well-developed brachial interarea and lamellose-costate ornamentation.

GENOTYPE: *Streptorhynchus lamellatum* King.

DEFINITION: Small Streptorhynchinae with deep conical pedicle valve which is attached to the substratum and often somewhat distorted. Brachial valve strongly convex and bearing a small but well-developed interarea. Both valves are ornamented by costae which are broken by strong growth lamellae.

Pedicle interior characteristic for the subfamily; muscle placement unknown. Brachial interior with a very high, bifid cardinal proc-

FIG. 13. *Diplanus*.

ess; socket ridges strong and forming a short process; crural plates recurved to join the posterior margin enclosing the deep sockets; adductor scars double, with the median pair oval and separated by a low septum while the outer pair are narrow and enclose the others except at the front.

COMPARISONS: *Diplanus* may be distinguished from both *Streptorhynchus* and *Kiangsiella* by the well-developed interarea on the brachial valve and the lamellose-costate ornamentation. It also differs from *Kiangsiella* in the absence of plication.

DISCUSSION: In so far as is presently known this genus has been found only in west Texas where it ranges from upper Pennsylvanian to the Leonardian.

Most specimens are very firmly attached to the substratum, often not only with the pedicle umbo but with a large part of the anterior slope as well. Individuals are frequently clustered together and show the effects of intense crowding in their asymmetry. It is believed that they were primarily reef dwellers, and this conclusion is upheld by the abundant representation of the genus *in situ* in the small Leonardian reef in Bone Canyon, Guadalupe Mountains.

The genus seems to be well represented in the lower Permian, occurring at many localities and horizons. It appears to include several species, of which only the genotype has as yet been described.

Diplanus lamellatum (King)

Plate 17, figures 27-29

Streptorhynchus lamellatum R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 49, pl. 4, figs. 1-3.

DEFINITION: Shell small, conical, attached and often strongly distorted; hinge usually less than the greatest width. Pedicle valve a deep cone with one side flattened by the high interarea which forms an angle of more than 90 degrees with the plane of commissure; pseudodeltidium very convex; beak and sometimes part or all of the anterior slope of the valve attached to some foreign object. Brachial valve rather evenly and highly convex; interarea about one-fourth as high as wide; chilidium slightly convex. Both valves are ornamented with four to seven irregular costae in a space of 5 mm.; costae increasing by intercalation and becoming coarser towards the front; growth lamellae strong and frequent, giving the shell a lamellose appearance.

The interiors of both valves as described for the genus.

Measurements (in mm.) of *Diplanus lamellatum* are as follows:

Length	13
Thickness	19
Width	16

DISCUSSION: Shells closely similar to those of *D. lamellatum* and believed to represent additional species are found at several localities and horizons in the lower Permian.

DERBYIINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Schuchertellidae in which there is a well-developed median septum in the pedicle valve; brachial valve with the crural plates not recurved.

DISCUSSION: The Derbyiinae are an upper Paleozoic stock probably arising from the Schuchertellinae in the late Mississippian by the development of a median septum and unrecurved crural plates. The tendency towards the development of costation, which is present in the Streptorhynchinae and in *Meekella* and its allies, appears also in the Derbyiinae with the genus *Plicatoderbya* Thomas. The trend appears late, however, and is feebly exhibited.

Genera included in the group are *Derbyia*

Waagen, *Plicatoderbya* Thomas, *Derbyaeconcha* Licharew, and *Grabauellina* Licharew. There is in addition a striking undescribed genus in the Permian of the Glass Mountains. *Derbyella* Grabau seems excluded, despite its name, by the possession of a spondylium in the pedicle valve. *Pseudoderbyia* Licharew is said to bear both dental plates and a median septum and is probably an orthotetid. *Derbyoides* Dunbar and Condra is said to possess a median septum (1932, p. 115), but figures show only the brachial interior and reveal a cardinal process and crural plates which would seem to place the genus in the Schuchertellinae.

GENUS **DERBYIA** WAAGEN, 1884
(EMEND. GIRTY, 1908)

DIAGNOSIS: Pennsylvanian and Permian non-plicate Derbyiinae with a simple median septum.

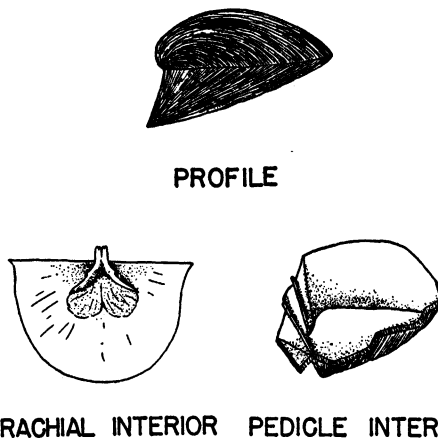
GENOTYPE: *Derbyia regularis* Waagen.

DEFINITION: Medium-sized to very large Derbyiinae. Pedicle valve usually with the form of a low, broad cone, with one side strongly flattened by the interarea. Brachial valve generally more or less convex with the interarea linear or obsolete. Both valves are costellate and usually bear concentric growth lines.

Pedicle interior with the diductor scars large and oval, lying on either side of the septum; adductor scars probably inserted on the septum. Brachial interior with a large, bifid cardinal process from which crural plates, bearing small socket ridges, extend into the shell enclosing the large oval adductor scars.

COMPARISONS: *Derbyia* is distinguished from *Plicatoderbya* by the absence of plication. It differs from *Derbyaeconcha* in the lesser convexity of the pedicle valve. It appears to differ from *Grabauellina* in the possession of a single, rather than double, walled median septum. If the septum of *Grabauellina* is truly double, the genus may be incorrectly placed in this subfamily.

DISCUSSION: *Derbyia* is abundant throughout the Permian section in west Texas. The genus is very difficult because of the great individual variation in ornamentation and in shape. Not infrequently the two valves of a single shell bear rather strikingly different ornamentation. *Derbyia*, as have most of the



BRACHIAL INTERIOR PEDICLE INTERIOR

FIG. 14. *Derbyia*.

other late Paleozoic Orthotetacea, has an attached habit of growth, and there is great resultant variability in the proportions of the valves. The determination of species is dependent on ornamentation and variation in form, but each species ranges widely about a mean, and in most cases large series of individuals are necessary in making specific designations.

Some Permian species reached very large size, being as much as 5 to 6 inches in width. Even these large shells are ordinarily attached to the substratum only by the tip of the pedicle beak, and it is believed that they lived in relatively quiet water. Some of the smaller species may have been reef dwellers, but it seems doubtful that reef dwelling was the preferred habitat of the genus, for it is abundant in the reefless Permian of north central Texas. In west Texas it probably lived in the quieter, shallow waters between small reefs.

Derbyia crenulata Girty

Derbyia ? *crenulata* GIRTY, 1908, Prof. Papers U. S. Geol. Surv., no. 58, pp. 183-184, pl. 26, figs. 5-5d.

Derbyia ? *crenulata* R. E. KING, 1930, Univ. Texas Bull., no. 3042, pp. 57-58.

DIAGNOSIS: Leonardian to Guadalupian *Derbyia* with strongly crenulate costellae.

DEFINITION: Shell of moderate size, biconvex, transversely ovoid. Pedicle valve frequently irregular, but when freely developed slightly convex with a low, broad interarea. Brachial valve rather strongly convex. Both

valves are ornamented, with costellae increasing by intercalation, the original ones sometimes remaining higher than the rest; costellae concave on the sides and bearing small, alternating, spine-like projections along their margins.

The interiors of both valves are characteristic of the genus.

DISCUSSION: Little can be added on the basis of the present material to the description of the species given by Girty, for none of the specimens is entire. The crenulate costellae are distinctive, and it is principally on this basis that the species was identified. The present material shows that the species belongs unquestionably to *Derbyia*.

Girty's type came from the Sierra Diablo, but the locality is indeterminate. The species appears to range from the Leonardian into the Wordian and has been reported from the Glass Mountains, Delaware Mountains, and the Sierra Diablo.

FAMILY ORTHOTETIDAE MACEWAN, 1939

DIAGNOSIS: Upper Ordovician to Permian Orthotetacea in which a simple median septum is lacking in the pedicle valve, and in which the dental plates are strong and may or may not join to form a spondylium before reaching the floor of the valve.

SUBFAMILY ORTHOTETINAE WAAGEN, 1884

DIAGNOSIS: Upper Ordovician to Permian Orthotetacea in which the shell is unaplicated, and in which the dental plates meet the floor of the valve without joining or join to form a spondylium.

DISCUSSION: This grouping is probably heterogeneous and includes several lines, but the genera are so numerous and range through so long a period of time that a special study of the subject will be necessary to achieve a satisfactory classification.

GENUS ORTHOTETELLA R. E. KING, 1930

DIAGNOSIS: Lower Permian Orthotetinae in which the dental plates join to form a deep, conical spondylium supported by a short median septum.

GENOTYPE: *Orthotetella wolfcampensis* R. E. King.

DEFINITION: Large, biconvex or plano-

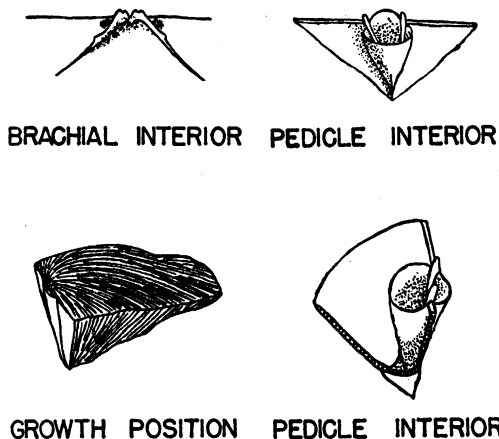


FIG. 15. *Orthotetella*.

convex, lower Permian Orthotetinae. Pedicle valve a broad, shallow half cone; interarea broad and high. Brachial valve slightly convex to flat; interarea obsolete. Both valves are ornamented with radial costellae and concentric growth lines.

Pedicle interior with a deep, conical spondylium supported at its anterior side, near the base, by a short median septum; muscle scars probably within the spondylium. Brachial interior with a very low cardinal process; crural plates low and extending into the valve enclosing the adductor scars; socket ridges low.

COMPARISONS: Externally *Orthotetella* resembles many of the non-plicate Orthotetacea. It may be distinguished on the basis of its internal structure from all other genera, and by its nearly flat brachial valve from most others.

DISCUSSION: *Orthotetella* is known from a single described species, though what may be an undescribed species is present in material from the Glass Mountains. Geographically it is restricted to the west Texas area and may never have achieved more than a local distribution. It is also possible that difficulty in distinguishing the genus by its external appearance explains the fact that it has not been recognized elsewhere. Stratigraphically the genus appears to be limited to the Wolfcampian and lowest Leonardian.

In his original diagnosis of the genus, R. E. King (1930, p. 51) states that there are muscle scars on the outside of the spondylium. While the specimen which he described has

not been available to the writer, it seems improbable that the muscles were so located. Specimens in the material studied do not show muscle scars, yet it would have been almost impossible for the animal to have opened the shell had the diductor been inserted outside the spondylium. King also fails to mention the presence of the median septum at the base of the spondylium.

In life the shell was attached to the substratum by the pedicle umbo and seems to have adopted the same general mode of life as *Derbyia*. Its extreme rarity makes it impossible to guess what the life requirements of the animal may have been. Whether the rarity is real or due to the fact that the animal did not live where it has been found is also uncertain.

***Orthotetella wolfcampensis* King**

Plate 17, figures 24-26; plate 18, figures 1, 2

Orthotetella wolfcampensis R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 51, pl. 9, figs. 27-28.

DIAGNOSIS: Wolfcampian and lower Leonardian *Orthotetella* in which the spondylium is joined to the floor of the valve only at the extreme apex.

DEFINITION: Shell often very large, plano-convex or biconvex; greatest width forward of the hinge. Pedicle valve a moderately deep cone, with one side flattened by the broad, high interarea which lies nearly at right angles to the plane of commissure; valve usually rather symmetrical. Brachial valve very slightly convex. Both valves are ornamented with costellae which increase by intercalation and number six to 12 in 5 mm.; costellae somewhat more closely spaced towards the front and certain of them frequently a little raised and more prominent than the rest.

Pedicle interior with a deep, conical spondylium of which the posterior margin is formed by the pseudodeltidium, while the remainder arises as modified dental plates which join anteriorly without a suture; spondylium supported by a short median septum near its base; position of the muscle insertions uncertain, but probably within the spondylium. Brachial interior characteristic of the genus.

COMPARISONS: *Orthotetella wolfcampensis* is the only described species of this genus, but

what seems to be a congeneric species is present in the Wolfcamp of the Glass Mountains. It differs from *O. wolfcampensis* in that it is more finely costellate, the interarea stands at considerably less than a right angle to the plane of commissure, and internally the spondylium is often attached to the floor of the valve for much of its length.

DISCUSSION: *Orthotetella wolfcampensis* is seemingly limited to the lower Permian, for it is known only from the Wolfcamp formation of the Glass Mountains, the lower Gym in the Hueco Mountains, and the lower Bone Spring formation of the Sierra Diablo.

MEEKELLINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Pennsylvanian and Permian plicate Orthotetidae in which the dental plates reach the floor of the valve without joining, or join just above the floor to form an elongate, triangular spondylium.

DISCUSSION: This subfamily appeared first in the Pennsylvanian and in the upper Pennsylvanian and Permian achieved world-wide distribution. *Meekella* is the first representative, but it is joined in the lower Permian by *Geyerella* and by an undescribed form.

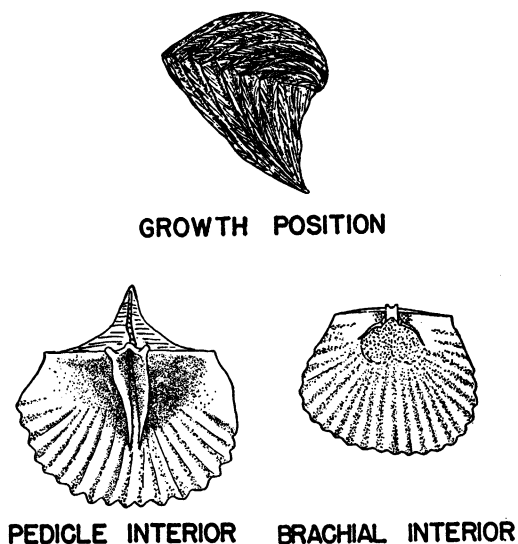
The relationship of unplicated forms, possessing similar internal structures, to the Meekellinae is uncertain. If some of the unplicated forms can be shown to have achieved that condition atavistically, they would deserve a place in the subfamily. No evidence of the existence of such a condition is now known.

GENUS MEEKELLA WHITE AND ST. JOHN, 1867

DIAGNOSIS: Pennsylvanian and Permian Meekellinae in which the dental plates meet the floor of the valve without joining.

GENOTYPE: *Plicatula striatocostata* Cox.

DEFINITION: Medium- to large-sized, strongly costate, biconvex Meekellinae. Pedicle valve a deep cone; beak usually long and bearing evidence of attachment; interarea high; hinge usually less than the greatest width. Brachial valve strongly convex; beak insignificant; interarea obsolete. In both valves the umbo is usually finely costellate, with costae appearing only towards the front; costellae tending to converge towards the crests of the costae.

FIG. 16. *Meekella*.

Pedicle interior with long, subparallel dental plates which reach the floor of the valve without joining; muscles probably inserted between the dental plates. Brachial interior with a high cardinal process from which diverging crural plates, bearing low socket ridges, extend into the shell enclosing the adductor scars.

COMPARISONS: *Meekella* is distinguished from *Geyerella* by the failure of the dental plates to meet to form a spondylium. It differs from an undescribed species in the lower Permian of the west Texas area in that the dental plates are distinctly separate on the floor of the valve, while in the other form they meet as they join it. *Meekella* resembles the streptorhynchid genus *Kiangsiella* but is distinguished by the presence of dental plates.

DISCUSSION: *Meekella* is abundant and widespread in the marine Permian faunas of the world and occurs in almost all outcrop areas. As with *Derbyia* and several other orthotetaceid genera the determination of species in *Meekella* is difficult and requires a large series of specimens. Specific distinctions are generally based on the character of the ornamentation and general shape, both of which are subject to a wide range of individual variation.

Meekella occurs in areas which display reef development as well as those which do not,

and it is believed that with the possible exception of a few species, members of the genus preferred quieter conditions than those offered by the reef environment.

Meekella attenuata Girty

Plate 18, figures 6-11

Meekella attenuata GIRTY, 1908, Prof. Papers U. S. Geol. Surv., no. 58, pp. 205-206, pl. 24, figs. 7-9a, pl. 25, figs. 4-4d.

Meekella attenuata R. E. KING, 1930, Univ. Texas Bull., no. 3024, pp. 52-53, pl. 5, figs. 2-7.

DIAGNOSIS: Small Wolfcampian to Guadalupian *Meekella* with the beak of the pedicle valve greatly elongated.

DEFINITION: Shell of small to moderate size for the genus; hinge equal to one-half to two-thirds of the width. Pedicle valve a variable but generally deep, asymmetrical cone; beak attenuate; extremities of the hinge sometimes auriculate; valve usually slightly to moderately convex. Brachial valve strongly convex; ears small. Both valves strongly costate but with the costae beginning at one-fourth to one-third of the length; costae increasing in size towards the front but not increasing in number; costae usually 15 to 25 in number but variable.

Pedicle interior with strong subparallel or slightly convergent dental plates. Brachial interior characteristic of the genus.

Measurements (in mm.) of *M. attenuata* are as follows:

Brachial valves					
Width	23	25	29	26	29
Length from hinge to front	19	21	22	20	23
Depth	7	11	8	8	8
Pedicle valves					
Width	26	22	21	27	24
Length from hinge to front	21	18	16	21	18
Depth	10	8	8	11	9

COMPARISONS: This species is distinguished by its attenuated pedicle umbo, fine costation, and relatively small size. It differs from *Meekella hessensis* in the attenuated beak and finer costation.

DISCUSSION: Girty's holotype of this species is a juvenile specimen and far from typical; his paratypes are more representative. The growth habit of the species is highly

characteristic but is seldom apparent until large series of specimens have been examined. *Meekella attenuata* has been reported from strata ranging in age from Wolfcampian to Wordian in the Glass Mountains. In the Sierra Diablo the species occurs throughout the Bone Spring formation, and it is known as well from the Delaware Mountains, Baylor Mountains, and Las Delicias, Coahuila, Mexico.

Meekella attenuata is often very abundant where it is found. In the collections treated here it is represented almost entirely by separate valves, probably owing to the rigid attachment of the pedicle valve which remained in place for some time after decomposition of the animal had freed the brachial valve. The two valves are about equally represented in the collections, however, which seems to indicate that the animal lived essentially where it is found. The evidence suggests that it lived near but not on the reefs. The conditions which kept the different species of *Meekella* from direct competition with one another are unknown, but it is not uncommon in this genus to find several species in association.

***Meekella hessensis* King**

Plate 18, figures 3-5

Meekella hessensis R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 56, pl. 5, figs. 8-9.

DIAGNOSIS: Small, Leonardian *Meekella* with coarse costation and normal development of the pedicle umbo.

DEFINITION: Shell small to moderate sized for the genus; hinge equal to one-half to two-thirds of the width; usually a little wider than long. Pedicle valve slightly convex; interarea moderately high; beak short, seldom attenuate. Brachial valve strongly convex, especially near the umbo; ears seldom developed; beak very low. Both valves are ornamented by 10 to 15 strong costae which approach the umbo quite closely; costellae are also present.

The interiors of both valves are characteristic of the genus.

Measurements (in mm.) of *Meekella hessensis* are as follows:

Length	24	22
Width	24	26
Thickness	18	20

COMPARISONS: *Meekella hessensis* may be distinguished from *M. attenuata* by its coarser costation and the general absence of elongation of the pedicle umbo.

DISCUSSION: This species is found with *M. attenuata* but is far fewer in numbers. Surprisingly many specimens are found with the valves in association. *Meekella hessensis* has been reported from the Hess formation of the Glass Mountains and from the lower Bone Spring formation in the Sierra Diablo.

STROPHOMENOIDS OF UNCERTAIN POSITION

FAMILY OLDHAMINIDAE SCHUCHERT, 1929

DIAGNOSIS: Pennsylvanian to Upper Triassic, pseudopunctate Brachiopoda in which the brachial valve is reduced to a pinnate structure or has become secondarily entire by union of the pinnae, and in which the pedicle valve contains a series of lateral ridges and a median ridge which support or surround the brachial valve.

DISCUSSION: Although this family is generally supposed to have died out at the end of the Permian, it has been noted by Watson (1917, pp. 217-218) that it persists at least into the upper Triassic. A single Mesozoic species belonging to the genus *Pterophloios* Gumbel has been found in the Kossen beds of the Austrian Rhaetic. The principal difference between *Pterophloios* and the Paleozoic representatives of the group is that its brachial valve is no longer pinnate but has become secondarily entire. It still shows its ancestral pinnate condition, however, and the solid nature of the valve is due to the filling of the spaces between pinnae with shell material. *Pterophloios* is therefore of interest not only for its survival into the Mesozoic but because it presents an example of reversion in evolution.

The majority of the Oldhaminidae were firmly attached to the substratum by all or part of the pedicle valve, and their mode of life was probably similar to that of the pelecypod genus *Ostrea*. *Oldhamina* and seemingly *Pterophloios* were atypical in being secondarily free living.

The relationships of the Oldhaminidae to other groups of brachiopods are obscure. Uncertainty as to their origin stems largely from the extreme modification of the group

for their specialized way of life. Specialization has tended to reduce many of the structures upon which much weight is placed in classification. The absence of spines in any known genus seems to indicate that Fredericks (1925) was in error in deriving the group from *Marginifera* Waagen, and it is extremely doubtful that the Oldhaminidae bear any close relationship to the Productacea. The ancestry of the group is rather to be sought in one of the other pseudopunctate stocks, probably of the Mississippian.

Two distinct groups are known among the Oldhaminidae which at some future date may be found to merit subfamily rank. These are the forms in which the muscles are symmetrically developed, and those in which there is asymmetrical muscle development.

GENUS **POIKILOSAKOS** WATSON, 1917

DIAGNOSIS: Pennsylvanian and Permian Oldhaminidae in which the pedicle valve is cemented by its entirety to the object of attachment, and in which there is asymmetrical muscle development.

GENOTYPE: *Poikilosakos petaloides* Watson.

DEFINITION: Small, simple Oldhaminidae. Pedicle valve cemented by its entire outer surface to some foreign object. Brachial valve much reduced, pinnate, highly irregular, and with accretional growth lines; hinge very narrow.

Pedicle interior with a raised rim outlining the brachial valve and a skirt of adventitious, faintly papillose shell material surrounding it; hinge short, with ear-like, anterolateral flattenings outside the raised rim; a deep median

area at the hinge expands forward into the shell; on the right side near the hinge is a trough which housed a single muscle. Brachial interior unknown.

COMPARISONS: *Poikilosakos* is readily distinguished from the adults of most other genera by its smaller size, few lateral septa, and the cementation of the entire outside of the pedicle valve. It differs from the young of the larger genera in its asymmetrical musculature. It is most like an undescribed genus from the Guadalupe Mountains with which it shares the asymmetry of the musculature, but from which it differs in the absence of a deeply conical growth form.

DISCUSSION: *Poikilosakos* attained a spotty but wide distribution in the Pennsylvanian and Permian, and seems also to have had rather broad ecologic tolerances. The genus is equally at home in the reefless strata of north central Texas and in the reef-bearing strata of west Texas. Apparently its chief requirements were relatively shallow water and some sort of solid object for attachment. Because of its small size it could attach to any hard object on the bottom and find ample anchorage, while the larger genera required firmer foundations and preferred the vicinity of reefs or rocky shores.

***Poikilosakos ? petaloides* Watson**

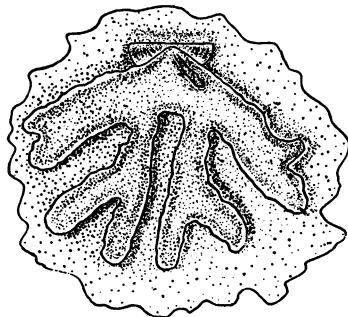
Plate 19, figure 4

DISCUSSION: Owing to the exceptionally irregular growth habit of *Poikilosakos*, there seems to be no effective way to separate species. If large numbers of specimens could be examined some consistent differences in growth habit might be recognized. In the present collections two specimens belonging to the genus have been found. They are placed questionably with the genotype for lack of evidence.

GENUS **LEPTODUS** KAYSER, 1883

GENOTYPE: *Leptodus richthofeni* Kayser.

DISCUSSION: Kayser described the genus *Leptodus* believing it to be a fish. A short time later it was correctly interpreted by Waagen as a brachiopod and given the name *Lyttonia*. Girty and others have pointed out that despite Kayser's misinterpretation the name *Leptodus* is the valid name of the genus.



PEDICLE INTERIOR

FIG. 17. *Poikilosakos*.

Lyttonia is more frequently found in the literature.

Study of the silicified faunas of west Texas reveals that *Leptodus* has been used for a large number of forms deserving separate generic designation. These genera are still undescribed but are clearly separable by their growth habits. Unfortunately Kayser's figures of *Leptodus* do not show the growth form clearly nor does his description make mention of it. Before it can be determined whether or not any of the Oldhaminidae in the west Texas Permian actually belong to *Leptodus*, it will be necessary to restudy the type in the light of recent knowledge on the growth forms of the group. Such restudy might well indicate that *Lyttonia* is distinct from *Leptodus* and therefore a valid genus.

Because of the confused status of *Leptodus*, the two related forms described in this paper have been questionably referred to the genus, though it is probable that one or both are actually new.

Several names have unfortunately been proposed by deGregorio (1930) for various Oldhaminidae of the Sicilian Permian, but it is doubtful that most of them can ever be recognized from his exceedingly poor descriptions and figures.

***Leptodus* ? *diabloensis* Stehli, new species**

Plate 18, figures 12-14

DIAGNOSIS: Leonardian *Leptodus* ? with simple lateral ridges and median ridge; without dental plates of a true median septum; growth habit conical.

TYPES: A.M.N.H. No. 27290; from locality 625.

DEFINITION: Medium to large *Leptodus* ? reaching a size of 75-80 mm.; growth asymmetrical. Pedicle valve a somewhat flattened, low cone in which the anterior margin is far higher than the posterior; cone attached to the substratum without callous wash; surface ornamented with irregular growth lines. Brachial valve pinnate; ornamented with fine papillae; anterior edge of each pinna serrate, posterior edge smooth.

Pedicle interior with the posterior wall of the cone strongly papillose; anterior wall bearing the lateral ridges and the median ridge; lateral ridges striated from oppo-

sition of the serrate edge of the brachial pinnae; neither a true median septum nor dental plates are present; muscle insertions not observed; lateral ridges seven to eight in 20 mm. Brachial interior with a rudimentary cardinal process; adductor scars not observed.

COMPARISONS: *Leptodus* ? *diabloensis* differs from *L. americanus* Girty in that the posterior part of the pedicle valve is modified to form a hood or posterior wall of the cone, while in *L. americanus* the posterior margin is turned back and aids in attachment. It differs from *Leptodus* ? *marshalli*, new species, in its conical growth habit, failure to attach habitually to crinoids or other objects above the bottom, and more closely spaced lateral ridges. Poor knowledge of the Eurasian species prevents adequate comparison.

DISCUSSION: This species seems to have attached itself to large shells or to stones on the bottom and was therefore not infrequently buried. For this reason it is sometimes found with the brachial valve in place and the pedicle valve little broken.

The larva of the animal, after settling on a suitable attachment base, began the growth of a shell which lay flat against the object of attachment, in a manner similar to that of *Poikilosakos*. After the development of shell about the size of a small coin the pedicle valve was abruptly geniculated upward, as was the brachial valve within it, and the conical growth form was initiated. There is considerable variation in the ontogenetic pattern because of the diverse nature of the objects to which the shell attached. It is evident that there was a high mortality rate among young shells, for they often attached to objects too small to support them when they reached adult size and were tipped over and buried. For this reason it is common to find shells smaller than the maximum size for the species under optimum conditions.

Leptodus ? *diabloensis* is believed to be limited in distribution to the vicinity of reefs or shores offering firm support—a conclusion which seems to apply equally to all the large, rigidly attached forms in this group.

The species is known only from the Bone Spring formation in the Sierra Diablo, but other species of similar growth habit are found throughout the Permian of west Texas,

and this growth form is probably characteristic of a generic or subgeneric group.

Leptodus ? *marshalli* Stehli, new species

Plate 19, figures 1-3

DIAGNOSIS: More or less flat, Leonardian *Leptodus* ? which habitually lived suspended above the bottom from some attachment site; posterior margin of the pedicle valve recurved and fused to the outside of the shell.

TYPES: A.M.N.H. No. 27291; from locality 625.

DEFINITION: Moderate-sized, more or less plate-like *Leptodus* ? which usually lived attached to a crinoid stem. Pedicle valve roughly linguloid in outline; variably but rather slightly convex; front somewhat truncated; shell rolled back and welded to the outside of the valve so as to form a hollow tube along the edge; attachment wash either smooth or minutely papillose; shell ornamented with irregular growth lines. Brachial valve pinnate but otherwise unknown.

Pedicle interior with unstriated lateral ridges and a median ridge; neither a true median septum nor dental plates present; muscle scars not observed; lateral septa averaging six in 20 mm. Brachial interior unknown.

COMPARISONS: This species differs from others in the west Texas Permian in its mode of attachment and in the rolled-back posterolateral margins. It resembles *L. catenatus* (Wanner and Sieverts) from the Permian of Timor in its habit of attachment, but differs in having enrolled posterolateral margins and in lacking rows of beads along the lateral septa.

DISCUSSION: *Leptodus* ? *marshalli* is represented by a great many specimens, but all are fragmentary, and some details of the shell are unknown. The attachment of the pedicle valve was of a rigid nature, and when the animal died the attachment remained. The brachial valve, held in place only by musculature, became loosened as the animal decayed and finally dropped off and became lost. For this reason there are no brachial valves in the collection which can surely be associated with this species. No entire pedicle valves have been found, but the species seems to have attained a length of at least 60 mm. The

absence of entire pedicle valves is explained by the habit of the animal in attaching above the bottom, for it was not easily buried, and was usually rolled about on the sea floor.

While the animal seems to have preferred crinoid stems as a site for attachment, it often attached to bryozoans, corals, and exceptionally to other individuals of its own species. In the latter case it is believed that it attached to dead shells still retaining their position above the bottom. In two specimens the brachiopod is attached to a small, platyceroid snail. These snails seem to have lived over the anus of crinoids, and its association with the brachiopod furnishes further evidence of the crinoid preference of both animals.

**SUPERFAMILY CHONETACEA SCHROCK
AND TWENHOFEL, 1953**

DIAGNOSIS: Upper Ordovician to Permian, pseudopunctate brachiopods of concavo-convex longitudinal profile; surface smooth, costellate, or costate; posterior margin of the pedicle valve usually bearing a single row of spines.

DISCUSSION: The Chonetacea are a large and long-ranging group. The fundamental pattern of the shell has remained clearly discernible, but there has been much variation upon it. The basic design of the shell suggests relationship to the sowerbyelloids of the early Paleozoic. Externally the main difference between the Chonetacea and the sowerbyelloids is the absence in the latter of cardinal spines. Internally there are differences in detail, but the fundamental arrangement of the muscles, the form of the cardinal process, and the apparent nature of the brachial apparatus are similar. It seems probable that the Chonetacea took their origin in one of the Ordovician sowerbyelloids, but at the present time no genus can be singled out as holding the ancestral position.

As a group the Chonetacea show a striking picture of radiation in which most possibilities in variation of the basic shell plan were attempted. Early genera were costellate, but smooth forms appear in the Devonian. This trend continued into the Permian and involved a large number of stocks. On the other hand a costate condition was attained by the

Permian genus *Waagenites* Paeckelmann. *Semenewia* Paeckelmann lost its costellation but developed in its place a marked concentric ornamentation of strong rugae.

In the lower Carboniferous of Eurasia appears a short-lived trend towards gigantism involving the two genera *Daviesiella* and *Airtonia*. *Daviesiella* attained a width of 3 to 4 inches, whereas *Airtonia* was somewhat smaller. Both developed very much thickened and massive shells. These two genera also exhibit the acme in concavo-convex shell form among the Chonetacea and are strongly reminiscent of a highly convex productid.

Like most other brachiopod groups, the Chonetacea experimented with various modifications of the anterior margin of the shell. This trend is probably related to the achievement of a more effective separation of incurrent and excurrent waters. The late Paleozoic is rich in genera showing diverse types of folding. *Mesolobus* Dunbar and Condra and *Quadrochonetes*, new genus, exhibit two adaptations, but the most specialized folding is found in *Chonetella* Waagen which developed a short projecting siphon not unlike that of the productid genus *Proboscoidella*, though shorter.

Modifications of the cardinal spines occurred in *Anoplia* Hall and Clarke, which lost them entirely, and in *Longispina* Cooper, in which they were very long and nearly parallel to the hinge. *Eodevonaria* Breger developed a denticulate hinge, a venture which, in this group, was apparently not successful as the genus is short lived. *Conostrophia* Hall and Clarke reversed the usual concavo-convex condition and became convexo-concave.

In specimens available for examination there is no evidence that the cardinal spines of the Chonetacea were ever used for attachment, and it seems that the chonetids were free-living forms. They probably lay on the bottom with the pedicle valve down and the cardinal spines thrust into the mud or lying along the surface in such a way as to reduce the danger of overturning. It is difficult to understand how small shells of this type could escape burial in the shifting sands and muds of the ocean floor. Perhaps the abundance of chonetids found with the valves together indicates that very often they did

not escape and that such accidents caused a high mortality which the animal by some fortunate reproductive device was able to overcome.

For many years all Chonetacea were placed in the single genus *Chonetes*, *sensu lato*, and it was not until late in the last century that a start was made in working out relationships within the group. At the present time some 20 genera and subgenera have been recognized, and it is apparent that many of the genera as they are now used are heterogeneous units. An inclusive and critical study of the Chonetacea as a biologic group and from an evolutionary point of view is necessary for the solution of many of the taxonomic problems.

The present study has of necessity been focused on the late Paleozoic Chonetacea. Among these genera it has been found that the most satisfactory characters on which to base generic divisions are the general shape and ornamentation of the exterior of the shell and the nature of the interior of the brachial valve.

It has been noted during the course of the study that many of the chonetid genera show low ridges which are directed into the valves between the hinge and the median septum. These ridges are related to the support of the lophophore and in some specimens can be seen to be contiguous with brachial ridges similar to those found in the Productacea. To this structure the term brachiophore is applied in the following descriptions.

The position of muscle insertion in the late Paleozoic Chonetacea is remarkably stable. In the pedicle valve there are large oval diductor scars which nearly surround the smaller adductors. In the brachial valve the adductors seem to be double, with one pair attached between the median septum and the brachiophore and the other pair attached between the brachiophore and the socket plates.

QUADROCHONETES STEHLI, NEW GENUS

DIAGNOSIS: Small, quadrate, Leonardian Chonetacea; shell smooth; pedicle valve with a deep sulcus bordered by folds.

GENOTYPE: *Quadrochonetes girtyi* Stehli, new species.



BRACHIAL INTERIOR PEDICLE EXTERIOR

FIG. 18. *Quadrochonetes*.

DEFINITION: Pedicle valve strongly convex, with a deep, broad, but angular sulcus bordered on either side by an angular fold; ears distinct, flattened, and short; beak inflated and overhanging the hinge. Brachial valve concave and bearing a sharp fold; ears strongly flattened. Both valves are smooth.

Pedicle interior with a high, short median septum which is confined to the beak; ornament consisting of radiating rows of fine papillae. Brachial interior with sockets elongate; median septum very low or even absent; brachiophores present but often poorly developed, radiating rows of fine papillae present but exceedingly faint and never forming a raised ridge around the visceral disc.

COMPARISONS: *Quadrochonetes* differs from *Lissochonetes* Dunbar and Condra in having a strong and angular fold and sulcus, an inflated and overhanging beak, and in the reduced nature of the radial ornamentation in the interior of the brachial valve. Comparisons with *Paeckelmannia* Licharew are difficult because that name is used to include a variety of forms, but *Quadrochonetes* differs from the genotype of *Paeckelmannia* in its quadrate outline, deep sulcus and bordering folds, and in its overhanging beak. It differs from *Dyoros*, new genus, in its strongly quadrate outline, much smaller size, overhanging beak, and the absence of a rim of papillae around the visceral disc of the brachial valve.

DISCUSSION: *Quadrochonetes* is a monotypic genus. It has been found to be abundant only at locality 629, though it is sparingly present at the other collecting localities.

***Quadrochonetes girtyi* Stehli, new species**

Plate 19, figures 23–26

Chonetes quadratus GIRTY, 1929, Jour. Washington Acad. Sci., vol. 19, p. 407, figs. 4–7.

TYPES: Syntypes: A.M.N.H. Nos. 27298/1:1, 27298/1:2, 27298/1:3, and 27298/1:4;

paratypes: A.M.N.H. Nos. 27298/1 and 27298/2; from localities 629 and 631.

DEFINITION: Shell small and strongly quadrate in outline. Pedicle valve very strongly convex, with the beak inflated and overhanging the hinge line; cardinal spines short, stout, and numbering up to seven on either side of the beak; sulcus broad, deep, and angular, with an angular to somewhat rounded, usually high, fold at either side; ears distinctly set off, short and flattened. Brachial valve concave, with a sharp fold bordered by deep depressions; ears flattened. Both valves are smooth except for occasional growth lines.

Interiors of both valves characteristic for the genus.

DISCUSSION: *Quadrochonetes girtyi* was first described by Girty (1929) under the name *Chonetes quadratus*, which is a homonym of *Chonetes uralica quadratus* Nikitin, 1890, and therefore has been changed. Robert E. King (1930) also gave the name *Chonetes quadratus* to a species from the west Texas Permian. This species seems distinct from *C. quadratus* Girty and must be renamed. No new name is here proposed, as the species does not occur in the collections under study.

GENUS LISSOCHONETES DUNBAR AND CONDRAS, 1932

GENOTYPE: *Chonetes geinitzianus* Waagen.

DEFINITION: Medium-sized, smooth, late

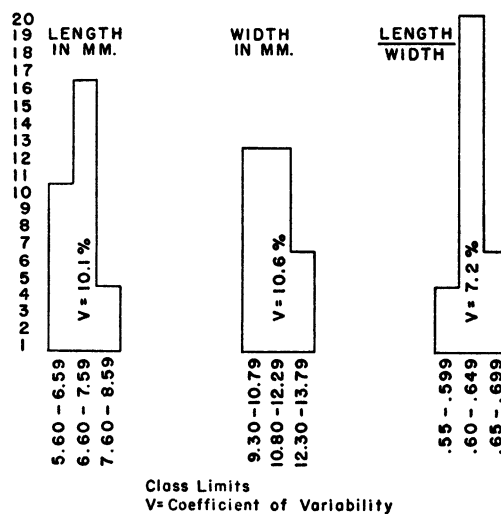


FIG. 19. Individual variation in *Quadrochonetes girtyi* Stehli, new species.

Paleozoic Chonetacea. Pedicle valve of low convexity; a faint sulcus or medium flattening is usually present; beak low and ending at the hinge; ears somewhat flattened and often slightly extended. Brachial valve rather strongly concave, with the median part depressed and the ears flattened. Both valves are smooth, or bear only infrequent concentric growth lines.

Pedicle interior with a rather low, short median septum in the beak; muscle scars poorly developed; radial rows of papillae are present, especially towards the margins. Brachial interior with the median septum low to obsolete; radiating rows of papillae present and well developed but not enlarged.

COMPARISONS: *Lissochonetes* differs from *Quadrochonetes* in its low convexity, shallow sulcus, and termination of the beak at the hinge. It differs from *Paeckelmannia* in being rather flat, strongly transverse, and in bearing a sulcus. Ramsbottom (1952, p. 15) states that the two genera differ also in that *Paeckelmannia* is without a septum. *Lissochonetes* differs from *Dyoros* in the absence of a strong sulcus bordered by folds and in the absence of a raised rim of papillae around the visceral disc of the brachial interior.

DISCUSSION: The definition given above includes the essential points of the original description and was drawn up in part from specimens of the genotype in the hope that the genus could be somewhat clarified. Unfortunately the brachial interior of the genotype has not been available to the writer, and important questions concerning its character remain unanswered. It is stated by Dunbar and Condra that the interior of the brachial valve resembles that of *Chonetes*, as the genus was understood by them. (The genotype of *Chonetes* was not fixed until 1952, by Ramsbottom.)

As presently defined *Lissochonetes* has proved difficult to interpret. Sokolskaya (1950) in his study of the Russian Devonian and Carboniferous Chonetacea has completely discarded the name in favor of *Paeckelmannia*. This procedure does not seem justified, for the genotype of *Paeckelmannia* is very different from the genotype of *Lissochonetes*. The writer believes that *Lissochonetes* should be retained for some of the smooth, late Paleozoic forms, but it must be

kept in mind that the genus as it has been used in recent years is polyphyletic and badly in need of a thorough revision.

Lissochonetes sinesulcus Stehli, new species

Plate 19, figures 5-8

Chonetes permianus R. E. KING, 1930 (*non* Shumard, 1859), Univ. Texas Bull., no. 3042, p. 62, pl. 9, figs. 1-4.

DIAGNOSIS: Leonardian *Lissochonetes* lacking a sulcus.

TYPES: A.M.N.H. No. 27293; from locality 625.

DEFINITION: Shell of moderate size; semi-circular in outline. Pedicle valve of low but even convexity; without a sulcus but sometimes with a median flattening; ears scarcely distinct from the curvature of the valve; cardinal margin with up to eight short, posterolaterally directed spines on either side of the beak. Brachial valve slightly concave; ears slightly flattened. Both valves completely free of radial ornament and bearing only infrequent growth lines or none at all.

Pedicle interior with a short, high, median septum in the beak which terminates abruptly anteriorly; radial rows of fine papillae are present. Brachial interior with a small cardinal process; sockets elongate and flanked by socket plates; brachiophores usually present and well developed; median septum very low; surface ornamented with radial rows of fine papillae which are not conspicuously enlarged.

Measurements (in mm.) of *Lissochonetes sinesulcus* are as follows:

Length	11.7	10.8	12.8	11.6	12.0
Width	18.0	17.6	18.6	16.5	18.3

COMPARISONS: *Lissochonetes sinesulcus* is distinguished from *L. geinitzianus* by its larger size, indistinct ears, and the virtual absence of a sulcus in the pedicle valve.

DISCUSSION: This species is placed in *Lissochonetes* because it resembles the genotype in general shape and in internal features in so far as they are known. It is one of the rarer species in the collection at hand and occurs only at locality 625. Its mode of life and ecological requirements are unknown. Stratigraphically it seems to be limited to the Leonardian.



BRACHIAL INTERIOR PEDICLE EXTERIOR

FIG. 20. *Dyoros*.**DYOROS STEHLI, NEW GENUS**

DIAGNOSIS: Permian, smooth Chonetacea in which the brachial interior bears a rim of enlarged papillae around the visceral disc.

GENOTYPE: *Chonetes consanguineus* Girty.

DEFINITION: Medium- to large-sized, smooth, strongly transverse, late Paleozoic Chonetacea. Pedicle valve moderately convex, with the beak low and not extending beyond the hinge; sulcus strong; ears distinct, extended, and flattened so that the body of the shell seems to be composed of two rounded folds bordering the sulcus; cardinal spines directed posterolaterally. Brachial valve with the ears large and flattened; median part of the shell strongly depressed except for the fold. Both valves are smooth.

Pedicle interior with a short, high, median septum in the beak which occasionally extends farther into the valve as a very low ridge; radiating rows of papillae present. Brachial interior with the cardinal process small; sockets elongate and flanked by socket ridges; median septum low, rising to a crest anteriorly where it bears several spines; brachiophores usually present; visceral disc depressed medially, ornamented by radiating rows of papillae on either side; at the anterior edge of the visceral disc several papillae in each row are enlarged, forming in aggregate a raised crescentic rim.

COMPARISONS: *Dyoros* is distinguished from *Lissochonetes* by its larger size, pronounced fold and sulcus, spinose median septum, and raised rim of papillae in the brachial valve. It differs from the genotype of *Paeckelmannia* in being strongly sulcate and in the possession of a median septum (Ramsbottom, 1952, p. 15). It may be distinguished from *Quadrochonetes* by its larger size, rounded fold and sulcus, and the presence of the papillose rim in the brachial interior.

DISCUSSION: *Dyoros* seems to be limited to the Permian, but is very common there, at least in the west Texas region. In addition to

the two species described below, others are known from the Leonard and Word formations of the Glass Mountains but await description. *Chonetes subliratus* Girty seems also to belong here. Certain Pennsylvanian and lower Permian Chonetacea resemble *Dyoros* in the possession of a crescentic row of papillae in the brachial valve, but differ in having costellate ornamentation.

***Dyoros consanguineus* (Girty)**

Plate 19, figures 9-12

Chonetes consanguineus GIRTY, 1929, Jour. Washington Acad. Sci., vol. 19, p. 409, figs. 8-9.

DIAGNOSIS: Moderate-sized, lower Leonardian *Dyoros* with a deep sulcus and extended ears.

DEFINITION: Shell of medium size and strongly transverse. Pedicle valve moderately convex, with a deep, rounded sulcus bordered by a broad, rounded fold at either side; ears distinct, large and extended; beak low; up to eight short, posterolaterally directed spines are present on either side of the beak. Brachial valve concave and bearing a strong fold; ears flattened; interarea low. Both valves devoid of radial ornamentation but usually bearing irregular concentric growth lines.

Interiors of both valves characteristic for the genus.

COMPARISONS: This species is distinguished from *D. ? magnus* by its more transverse outline, deeper sulcus, higher marginal folds, and smaller size. It differs from *D. subliratus* (Girty) in being generally more strongly transverse and in having a less convex pedicle valve and a more concave brachial valve.

DISCUSSION: The specimens studied in the preparation of this report were derived, in so far as Girty's citation permits its recognition, from his locality and may be considered as topotypes. The specimens were found at locality 629 where the species is very abundant; it has also been found at locality 625.

***Dyoros ? magnus* Stehli, new species**

Plate 19, figures 13-15

DIAGNOSIS: Large, lower Leonardian *Dyoros* ? of subquadrate outline and low convexity.

TYPES: A.M.N.H. No. 27295; from locality 628.

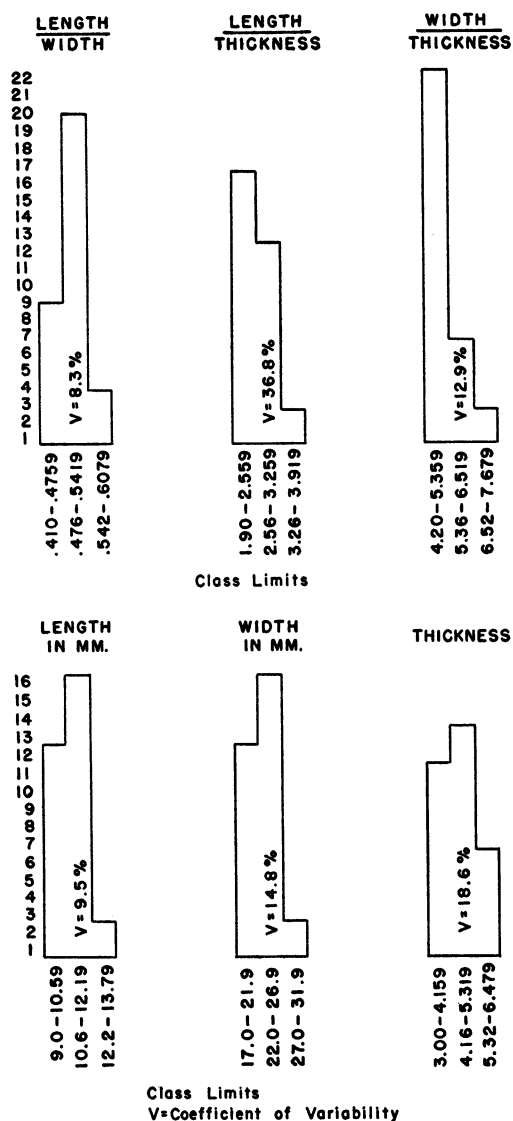


FIG. 21. Individual variation in *Dyoros consanguineus* (Girty).

DEFINITION: Shell large for the genus, transverse, and rather flat. Pedicle valve slightly and evenly convex, with a deep rounded sulcus; ears distinct, but only slightly extended; beak low; number and inclination of the cardinal spines unknown. Brachial valve concave and bearing a strong fold near the anterior margin; ears flattened. The surface of both valves is smooth (or possibly finely costellate; see below).

Pedicle interior characteristic for the genus. Brachial interior with the median septum

low, anteriorly crested, and bearing spines; brachiohores usually prominent; anterior and lateral margins of the valve flattened.

Measurements (in mm.) of *Dyoros ? magnus* are as follows:

Length	20.0	18.2	16.0	15.0	14.2	17.5
Width	34.6	33.8	31.3	29.5	27.0	30.0

COMPARISONS: This species is distinguished from *D. consanguineus* by being less strongly convex, less transverse, having shorter ears, a shallower sulcus, and lower folds. It is separated from *D. subliratus* (Girty) by the fact that it is far less convex and considerably larger.

DISCUSSION: The shell surface in this species was probably smooth, but one specimen shows traces of a radial ornamentation, which probably is a feature of an inner layer of the shell rather than the surface, as the silicification is coarse and the shells are badly worn. Should this radial ornamentation be a real feature of the surface, the species is incorrectly placed in *Dyoros* and belongs, rather, with the group of shells typified by "*Chonetes*" *granulifer*. *Dyoros ? magnus* is known only from locality 628 in the lower Bone Spring formation of the Sierra Diablo.

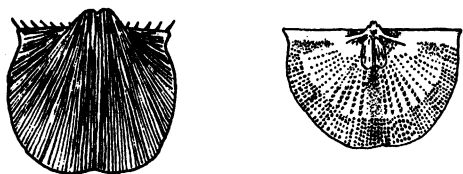
GENUS *CHONETINELLA* RAMSBOTTOM, 1952

DIAGNOSIS: Pennsylvanian and Permian Chonetacea, generally transverse and ornamented with fine costellae.

GENOTYPE: *Chonetes flemingi* Norwood and Pratten.

DEFINITION: Small to medium-sized Chonetacea. Pedicle valve moderately to strongly convex; beak often somewhat inflated and overhanging the hinge line; sulcus present; ears more or less distinct, somewhat flattened and not greatly extended. Brachial valve with a median depression bisected by a fold; ears flattened. Both valves are costellate and marked by occasional concentric growth lines.

Pedicle interior with the median septum usually low; a small callist is present in the beak at the apex of the deltidium; radiating rows of fine papillae present. Brachial interior with a low median septum; brachiohores usually present; visceral disc ornamented with radial rows of papillae which are enlarged near the middle of the valve.



PEDICLE EXTERIOR BRACHIAL INTERIOR

FIG. 22. *Chonetinella*.

COMPARISONS: *Chonetinella* is distinguished from *Chonetina* Krotow by the costellate nature of the shell (Ramsbottom, 1952, p. 15).

DISCUSSION: The name *Chonetina* has been widely used for Pennsylvanian and Permian Chonetacea by Dunbar and Condra (1932) and subsequent authors. The use of the name for species in the Pennsylvanian of North America has been questioned by Girty (1938, p. 283) and by R. H. King (1938, p. 270). Ramsbottom (1952) has pointed out that the genus seems to have been misinterpreted by Dunbar and Condra and later authors. *Chonetina* seems to be a smooth-shelled form and thereby clearly separable from the group to which the name has been applied in North America. Ramsbottom has therefore proposed the subgenus *Chonetinella* for the reception of these shells. In view of the present imperfect knowledge of relationships among the Chonetacea it seems better to use *Chonetinella* in a generic rather than a subgeneric sense for the present.

Ralph H. King (1938, p. 257) has noted that the shells commonly called *Chonetina* in this country seem to constitute a polyphyletic assemblage. This situation is not clarified by the change of names but is sufficiently complex to require special study and is beyond the scope of this work.

Chonetinella victoriana (Girty)

Plate 19, figures 19-22

Chonetes victoriana GIRTY, 1929, Jour. Washington Acad. Sci., vol. 19, p. 410, figs. 1-3.

Chonetes spinoliratus diabloensis R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 63, pl. 9, figs. 1-3.

DIAGNOSIS: Strongly convex, sulcate, lower Leonardian *Chonetinella* in which the costellae are fasciculate.

DEFINITION: Shell small, subpentagonal to

subcircular in outline, a little wider than long. Pedicle valve very highly convex, with the beak strongly inflated and extending well beyond the hinge line; ears small and pointed; sulcus sharp and strong near the beak but often somewhat less distinct towards the front; beak ridges bearing up to eight spines on either side. Brachial valve with a median depression bisected by a sharp fold; ears flattened. Both valves are strongly costellate, with the costellae numbering six to eight in 2 mm.; costellae increasing by bifurcation and conspicuously fasciculate towards the beak.

Pedicle interior characteristic of the genus except that the papillae are very strong on the ears and very faint elsewhere. Brachial interior with the median septum very low and nearly obsolete; brachioophores usually faint.

COMPARISONS: *Chonetinella victoriana* differs from *C. biplicata* (King) in being much more coarsely costellate, having a more convex pedicle valve and in the absence of the two folds bordering the sulcus. It differs from *C. hessensis* (King) in having the pedicle valve more strongly convex, the beak more inflated and more strongly overhanging the hinge. It is distinguished from *C. spinolirata* (King) by its coarser costellation. It may be separated from *C. verneuilliana* (Norwood and Pratten) by its more evenly convex transverse

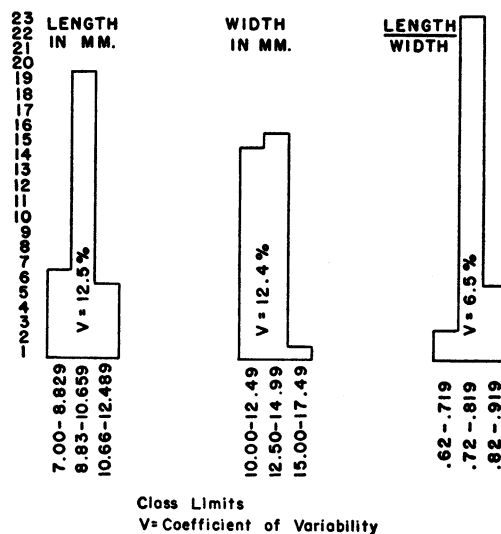


FIG. 23. Individual variation in *Chonetinella victoriana* (Girty).

curvature and from *C. flemingi crassiradiata* in being much narrower.

DISCUSSION: *Chonetinella victoriana* is abundant at locality 629 and is present sparingly at locality 625, though its place here seems to be largely filled by *C. biplicata*. The two valves are seldom associated but are so little worn as to indicate that transportation has been slight.

The species is known only from the lower part of the Bone Spring formation.

***Chonetinella biplicata* (King)**

Plate 19, figures 16–18

Chonetes biplicatus R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 60, pl. 9, figs. 12–13.

DIAGNOSIS: Wolfcampian and Leonardian *Chonetinella* in which the sulcus is bordered by a fold at either side.

DEFINITION: Shell of medium size for the genus; variable in outline but usually semi-circular to elliptical. Pedicle valve strongly convex, with the beak moderately inflated and overhanging the hinge line; ears quite distinct, somewhat flattened, slightly extended at the hinge and pointed; sulcus strong, bordered on either side by a low fold which is often flanked by a shallow sulcus causing it to stand high above the general surface of the valve. Brachial valve with the ears and lateral margins flattened; a median depression is bisected by the fold. Both valves are ornamented with very fine costellae numbering nine to 10 in 2 mm.; costellae increasing by bifurcation, not conspicuously fasciculate; occasional concentric growth lines are present.

Pedicle interior with papillae especially large and abundant on the ears. Brachial interior, in so far as it is known, characteristic for the genus.

Measurements (in mm.) of pedicle valves of *Chonetinella biplicata* are as follows:

Length

11.4 10.1 10.9 8.5 10.3 10.6 8.7 12.4

Width

14.0 12.3 12.3 11.4 17.1 15.0 13.5 16.0

Depth of pedicle valve

5.3 4.5 5.6 4.3 4.9 5.0 4.3 5.7

COMPARISONS: *Chonetinella biplicata* is distinguished from *C. victoriana* and from other species of the genus in the west Texas Per-

mian by the presence of the two plications bordering the sulcus in the pedicle valve.

DISCUSSION: *Chonetinella biplicata* is found at localities 625 and 628 but is never common and the shells generally show signs of transport. The species is known from the Wolfcamp and Hess of the Glass Mountains and from the lower Bone Spring in the Sierra Diablo.

**SUPERFAMILY PRODUCTACEA MAILLIEUX,
1941**

DIAGNOSIS: Small to large, concavo-convex, Devonian to Permian, pseudopunctate Brachiopoda, bearing spines on the body of the shell.

DISCUSSION: Among the late Paleozoic brachiopods no group can rival the Productacea in abundance or diversity. In Permian faunas the end members of many evolutionary lines achieve striking and bizarre aspects unduplicated in the phylum. This is especially evident in the west Texas faunas in which silicification allows the recovery of specimens of unusual beauty and completeness. Study of such material is highly instructive and gives an insight into the group not ordinarily possible.

The most interesting feature of productid evolution has been the development and utilization of the spines. A multitude of spine patterns has developed, and the spines have been modified to serve many functions. Attachment to the substratum is the most frequent use and was achieved either by cementation of the spines to some object, or, with the spines as anchoring struts, to hold the shell in position on soft bottoms.

Abundant material in the position of growth indicates that the normal position for the productid in life was with the pedicle valve downward. If exceptions to this rule exist they are not known to the writer.

The consistency in the spine patterns of the Productacea is useful in grouping closely related forms, especially in the recognition of genera. That the spine patterns were adaptive seems beyond doubt, but except in a few striking cases the conditions to which they were adapted cannot be determined.

Only fairly recently has the great genus *Productus*, *sensu lato*, begun to fall before the advance of discriminating studies. The tre-

mendous diversity of the group is indicated by the fact that there are already more than 100 described genera. Many species have not as yet received proper generic assignment, and undoubtedly many genera remain to be discovered. Continuing studies will greatly add to the number of known genera and species.

Our knowledge of the evolutionary patterns within the Productacea is rudimentary; however, certain of the more obvious relationships are becoming apparent. While no comprehensive attempt at classification of the group is yet possible, several units are here assigned family and subfamily rank. The great body of genera remains too poorly known to permit such grouping.

DICTYOCLOSTIDAE STEHLI, NEW FAMILY

DIAGNOSIS: Upper Paleozoic Productacea in which the shell is ornamented by costae or costellae; umbo reticulate or not; body spines few to many. Brachial interior with a strong, low cardinal process of the general type found in *Dictyoclostus*.

DICTYOCLOSTINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Generally large Dictyoclostidae in which the shell is costate to costellate and the umbo reticulate.

DISCUSSION: This is a widespread and important group occurring in most fossiliferous marine strata of Mississippian to Permian age. The subfamily includes the following genera: *Dictyoclostus* Muir-Wood; *Pugilis* Sarycheva; *Antiquatonia* Miloradovich; *Chaoiella* Fredericks; *Nudauris*, new genus; and *Spinifrons*, new genus. There are in addition a number of still unnamed genera.

GENUS ANTIQUATONIA MILORADOVICH, 1945

DIAGNOSIS: Medium- to large-sized, Mississippian to Permian Dictyoclostinae in which a ridge bearing a single row of enlarged spines runs from the beak across the ears.

GENOTYPE: *Productus antiquatus* Sowerby.

DEFINITION: Pedicle valve strongly convex, geniculate or not; beak inflated or not; ears distinctly set off by a ridge running anterolaterally from the beak and bearing a single row of large spines; a row of spines follows the cardinal margin from the beak

onto the ears which are smooth and bear few other spines; scattered spines are present over the remainder of the valve; posterior slope reticulate; anterior slope costellate but with a tendency towards the formation of costae in front of the spine bases. Brachial valve strongly concave; visceral disc reticulate; trail costellate; without spines.

Pedicle interior usually with a ridge separating the ears from the visceral disc; adductors elongate and inserted on a raised platform; diductors large, flabellate, and located at the sides of the adductors. Brachial interiors with a strong cardinal process buttressed by lateral ridges; median septum very low or absent and with an elongate adductor scar at either side; visceral disc reticulate and ornamented with low spines around its anterior margin; trail costellate; ears separated from the visceral disc by a low ridge and deep groove; brachial ridges seldom visible.

COMPARISONS: The genus is readily recognized by the ridges across the ears which distinguish it from other Dictyoclostinae.

DISCUSSION: *Antiquatonia* was erected by Miloradovich for shells of the type of *Productus antiquatus* Sowerby, but it seems to have been established in a manner not according to the Rules, with the genus *Horridonia* as a subgenus. Sarycheva (1949, p. 167) redefined the genus, so that it appears now to have legal standing. Sarycheva would seem to be the author of the genus, but as he attributes it to Miloradovich the same procedure is followed here.

Antiquatonia planumbona Stehli, new species

Plate 20, figures 1-5

DIAGNOSIS: Leonardian *Antiquatonia* in which the posterior slope of the pedicle valve is strongly flattened.

TYPES: Syntypes: A.M.N.H. Nos. 27299/

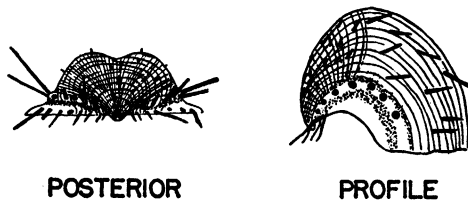


FIG. 24. *Antiquatonia*.

2:1 and 27299/2:2; paratypes: A.M.N.H. No. 27299/1; from localities 625 and 629.

DEFINITION: Shell of moderate size, strongly concavo-convex, transverse in outline; widest near the hinge. Pedicle valve geniculate and bearing a strong rounded sulcus originating somewhat anterior to the beak; posterior slope flattened, strongly and finely reticulate; anterior slope costate only, with eight to 10 costae in 10 mm.; spines scattered thinly and irregularly over the shell except for the row along the cardinal margin and that above the ears; ears prominent, rounded, and nearly smooth. Brachial valve strongly geniculate, with the finely reticulate visceral disc flat except for the rounded fold; trail long and costellate; ears separated from the visceral disc by a sharp ridge; valve without spines.

The interiors of both valves are characteristic for the genus.

Measurements (in mm.) of *Antiquatonia planumbona* are as follows:

Length	27
Width	55

COMPARISONS: *Antiquatonia planumbona* differs from *A. coloradoensis* (Girty) and from *A. antiquata* (Sowerby) in that the posterior slope of the pedicle valve is strongly flattened and the shell rather strongly transverse.

DISCUSSION: This species is rare and known only from a few specimens. A single complete specimen is known. It has been found only in the lower Bone Spring formation of the Sierra Diablo.

NUDAURIS STEHLI, NEW GENUS

DIAGNOSIS: Moderate-sized, Leonardian Dictyoclostinae in which the ears are naked except for a row of cardinal spines.

GENOTYPE: *Nudauris diabloensis* Stehli, new species.

DEFINITION: Pedicle valve strongly convex and bearing a sulcus; posterior slope somewhat flattened, reticulate; anterior slope finely costellate, with a tendency towards the development of strong costae in front of the spine bases; ears distinct, smooth, and usually without spines, except for a cardinal row which extends from the beak onto the ears, diverging slightly from the hinge; remainder

of the valve with infrequent, scattered spines. Brachial valve strongly concave and bearing a low fold; visceral area somewhat flattened, usually smooth or indistinctly costellate; trail long; ears concave and distinctly set off; valve without spines.

Pedicle interior with the adductor scars elongate and located on a low ridge; diductor scars large, oval, and located outside the adductors. Brachial interior with a strong cardinal process buttressed by cardinal ridges; median septum low but rising to a rounded crest anteriorly; adductor scars ovate and located at the base of the cardinal process on either side of the septum; brachial ridges often indistinct; anterior margin of the visceral disc ornamented with several rows of low spines; much reduced spines are also present on the trail.

COMPARISONS: *Nudauris* is distinguished from other members of the Dictyoclostinae by its row of cardinal spines and otherwise naked ears, scattered body spines, and the absence of spines on the brachial valve.

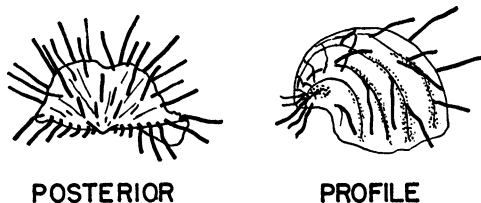


FIG. 25. *Nudauris*.

DISCUSSION: The genus is known only from the lower Bone Spring formation in the Sierra Diablo. It is relatively common at localities 629 and 625 but is generally represented by dissociated valves and evidently did not live where found.

Nudauris diabloensis Stehli, new species

Plate 21, figures 1-5

TYPES: Syntypes: A.M.N.H. Nos. 27301/1:1, 27301/1:2, 27301/1:3, 27301/1:4, and 27301/1:5; paratypes: A.M.N.H. Nos. 27301/2 and 27301/3:1; from localities 625, 628, and 629.

DEFINITION: Shell of moderate size, much wider than long, with the greatest width at the hinge. Pedicle valve somewhat geniculate, bearing a strong sulcus; posterior slope

faintly and finely costellate, with about 10 costellae in 10 mm.; strong costae frequently arise in front of the spine bases; ears distinct, convex, extended; spines stout and irregularly scattered except for the cardinal row. Brachial valve strongly concave, geniculate, with the somewhat flattened visceral disc interrupted by a low fold; visceral disc indistinctly wrinkled or smooth; trail finely and faintly costellate; ears distinct, concave, and extended; valve without spines.

The interiors of both valves characteristic of the genus.

Measurements (in mm.) of *Nudauris diabloensis* are as follows:

Length	33	32	30	30
Width	55	51	53	52

SPINIFRONS STEHLI, NEW GENUS

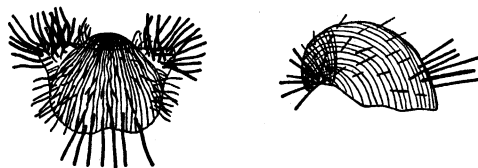
DIAGNOSIS: Medium- to large-sized Dictyoclostinae in which there are tufts of enlarged spines on the ears and in the middle of the anterior slope.

GENOTYPE: *Spinifrons quadratus* Stehli, new species.

DEFINITION: Medium- to large-sized upper Paleozoic Dictyoclostinae; wider than long; subquadrate in outline. Pedicle valve strongly convex, with a shallow sulcus; beak inflated; posterior slope strongly reticulate; anterior slope costate; ears short but distinct and bearing a tuft of stout anchoring spines; commonly with one or more rows of cardinal spines merging with the ear tufts; body of the shell ornamented by irregular fine spines except near the front where the median portion of the valve bears a cluster of enlarged spines. Brachial valve strongly concave and bearing a low fold; visceral disc somewhat flattened and reticulate; trail costate; ears set off, concave and more or less smooth; entire valve bearing fine erect spines.

Pedicle interior with adductor scars elongate and bordered by the large oval diductors. Brachial interior with a strong cardinal process supported by cardinal ridges; median septum low but crested towards the front; adductor scars elongate; brachial ridges seldom evident; the anterior edge of the visceral disc bearing low spines.

COMPARISONS: *Spinifrons* differs from *Dictyoclostus* in the possession of the tuft of



PEDICLE EXTERIOR

PROFILE

FIG. 26. *Spinifrons*.

enlarged spines on the ears and in the presence of an area of enlarged spines on the anteromedian part of the pedicle valve. *Dictyoclostus semireticulatus* is said by Muir-Wood (1928, p. 94) to have a cluster of spines at the cardinal extremity but neither her illustrations nor specimens examined by the writer show them. Although *D. semireticulatus* does not show an area of enlarged spines towards the front, *D. pinguis* does. It is uncertain whether *D. pinguis* actually belongs in *Spinifrons*, or the spine pattern is one that was repeated in different stocks.

The presence of well-developed spines on the brachial valve distinguishes *Spinifrons* from many of the genera of Dictyoclostinae.

DISCUSSION: *Spinifrons* is known with certainty only from the west Texas Permian, but "*Dictyoclostus*" *portlockianus* from the Pennsylvanian of the mid-continent region of the United States seems to belong to the genus.

Spinifrons quadratus Stehli, new species

Plate 20, figures 6-10

TYPES: A.M.N.H. No. 27300; from locality 625.

DEFINITION: Shell of moderate size, wider than long; subquadrate in outline. Pedicle valve strongly and evenly convex and bearing a moderately deep sulcus; beak inflated; umbo strongly reticulate; anterior slope costate, with four to seven costae in 10 mm.; ears distinct but short and bearing a sparse tuft of stout, anchoring spines into which the row of cardinal spines merges; remainder of the valve with sparing, irregular, rather fine spines, except for the stout spines at the front. Brachial valve concave, with the visceral disc flattened, reticulate, and bearing a low fold; trail costate; ears set off, concave, wrinkled; entire valve with fine spines.

The interior of both valves is characteristic of the genus.

Measurements (in mm.) of *Spinifrons quadratus* are as follows:

Length	38	36	35
Width	48	55	47

COMPARISONS: *Spinifrons quadratus* is the only species of the genus sufficiently well preserved to merit description, but a second species is represented by fragmentary material. It differs from *S. quadratus* in being far larger and in having finer but more abundant spines composing the ear tufts.

LINOPRODUCTINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Dictyoclostidae in which the shell is costellate, or costellate and rugose, but in which the umbo is not reticulate.

DISCUSSION: This family ranges from the Mississippian to the Permian and includes the following genera: *Linoproductus* Chao; *Cancrinella* Fredericks; *Anidanthus* Whitehouse; and at least one undescribed genus.

GENUS LINOPRODUCTUS CHAO, 1927

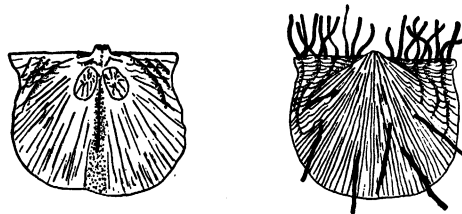
DIAGNOSIS: Small to large, Mississippian to Permian Linoproductinae; rugae on the pedicle valve restricted to the shoulders and ears; not strikingly transverse in outline.

GENOTYPE: *Productus cora* D'Orbigny.

DEFINITION: Pedicle valve strongly convex; beak inflated; ears usually well developed, flattened; trail long; one or two rows of spines usually present along the cardinal margin; ears and shoulders often rugose. Brachial valve moderately to strongly concave; with a long trail; without spines. Both valves are costellate; spines sparse to almost lacking; shell material very thin.

Pedicle interior with the adductor scars elongate, oval, and a little in front of the beak; diductor scars located at the side and partly in front of the adductors. Brachial interior with a low cardinal process buttressed by cardinal ridges; a low median septum may be present; adductor scars oval and located at the base of the cardinal process; brachial ridges seldom evident.

COMPARISONS: *Linoproductus* is distinguished from *Cancrinella* by its generally larger size, fewer spines, and the absence of



BRACHIAL INTERIOR PEDICLE EXTERIOR

FIG. 27. *Linoproductus*.

concentric rugae on the anterior slope of the pedicle valve. It differs from *Anidanthus* in lacking the elevated ears and reticulate ornamentation present in the brachial valve of that genus, and in being less transverse.

DISCUSSION: *Linoproductus* is world-wide in distribution and includes a vast number of species. The abundance of species indicates that the group successfully radiated into a number of environments, and the abundance of individuals shows that it must have been extremely successful in many of them. The large number of species suggests that the group may still be polyphyletic despite the relatively recent removal of several generic units.

No particular mode of life can be given as being characteristic of *Linoproductus* as a whole because of the diversity of the group and the extreme range of conditions under which it seems to have flourished.

Linoproductus philocrinus Stehli, new species

Plate 21, figures 6-10

DIAGNOSIS: Leonardian *Linoproductus* in which an attached habit was adapted and in which spines other than the single cardinal row were lost.

TYPES: A.M.N.H. No. 27302; from locality 629.

DEFINITION: Large attached *Linoproductus* with a strong fold and sulcus; widest near mid length. Pedicle valve strongly convex; beak inflated and bearing a cicatrix of attachment at the apex; without spines except for a single row along the cardinal margin which converged on the beak and entangled the object of attachment; ears wrinkled, well developed but not extended; costellae increasing by intercalation and numbering 11 to 14 in 10 mm. Brachial valve concave; with a

strong fold; ears flattened and wrinkled; cardinal margin marked by a series of pits and ridges due to the spines of the other valve; remainder of the shell costellate; with a thin trail.

Pedicle interior with muscle scars poorly developed; cardinal margin appearing denticulate because of the strong spine bases. Brachial interior appearing denticulate at the cardinal margin; median septum low; adductor scars usually visible at the base of the cardinal process.

COMPARISONS: *Linoproductus philocrinus* is most closely related to *L. inornatus* King but differs from it in lacking body spines, being attached, and possessing a fold and sulcus. It is also similar to *L. cora angustus* King from which it differs in the possession of a fold and sulcus.

DISCUSSION: The close relationship of *L. philocrinus* to *L. inornatus* from the high Pennsylvanian strata of Texas is worthy of note. According to R. H. King (1938, p. 274) specimens from the highest strata in which *L. inornatus* occurs show a median flattening in the pedicle valve and a low, broad fold in the brachial. For this reason and because *L. inornatus* is said sometimes to possess a cicatrix of attachment, it seems probable that the latter is very near if not on the phyletic line of *L. philocrinus*. The fact that both species are found in the Texas region further strengthens the possibility that *L. philocrinus* is to be derived from *L. inornatus*. This trend towards an attached habit is unique in *Linoproductus* and may at some future time be shown to merit subgeneric rank.

Attachment was effected not only by cementation of the beak, but by the single row of very stout cardinal spines which converged towards the beak and wrapped around the object of attachment. All specimens examined show a strong cicatrix of attachment which is of a shape requiring that it be made by a cylindrical body. In two cases the shell has been found still in its life position with the beak attached to, and the spines entangling, a crinoid stem. It is believed that this was the customary mode of existence for the species.

Linoproductus philocrinus is known only from the lower Bone Spring formation in the Sierra Diablo. Its occurrence is such as to suggest that it may have lived in crinoid gar-

dens in inter-reef areas. Owing to its attached habit no complete pedicle valves have been found. One complete brachial valve, however, indicates that the species was of relatively large size.

GENUS *CANCERINELLA* FREDERICKS, 1928

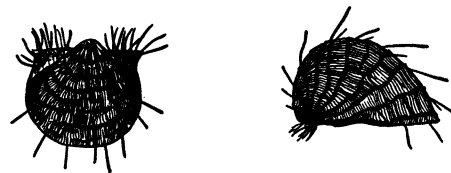
DIAGNOSIS: Small, thin-shelled, costellate, and rugose *Linoproductinae*.

GENOTYPE: *Productus cancrini* de Verneuil.

DEFINITION: Pedicle valve strongly convex; beak somewhat inflated; ears short and flattened, usually spinose; ornamented by fine costellae and by irregular rugae; spines abundant but irregularly placed. Brachial valve concave; ears flattened; costellae and rugae present; spines absent.

Pedicle interior with the muscle placement unknown but probably as in *Linoproductus*. Brachial interior with a low cardinal process; median septum, when present, short and low; anterior part of the visceral area with irregular short spines; muscle placement as in *Linoproductus*.

COMPARISONS: *Cancrinella* may be distinguished from both *Linoproductus* and *Anidanthus* by the presence of rugae on the anterior slope of the pedicle valve.



PEDICLE EXTERIOR

PROFILE

FIG. 28. *Cancrinella*.

DISCUSSION: *Cancrinella* represents a stock which has diverged rather significantly from an ancestry probably close to that of *Linoproductus*, but within the genus variation is slight and mostly a matter of degree. For this reason the determination of species is difficult. The spacing and character of the costellae seem most useful, but even here there is considerable overlap between species. Perhaps in the last analysis determination of species will be found to rest on the general growth form and will require large series of specimens. The identification of single specimens will always remain a very difficult matter.

***Cancrinella altissima* King**

Plate 22, figures 1-5

Cancrinella altissima R. H. KING, 1938, Jour. Paleont., vol. 12, pp. 275-276, pl. 39, figs. 27-28.

DIAGNOSIS: Upper Pennsylvanian and lower Permian *Cancrinella* in which the costellae average seven to 10 in 3 mm.

DEFINITION: Shell small to medium sized for the genus. Pedicle valve somewhat variable in outline; ears short, flattened, and pointed in mature specimens; beak mildly inflated; shell usually somewhat geniculate, with the posterior slope more strongly wrinkled than the anterior; costellae seven to 10 in 3 mm.; spines long, sloping or erect and scattered over the shell; ears bearing numerous spines. Brachial valve strongly concave; costellate throughout, with rugae on the ears and lateral margins; without spines; ears small and flattened.

Pedicle interior characteristic for the genus. Brachial interior with a low median septum; low, irregularly placed spines are present on the anteromedian part of the valve.

Measurements (in mm.) of a pedicle valve of *Cancrinella altissima* are as follows:

Length	14
Width	15

COMPARISONS: *Cancrinella altissima* is distinguished from other species of about the same age by its finer costellation, seven to 10 costellae in 3 mm. as compared with eight to 10 in 5 mm. for *C. rugosa* Cloud and five to seven in 5 mm. for *C. phosphatica* Girty.

DISCUSSION: The specimens in the present collection are indistinguishable from specimens collected in the Graham formation from which King obtained the types of *C. altissima*. That this species remained virtually unchanged during a time interval which sufficed for the production of a new species in *Lino-productus* is probably owing to exceptionally rapid evolution in the latter as it adopted a new, attached mode of life.

Cancrinella altissima is known from the Bone Spring formation of the west Texas Permian and from the Pennsylvanian Graham formation of north central Texas. The species probably lived in shallow waters on soft bottoms. It has not been found in reefs, and in west Texas probably lived in inter-reef areas.

MARGINIFERINAE STEHLI, NEW SUBFAMILY

DIAGNOSIS: Upper Paleozoic costate, costellate, or smooth, sparsely spinose, generally small Dictyoclostidae in which the posterior slope of the pedicle valve is flattened; brachial interior with a marginal ridge bounding the visceral disc.

DISCUSSION: This subfamily is clearly recognizable as a compact group ranging from the Mississippian to the Permian and attaining world-wide distribution. Its affinities are not clear, however, and it is placed provisionally in the Dictyoclostidae.

A host of small Productacea have been commonly referred to the genus *Marginifera* which do not, in fact, belong here. These are, for the most part, rather highly spinose forms usually lacking the marginal ridge. Further study may show that these forms compose a closely related subfamily.

As now proposed the Marginiferinae include the following genera: *Marginifera* Waagen, *Eomarginifera* Muir-Wood, and *Kozlowskia* Fredericks. Several other genera which may belong here but are not well known are *Spinomarginifera* Huang, *Paramarginifera* Fredericks, and *Pseudomarginifera* Stepanow.

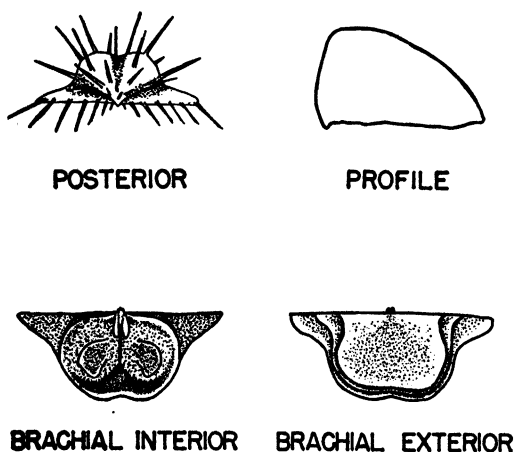
GENUS KOZLOWSKIA FREDERICKS, 1933

DIAGNOSIS: Pennsylvanian and Permian Marginiferinae having a row of cardinal spines but lacking a row above the ears; brachial valve with a lamellar fringe at the margin.

GENOTYPE: *Productus capaci* D'Orbigny.

DEFINITION: Shell small, highly transverse; greatest width at the hinge. Pedicle valve strongly convex, geniculate; posterior slope flattened, smooth or wrinkled; anterior slope faintly costellate; a row of cardinal spines is present, but the remainder of the valve bears only irregularly scattered spines; ears distinct and extended. Brachial valve geniculate; visceral area slightly concave, with the ears flattened; trail long, with traces of trails from younger growth stages forming a series of lamellae around the margin; valve without ornament or spines.

Pedicle interior with a sharp, striated ridge dividing the ears from the visceral area and sometimes encircling the valve; adductors elongate and raised on a platform, at either

FIG. 29. *Kozlowskia*.

side of which are the large, oval diductors. Brachial interior with a small cardinal process; marginal ridge encircling the visceral disc and paralleled anteriorly by a row of spines; adductor scars raised, elongate; a low median septum rises to a crest and often unites with the row of spines; brachial ridges usually present.

COMPARISONS: *Kozlowskia* differs from *Marginifera* in the presence of a row of cardinal spines, the absence of a row of spines above the ears, the presence of a marginal fringe of lamellae on the brachial exterior, and in the absence of the sharp flexure separating the ears from the visceral disc on the brachial exterior.

DISCUSSION: *Kozlowskia* is one of several genera which have been removed from the heterogeneous grouping to which the name *Marginifera* has been loosely applied. The genotype is a South American species, but the genus seems well represented in North America. It is known in the Pennsylvanian from such species as *K. splendans* (Norwood and Pratten) and *K. haydenensis* (Girty). It is also well represented in the late Paleozoic of the Soviet Union. The genus will probably be found to have a world-wide distribution as it becomes more widely known.

In west Texas the genus is present only in the lower part of the Permian section and has not been found above the Leonardian. Its life requirements are not known, but it has not been found in the reefs.

Kozlowskia kingi Stehli, new species

Plate 22, figures 6-11

DIAGNOSIS: Large, faintly costellate, slightly sulcate *Kozlowskia* of Leonardian age.

TYPES: Syntypes: A.M.N.H. Nos. 27304/1:1, 27304/2:1, 27304/1:2, 27304/2:2, and 27304/3:1; paratypes: A.M.N.H. Nos. 27304/1, 27304/2, and 27304/3; from localities 625, 628, and 629.

DEFINITION: Shell rather large for the genus and very strongly transverse. Pedicle valve with the posterior slope smooth or slightly wrinkled and much flattened; valve strongly geniculate; anterior slope evenly curved and sometimes bearing a sulcus which originates at the geniculation; ornamentation of the anterior slope consisting of indistinct costellae; ears very much extended and generally without spines; cardinal spines present and numbering four to six on either side of the beak; scattered, long, stout, erect spines are present over the valve. Brachial valve smooth or concentrically wrinkled on the visceral disc; trail long; traces of three to four old trails present around the margin of the visceral disc in adults; ears smooth, flattened or concave.

Pedicle interior generally with a strong, encircling, striate ridge and a well-developed adductor platform. Brachial interior characteristic for the genus.

COMPARISONS: *Kozlowskia kingi* differs

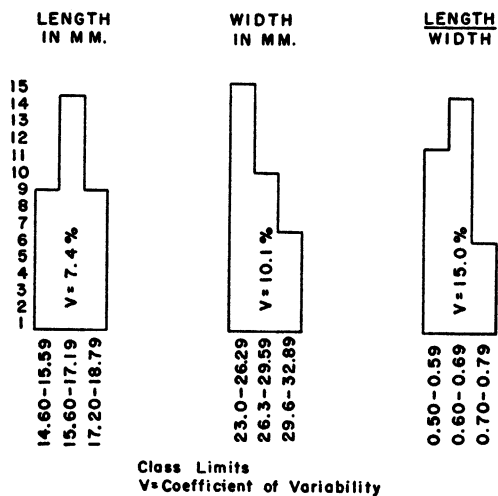


FIG. 30. Individual variation in *Kozlowskia kingi* Stehli, new species.

from the genotype in its much larger size, though there is little difference in ornamentation. It differs from *K. haydenensis* in having fainter costellation of the anterior slope of the pedicle valve. From *K. splendans* it is distinguished by its poorly developed sulcus.

DISCUSSION: *Kozlowskia kingi* is known only from the lower part of the Bone Spring formation in the Sierra Diablo and from the Hess formation in the Glass Mountains. Robert E. King (1930, p. 86) recognized *K. capaci* from the Wolfcamp of the Glass Mountains and the Gym of the Hueco Mountains. His specimens are poor, and adequate comparison with the present material is not possible.

PRODUCTACEA OF UNCERTAIN POSITION

DISCUSSION: The following two genera, *Psilonotus* and *Alexenia*, are placed here arbitrarily, as their affinities are not understood. *Psilonotus* belongs to the group of heavily spined and costate, small Productacea which have often erroneously been referred to *Marginifera* but which differ from that genus in lacking the marginal ridge and in the character of the spine pattern. *Alexenia* possesses a marginal ridge but differs strongly from the Marginiferinae in general shape and in spine pattern. *Psilonotus* and *Alexenia* do not appear to be closely related.

PSILONOTUS STEHLI, NEW GENUS

DIAGNOSIS: Small, costate, heavily spined, Pennsylvanian and Permian Productacea; brachial valve without spines; marginal ridge absent.

GENOTYPE: *Psilonotus transversalis* Stehli, new species.

DEFINITION: Pedicle valve of suboval to subquadrate outline, strongly convex; with or without a sulcus; beak somewhat flattened to slightly inflated; posterior slope usually flattened and smooth to slightly wrinkled, with the spines irregularly placed; ears distinct, short; anterior slope costate, with spines following the crests of the costae; an indistinct row of cardinal spines is often present. Brachial valve concave; visceral disc smooth or slightly wrinkled; trail costate; ears distinct; valve without spines.

Pedicle interior with the adductor scars elongate and usually inserted on a raised plat-

form; diductors large, oval, and flanking the adductors; ears sometimes set off from the visceral area by a low striated rim, especially in gerontic individuals. Brachial interior with a low cardinal process supported by cardinal ridges which curve anterolaterally and separate the ears from the visceral disc; a low median septum present, often rising to a crest anteriorly; adductor muscles inserted on elongate platforms; brachial ridges, when developed, rather angular; anterior part of the visceral disc with several rows of low spines.

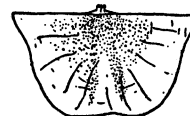
COMPARISONS: *Psilonotus* closely resembles an undescribed genus from the Glass Mountains, but may be readily distinguished by the absence of spines and pitted ornamentation on the brachial valve. Many species belonging to *Psilonotus* and closely related genera



PEDICLE EXTERIOR



BRACHIAL INTERIOR



BRACHIAL EXTERIOR

FIG. 31. *Psilonotus*.

have generally been placed in *Marginifera*. Their proper assignment, in the absence of specimens, remains uncertain.

DISCUSSION: *Psilonotus* is represented in the Permian of the Sierra Diablo by the two species described below. A third species, as yet undescribed, is present in the Glass Mountains. In the North American Pennsylvanian the genus may be represented by such a species as "*Marginifera missouriensis*," though it may belong to another genus if, as suggested by Dunbar and Condra (1932, pp. 222-223), it bears spines on the brachial valve. The genus has not been unquestionably recognized outside the west Texas Permian.

Psilonotus occurs in the Sierra Diablo and in the Glass Mountains and ranges from the Leonardian to the Guadalupian.

***Psilonotus transversalis* Stehli, new species**

Plate 22, figures 12-16

DIAGNOSIS: Large Leonardian *Psilonotus* of strongly transverse outline; costae moderately coarse.

TYPES: Syntypes: A.M.N.H. Nos. 27305/2:1, 27305/1:1, 27305/1:2, and 27305/1:3; paratypes: A.M.N.H. No. 27305/2; from localities 628 and 629.

DEFINITION: Shell rather large for the genus; subquadrate to suboval in outline; wider than long. Pedicle valve strongly convex and bearing a sulcus; posterior slope somewhat flattened and often finely wrinkled; anterior slope strongly costate, with six to seven costae in 10 mm.; ears distinct, short, wrinkled or smooth; spines long, strong, abundant, and following the costae where the latter are present. Brachial valve concave, usually bearing a low fold; visceral disc smooth or wrinkled; trail costate; ears smooth or wrinkled; without spines.

Interior of both valves characteristic for the genus, except that the brachial valve seldom shows either the ridge separating the ears or the brachial ridges save in gerontic individuals.

COMPARISONS: *Psilonotus transversalis* is

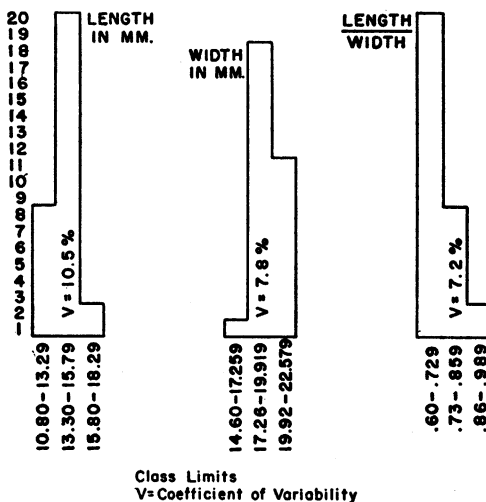


FIG. 32. Individual variation in *Psilonotus transversalis* Stehli, new species.

distinguished from *P. minimus*, new species, by its much more strongly transverse outline, coarser costation of the anterior slope of the pedicle valve, and the virtual absence of costation on the brachial valve. It differs from a second species in the Word formation of the Glass Mountains in being less coarsely costate and more transverse in outline.

DISCUSSION: *Psilonotus transversalis* has been found only in the lower Bone Spring formation of the Sierra Diablo at localities 628 and 629. It is abundant at locality 629 but is evidently mutually exclusive with *P. minimus* and is replaced by that species at locality 625.

The species probably did not live where it is found, because the two valves are rarely associated and the spines are generally broken. The species occurs also at locality 628 but is not common; however, almost all individuals bear long, little broken spines which suggests that this may have represented the preferred life environment.

***Psilonotus minimus* Stehli, new species**

Plate 22, figures 17-19

DIAGNOSIS: Small, finely costate, Leonardian *Psilonotus* in which the width is only slightly greater than the length.

TYPES: Syntypes: A.M.N.H. Nos. 27306/1:1 and 27306/1:2; paratypes: A.M.N.H. Nos. 27306/1 and 27306/2; from localities 625 and 631.

DEFINITION: Pedicle valve subcircular in outline; strongly convex, with a faint sulcus; posterior slope often somewhat flattened; anterior slope with seven to eight strong costae in 10 mm.; ears distinct, short, and generally smooth. Brachial valve strongly concave; fold low and often indistinct; costae strong, absent on the umbo.

The interiors of both valves essentially as described for the genus, but brachial ridges seldom developed.

COMPARISONS: *Psilonotus minimus* differs from *P. transversalis* in being much longer in proportion to its width, slightly more finely costate, and in having more distinct costation of the brachial valve. It differs from a species in the Glass Mountains in being smaller and more finely costate.

DISCUSSION: *Psilonotus minimus* has been

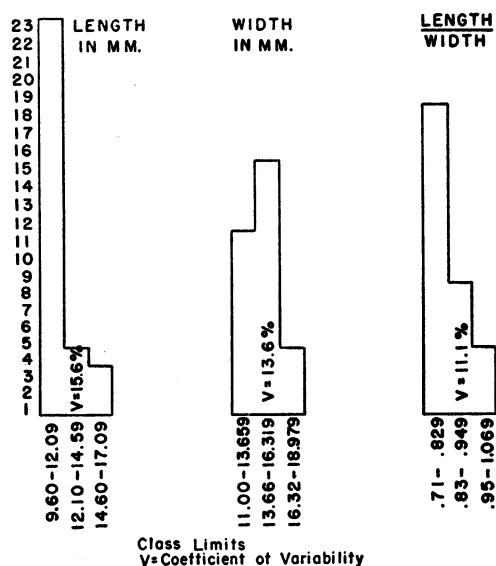


FIG. 33. Individual variation in *Pylonotus minimus* Stehli, new species.

found only at locality 625. It has not been found with *P. transversalis*, and the two may be mutually exclusive. The cause for this is not known.

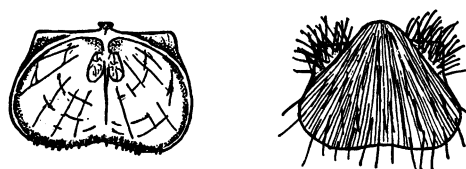
GENUS *ALEXENIA* ? IVANOV, 1935

DIAGNOSIS: Triangular Productacea of the Pennsylvanian and Permian; abundantly spinose; brachial interior with a marginal ridge.

GENOTYPE: *Alexenia reticulata* Ivanov.

DEFINITION: Medium-sized, late Paleozoic Productacea; strongly concavo-convex; subtrigonal in outline, exclusive of the ears. Pedicle valve with the beak inflated and strongly incurved; sulcus shallow; ears small, distinct, flattened, and bearing few to many spines; umbo somewhat reticulate, remainder of the valve costellate and irregularly spinose; trail long. Brachial valve geniculate; visceral portion rather flattened; ears flattened; fold low or absent; visceral disc reticulate; trail costellate; valve very finely and abundantly spinose.

Pedicle interior with the position of the muscle insertions uncertain. Brachial interior with a strong cardinal process, buttressed by a median ridge, running into the low median septum and by lateral ridges which at first parallel the hinge and then swing anteriorly



BRACHIAL INTERIOR PEDICLE EXTERIOR

FIG. 34. *Alexenia*.

to delimit the ears and lateral margins of the visceral disc; marginal ridge continuing across the front or not; adductor scars oval; brachial ridges located far forward.

COMPARISONS: *Alexenia* ? resembles *Marginifera* in the presence of a marginal ridge around the visceral disc of the brachial valve but differs in its subtriangular outline and abundant, fine spines.

DISCUSSION: *Alexenia* ? is present in both the Pennsylvanian and the Permian of the United States. "*Marginifera*" *lasallensis* is a well-known Pennsylvanian representative. Descriptions and illustrative material accompanying the publication of the genus (Ivanov, 1935) did not conclusively show *Alexenia* ? to be congeneric with "*Marginifera*" *lasallensis*. A recent paper (Sarycheva and Sokolskaya, 1952) strongly suggests that the latter should be placed in the genus *Alexenia* ?.

The presence of the genus in both the reefless strata of the mid-continent region and the reef-bearing strata of west Texas suggests that its representatives may have occupied the relatively quiet waters and soft bottoms of the inter-reef areas.

Alexenia ? *parvispinosa* Stehli, new species

Plate 22, figures 20-22; plate 23, figures 1, 2

DIAGNOSIS: Leonardian *Alexenia* ? with uniformly fine spines.

TYPES: A.M.N.H. No. 27307; from locality 625.

DEFINITION: Shell of medium size for the genus; wider than long and of subtrigonal outline exclusive of the ears. Pedicle valve with the beak inflated and strongly incurved; sulcus well developed; ears distinct, flattened, and strongly but finely spinose; umbo sometimes indistinctly reticulate; remainder of the shell with eight to 12 costellae in 10 mm.; spines anteriorly directed but becoming more

erect towards the front. Brachial valve geniculate, with the flattened visceral disc slightly reticulate and the trail costellate; ears flattened and more or less smooth; valve abundantly and very finely spinose.

Pedicle interior with the muscle scars faint or absent. Brachial interior with the marginal ridge not completely encircling the visceral disc, its place being taken at the front by several irregular rows of spines.

Measurements (in mm.) of *Alexenia parvispinosa* are as follows:

Length	23	24	25
Width	28	33	22
Depth of pedicle valve	15	16	16

COMPARISONS: *Alexenia* ? *parvispinosa* differs from the genotype in its more numerous fine spines, lack of much enlarged spines forward of the ears and at the front, less conspicuous reticulation of the umbo, and the failure of the marginal ridge to continue unbroken across the front of the visceral disc. It is distinguished from "*Marginifera*" *lasallensis* (Worthen) by its finer costellation and probably by details of the spine development which are unknown for "*M.*" *lasallensis*.

DISCUSSION: *Alexenia* ? *parvispinosa* is known only from the lower Bone Spring formation in the Sierra Diablo. It has been found only at locality 625. Most specimens are badly worn and are without spines or ears; however, a few specimens in very good shape suggest that the animal may have lived either here or in a near-by area and that the worn specimens are those brought in from more distant areas by currents.

ECHINOCONCHIDAE STEHLI, NEW FAMILY

DIAGNOSIS: Upper Paleozoic Productacea in which the body of the shell is abundantly spinose; spines of one or two sizes and usually concentrically or quincuncially arranged; interarea absent. Brachial interior with the cardinal process elongate and usually lying in or nearly in the plane of the valve.

DISCUSSION: The Echinoconchidae range from the Mississippian to the end of the Permian. The family at present includes: *Echinoconchus* Weller; *Juresania* Fredericks; *Pustula* Thomas; *Waagenoconcha* Chao; *Overtonia* Thomas; *Ramavectus*, new genus; and

probably other genera. It may be possible, as relationships become better known, to distinguish several subfamilies within the group.

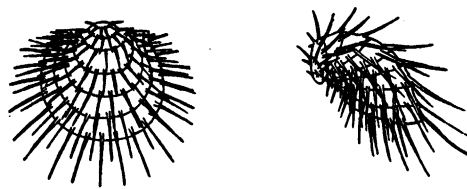
GENUS OVERTONIA THOMAS, 1914

DIAGNOSIS: Small Mississippian to Permian Echinoconchidae with concentric rows of single spines; brachial ridges at 45 degrees to the hinge.

GENOTYPE: *Producta fimbriata* Sowerby.

DEFINITION: Shell subcircular to ovate in outline; as long as or longer than wide, with the greatest width forward of the hinge. Pedicle valve strongly convex and ornamented with concentric ridges, each bearing at the posterior margin a single row of long, forward-directed spines; beak much inflated and strongly incurved; ears small, slightly flattened. Brachial valve concave; ornamented with concentric single rows of spines.

Pedicle interior with the muscle placement uncertain. Brachial interior with a strong, deeply trifid cardinal process; median septum low and rising to a crest at its anterior end; adductor muscle scars located on either side of the septum just forward of the base of the cardinal process; brachial ridges extending



PEDICLE EXTERIOR

PROFILE

FIG. 35. *Overtonia*.

into the valve at about 45 degrees to the hinge; anterior two-thirds of the valve bearing scattered low spines.

COMPARISONS: *Overtonia* is distinguished from closely related genera by its spine pattern. It most nearly resembles *Pustula*, from which it differs in its generally smaller size, more regular spine pattern, and in the oblique placement of the brachial ridges. It differs from *Echinoconchus* in generally smaller size and in having all the spines in a row of the same size.

DISCUSSION: *Overtonia* seems never to be an abundant genus, but it achieved a world-

wide distribution. It ranges from the Mississippian to the Permian. In west Texas it seems to be limited to the lower part of the Permian section. The genus is also present in north central Texas, and occurrence suggests that it was not a reef inhabitant but an animal which preferred areas of quieter water. It probably lived in the inter-reef areas.

Overtonia plummeri King

Plate 23, figures 5-7

Overtonia cristato-tuberculata R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 82, pl. 20, figs. 1-3.

Overtonia plummeri R. H. KING, 1938, Jour. Paleont., vol. 12, pp. 276-277, pl. 39, figs. 19-22.

DIAGNOSIS: Upper Pennsylvanian and lower Permian *Overtonia* of small size in which there are 15 to 25 spines in each row.

DEFINITION: Shell small for the genus and of subcircular outline. Pedicle valve highly arched; beak inflated and strongly incurved; ears small and slightly flattened; valve ornamented by concentric ridges about 2 mm. apart and each bearing on its posterior margin a single row of 15 to 25 evenly spaced, long, anteriorly directed spines; the number of spines in each row seems to remain rather constant in an individual. Brachial valve strongly concave, with small, flattened ears; ornament consisting of concentric, single rows of very fine spines intercalated between fine lamellae.

The interiors of both valves are characteristic of the genus. Brachial interior with the cardinal process appearing almost two pronged; muscle scars elongate and extending to one-third of the length of the valve.

Measurements (in mm.) of pedicle valves of *Overtonia plummeri* are as follows:

Length	7.7	6.8	8.3
Width	8.6	7.5	7.8
Spines in 5 mm. on front row	7.0	5.0	7.0
Distance between last two rows of spines	2.0	2.0	2.2

COMPARISONS: *Overtonia plummeri* is distinguished from the genotype by its much smaller size and more closely placed rows of spines. It differs from *O. cristato-tuberculata* Koslowski in having 15 to 25 spines in each row as compared with nine to 11 for that species.

DISCUSSION: Robert E. King (1931) referred specimens of *Overtonia* from the Wolfcamp formation of the Glass Mountains to the South American species *O. cristato-tuberculata*. Ralph H. King (1938) has noted that the specimens from the Glass Mountains were not referable to that species but expressed some reservations as to their placement in *O. plummeri*. Specimens of the genus in the present collection seem to agree with *O. plummeri* in all details except size; however, they are only slightly smaller.

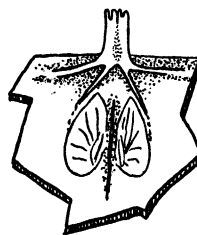
Overtonia plummeri is known from the Graham formation of north central Texas, the Wolfcamp formation of the Glass Mountains, and the lower part of the Bone Spring formation of the Sierra Diablo.

RAMAVECTUS STEHLI, NEW GENUS

DIAGNOSIS: Large Permian (at least) Echinoconchidae in which the cardinal process is buttressed by four supporting plates, two along the hinge and two diverging into the valve.

GENOTYPE: *Ramavectus diabloensis* Stehli, new species.

DEFINITION: Pedicle valve unknown. Brachial valve subquadrate, with a low fold; hinge nearly equal to the greatest width; abundant spines irregularly arranged, flat-lying and of two sizes. Brachial interior with a strong cardinal process supported by cardinal ridges along the hinge and by two buttressing plates which diverge into the valve; adductor scars located between these two



BRACHIAL INTERIOR

FIG. 36. *Ramavectus*.

plates and on either side of the low median septum.

COMPARISONS: The nature of the supporting plates of the cardinal process readily distinguishes this genus from others of the family.

The supporting plates of the cardinal process in *Buxtonia* split in a somewhat similar manner but are then reunited. Certain species assigned to *Juresania*, such as *J. nebrascensis*, show a rudimentary splitting of the supporting plates and are probably closely related to *Ramavectus*. *Juresania* is distinguished from *Ramavectus* by the concentric arrangement of spines.

DISCUSSION: This genus is known only from the lower Bone Spring formation at locality 625 in the Sierra Diablo. It is represented by fragmentary material and the pedicle valve is unknown. It is hoped that further collecting in the west Texas Permian will produce more complete specimens.

***Ramavectus diabloensis* Stehli, new species**

Plate 23, figures 3, 4

TYPES: A.M.N.H. No. 27308; from locality 625.

DEFINITION: Pedicle valve unknown. Brachial valve concave, with a distinct, rounded fold; ears indistinct and very small; hinge slightly less than the greatest width of the shell; ornamentation consisting of irregularly arranged, flat-lying spines of two sizes. Brachial interior with a strong cardinal process which is posteriorly directed and deeply grooved; cardinal process supported by cardinal ridges and diverging plates; median septum low; anterior part of the shell with low and irregularly placed spines.

DISCUSSION: In the present material no pedicle valves have been found which can be definitely said to belong to this species. Several fragmentary pedicle valves belonging to this family but not to other known genera are present and may belong to *R. diabloensis*. They are characterized by having spines of two sizes which lack concentric arrangement, by showing a cicatrix of attachment at the beak, and by the development of a dense tuft of attachment spines on the short, indistinct ears.

FAMILY STROPHALOSIIDAE

DISCUSSION: This family name appears in the 1948 volume of the Zoological Record but the author is not given. Search of earlier volumes failed to reveal any citation of either the name or its author.

GENUS HETERALOSIA KING, 1938

DIAGNOSIS: Pennsylvanian and Permian Strophalosiidae in which the interior of the pedicle valve bears hinge teeth; brachial valve without spines.

GENOTYPE: *Heteralosia slocomi* King.

DEFINITION: Small Strophalosiidae of sub-circular to transversely suboval outline. Pedicle valve of low to strong convexity; beak with a strong cicatrix of attachment; interarea low; spines on the posterior portion of the valve directed towards the beak and used in attachment; anteriorly the spines directed forward and lying flat against the shell. Brachial valve concave; interarea low; valve without spines.

Pedicle interior with the adductor scars small, elongate; diductor scars lateral to the adductors and oval in shape; hinge teeth strong. Brachial interior with a high, erect cardinal process; median septum low; sockets



PEDICLE INTERIOR



FRONT

FIG. 37. *Heteralosia*.

deep and located on either side of the cardinal process; adductor scars small and oval.

COMPARISON: *Heteralosia* is distinguished from *Strophalosia* by the absence of spines on the brachial valve.

DISCUSSION: *Heteralosia* attained worldwide, though spotty, distribution during the Permian and occurs in North America, Eurasia, and Australia. The genus seems to have been flexible in its habitat requirements, for it occurs in association with the west Texas reefs as well as in the strata of north central Texas.

***Heteralosia* sp.**

Plate 23, figures 13, 14

DISCUSSION: A single pedicle valve in the present material seems to belong to *Heteralosia*, though in the absence of the brachial valve it is not possible to determine definitely whether it belongs to *Heteralosia* or *Strophalosia*. It appears most closely to re-

semble *Heteralosia hystricula* (Girty) and is therefore tentatively referred to this genus.

LIMBELLA STEHLI, NEW GENUS

DIAGNOSIS: Medium to large Wolfcampian and Leonardian Strophalosiidae in which hinge teeth are absent; brachial valve without spines.

GENOTYPE: *Aulosteges wolfcampensis* King.

DEFINITION: Pedicle valve subcircular in outline, of moderate convexity and bearing a shallow sulcus and in adults a recurved marginal skirt; ears bearing stout anchoring spines; remainder of the valve with frequent, irregularly spaced spines of moderate size; beak bearing a cicatrix of attachment; inter-area low but well developed; delthyrium partly closed by a thin plate which is seldom preserved. Brachial valve concave, slightly flattened on the ears; ornamented with roughly concentric wrinkles and pits; faintly to strongly costellate; without spines.

Pedicle interior with the adductor scars, together, forming an oval scar indicating the insertion of four muscles; diductor scars large and oval, located on either side of, and somewhat anterior to, the adductors. Brachial interior with a stout cardinal process buttressed at either side by a large ridge parallel to the hinge and by an anteriorly directed ridge which gives rise to a low median sep-

size, and in the placement and character of the spines. It may be distinguished from *Heteralosia* King by the absence of spines on the brachial valve.

DISCUSSION: *Limbella* is represented by two species, the genotype and a new species described below. It is known from the Wolfcamp formation of the Glass Mountains and from the Bone Spring formation of the Sierra Diablo.

These animals were in life fastened to the substratum. Initial attachment was by direct cementation of the pedicle beak, but at an early stage in ontogeny this was augmented by the growth of large anchoring spines from the ears. These spines were used to entangle the object of attachment. Like most shells which adopted this rigid mode of attachment, *Limbella* probably lived in strongly agitated waters either on reefs or on rocky shores. Unlike many of the other attached forms in this fauna *Limbella* has not been found to show signs of attachment to crinoids, and the rather massive shell may have been too heavy for this mode of life.

***Limbella victorioensis* Stehli, new species**

Plate 23, figures 8-12

DIAGNOSIS: Leonardian *Limbella* in which the brachial valve bears very faint costellae or none at all, while the pedicle valve lacks costellae completely.

TYPES: A.M.N.H. No. 27310; from locality 629.

DEFINITION: Shell irregularly subhemispherical but often rather symmetrical. Pedicle valve more or less evenly convex; sometimes with a faint sulcus; beak more or less flattened, sometimes slightly incurved; inter-area low, usually lying in the plane of commissure; ears convex, not distinctly set off and bearing crowded anchoring spines which become coarser away from the beak; ornamented with a few irregular growth wrinkles and with scattered fine spines which lie against the shell posteriorly while towards the front they are stout, erect, and often give rise to low, rounded costae at their bases; marginal skirt well developed at the anterior and lateral margins and strongly recurved. Brachial valve concave and sometimes bearing a low fold; ears flattened and indistinct; ornamentation consisting of concentric wrin-

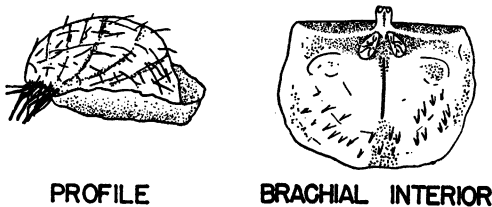


FIG. 38. *Limbella*.

tum; adductor scars raised, large, oval, and placed at the base of the cardinal process; low spines present at the anterior margin of the visceral disc; brachial ridges rarely distinct.

COMPARISONS: *Limbella* differs from *Aulosteges* Heltersen in its low area and the presence of ears bearing stout anchoring spines, the few and scattered spines on the remainder of the valve, the recurved front, and the absence of spines on the brachial valve. It differs from *Strophalosia* King in lacking hinge teeth, in being of much larger

kles and rows of irregular pits, and in a few very well-preserved specimens, fine but indistinct costellae.

The interiors of both valves are characteristic for the genus.

Measurements (in mm.) of pedicle valves of *Limbella victorioensis* are as follows:

Length	29	32	46	52
Width	34	38	38	35
Depth of valve	11	16	—	—

COMPARISONS: *Limbella victorioensis* differs from *L. wolcampensis* in lesser development of the costellate ornamentation which is strong in the latter.

DISCUSSION: *Limbella victorioensis* has been found only at locality 629. All specimens have their valves dissociated, but as the pedicle valve was attached rigidly to the substratum, this probably does not indicate severe transportation. The fact that both the pedicle and brachial valves, though of very different shape, are found at the same locality argues against much transporting by currents. The species probably lived attached to reefs and to rocks on the bottom of inter-reef areas.

FAMILY RICHTHOFENIDAE WAAGEN, 1885

DIAGNOSIS: Aberrant Pennsylvanian and Permian Productacea in which the pedicle valve is a deep cone; brachial valve operculiform and located within the pedicle cone.

DISCUSSION: The Richthofenidae clearly represent an extreme specialization of the productid stock. The relationship is demonstrated by the presence of spines and brachial ridges of productid form. The conical shape of the shell is one adopted by many groups of sessile animals. Among the brachiopods it occurs in the Orthotetacea, Scacchinellidae, Gemmellarioiidae, and the Richthofenidae. Concomitant with the development of a conical pedicle valve is development of an operculiform brachial valve. The main evolutionary developments of the Richthofenidae have been concerned with the gradual abandonment of an orthodox productid shape and the acquisition of the conical form.

The family probably separated from other productid stocks in the early Pennsylvanian, for in the upper Pennsylvanian primitive teguliferinid genera are widespread. The teguliferinids are considerably less special-

ized than the later forms such as *Richthofenia* and *Prorichthofenia*, for the brachial valve is still attached in a basal position within the pedicle cone, and there is little development of the internal "area" formed in later genera by the upward migration of the brachial valve.

Among the more advanced forms, representatives of the genus *Richthofenia* seem to be limited to Eurasia, though there is a good possibility that further study of the Permian of Alaska and the west coasts of Canada and the United States will disclose its presence. *Prorichthofenia* is found both in Eurasia and North America, though it seems to find its primary development in the latter area.

The west Texas Permian has been found to contain a great variety of species of Richthofenidae and several new genera are present as well. It is evident that the Richthofenidae are a much larger family than has generally been realized.

GENUS TEGULIFERINA SCHUCHERT AND LEVENE, 1929

GENOTYPE: *Tegulifera deformis* Schellwein.

DISCUSSION: *Teguliferina* is poorly known and has apparently been used to include several groups of primitive richthofenids. Schellwein's original description fails to make clear several points which now appear critical in generic determinations. Repeated attempts to obtain authentic specimens of the genotype have been unsuccessful, so its characters remain inadequately known. Two genera in the present collection belong to this group. One, *Planispina*, differs in so many details from *Teguliferina* that it is certainly generically distinct. The other genus is also probably distinct but the material is so much better than the original material of the genus that satisfactory comparison is impossible, so is referred questionably to *Teguliferina*.

Teguliferina ? *teguliferoides* (King)

Plate 24, figures 5-8

Prorichthofenia teguliferoides R. E. KING, 1930, Univ. Texas Bull., no. 3042, pp. 99-100, pl. 30, figs. 2-7.

DIAGNOSIS: Small, squat, Wolfcampian and Leonardian Richthofenidae; pedicle valve bearing abundant round spines.

DEFINITION: Pedicle valve a very shallow

cone, usually somewhat asymmetrical owing to cementation of the umbo; anchoring spines borne on all parts of the valve; posterior margin formed by a flattened, anteriorly inclined, papillose hood; anterior margin with irregular, stout, posteriorly inclined spines. Brachial valve reduced, operculiform, and seated deep in the pedicle cone so that articulation is in the umbo and the valve lies at an angle in the pedicle cone; valve pear-shaped in outline, with the posteriorly projecting tongue terminated by a short, straight hinge; surface papillose.

Pedicle interior with a very low but otherwise well-developed "area" in the umbo. Brachial interior with a low median ridge buttressing a bifid cardinal process; adductor scars present on either side of the ridge; brachial ridges of productid type sometimes present; anterior margin bearing several low spines.

COMPARISONS: This species differs from species of the genus *Planispina* in the absence of flattened spines and in the simple nature of the cone. Its relationships to the genotype of *Teguliferina* are uncertain, as it is unknown, for example, whether or not *Teguliferina deformis* bears spines around the margin of the cone.

DISCUSSION: Robert E. King (1930, pp. 99-100) assigned this species to his genus *Prorichthofenia* because of the presence in the umbo of the pedicle valve of a small "area" and stated that were it not for this feature he would have placed it in *Teguliferina*. Schellwein (1900, pl. 6, fig. 7c) figures a specimen which clearly shows that the same kind of elementary "area" is present in the genotype.

Teguliferina ? *teguliferoides* is limited to the lower part of the Permian section in west Texas, is unknown from rocks younger than the Leonardian, and unknown outside the west Texas area. The species is strongly attached to the substratum and, while it is found fastened to shells of other brachiopods and may have lived occasionally in the inter-reef areas, it is believed that the animal was primarily a dweller in the agitated waters of reefs or near-shore areas.

PLANISPINA STEHLI, NEW GENUS

DIAGNOSIS: Primitive, flat-spined, Wolfcampian and Leonardian Richthofenidae.

GENOTYPE: *Planispina conida* Stehli, new species.

DEFINITION: Small to moderate in size. Pedicle valve a shallow to moderately deep, round-bottomed cone; spines round at the umbo but elsewhere modified into flat anastomosing plates; posterior side of the cone formed by a flattened, anteriorly inclined, papillose hood; anterior margin with stout, posteriorly inclined spines which arise at the inner edge of a projecting, marginal lip. Brachial valve operculiform, almost flat, and ornamented by fine papillae; more or less elliptical in outline with a posteriorly projecting tongue terminating in a short, straight hinge; valve articulated near the umbo of the pedicle valve so that it lies at an angle in the cone.

Pedicle interior with a very short internal "area" formed by the upward migration of the articulation; with a narrow shelf on which the brachial valve rests; muscles inserted on a slight ridge at the base of the cone. Brachial interior with a small bifid cardinal process buttressed by a low, median ridge; adductors inserted on either side of this ridge; a few long, anteriorly directed spines present at the front of the valve; brachial ridges generally indistinct.

COMPARISONS: *Planispina* is distinguished from the highly advanced genera *Richtho-*



GROWTH POSITION

ENLARGED SPINE
CROSS SECTION

FIG. 39. *Planispina*.

fenia and *Prorichthofenia* by the absence of a high, internal "area" and by the tipped position of the brachial valve within the pedicle cone. It is distinguished from other primitive genera in the west Texas Permian by the possession of flattened spines.

DISCUSSION: *Planispina* occurs in Wolfcampian and Leonardian strata in the west Texas region but has not been noted else-

where. In the absence of silicified material showing the flattened spines and details of structure and ornamentation the genus may prove difficult to recognize.

***Planispina conida* Stehli, new species**

Plate 24, figures 9-13

DEFINITION: Shell of moderate size. Pedicle valve attached by direct cementation of the umbo and by anchoring spines; earliest spines round and slender, later ones flat; front of the cone with a conspicuous, projecting papillose lip which develops only when the shell is of considerable size; once a lip has developed, further growth results in another lip higher on the cone, so that mature shells have the appearance of nested cones; spines absent above the first lip; stout, irregular, posteriorly directed spines arise from the inner margin of the lip and may bifurcate or anastomose; posterior side of the cone flattened and hood-like, papillose but not spinose. Brachial valve nearly flat to strongly concave; more or less pear-shaped in outline; surface papillose; valve placed deep in the pedicle cone, and hinged almost in the umbo so that its position in the valve is not horizontal but tipped upward towards the front.

Pedicle interior with the internal "area" very low and rudimentary; large shells show a slightly raised muscle platform in front of the umbo which is suggestive of the median ridge of *Prorichthofenia*, but still poorly developed. Brachial interior with the cardinal process slightly expanded at the end; a low median ridge buttresses the cardinal process and there is a muscle area at either side; anterior of the valve with forward-directed spines; a short median septum may develop just behind the spines and may be high or low and indistinct.

DISCUSSION: *Planispina* is strongly attached to the substratum and was well adapted for life in areas of strong currents. It seems to have lived mainly in reefs or along rocky shores, though it could live in any place in shallow water which afforded adequate attachment sites.

GENUS PRORICHTHOFENIA KING, 1930

DIAGNOSIS: Highly specialized, deeply conical, Leonardian to Guadalupian Richtho-

fenidae; brachial valve lying horizontally in the pedicle cone; margin of pedicle valve bearing spines.

GENOTYPE: *Crania permiana* Shumard.

DEFINITION: Pedicle valve a deep cone, attached by scattered spines near the base and by direct cementation of the umbo; ornamentation consisting of numerous growth wrinkles; posterior side of the cone at the top formed by a low, flattened hood which is slightly inclined anteriorly; stout spines are present around the margin of the cone and are inclined towards the middle of the valve. Brachial valve nearly flat and located deep within the pedicle cone; transversely oval in outline, with a posteriorly projecting tongue terminating in a short hinge; valve devoid of ornamentation.

Pedicle interior with a high, well-developed "area" and a low, broad median ridge for muscle attachment on the anterior side near the apex of the cone. Brachial interior with a low, two-pronged cardinal process; median septum low or absent; adductor muscles inserted on a raised area on either side of the median line forward of the cardinal process; spines sparingly present along the anterior margin of the valve; brachial ridges productoid but rarely observed.

COMPARISONS: *Prorichthofenia* is distinguished from the Eurasian genus *Richthofenia* Kayser by the absence of a myophore chamber along the "area." It is distinguished from both *Planispina* and *Teguliferina* ? by its high internal "area" and by the horizontal position of the brachial valve in the pedicle cone.

DISCUSSION: *Prorichthofenia* is absent in the Wolfcampian where its place is taken by more primitive genera, but it is abundant in Leonardian and younger Permian rocks. As used by R. E. King (1930) the genus is polyphyletic and needs revision.

***Prorichthofenia* sp.**

DISCUSSION: Fragmentary material clearly showing the characters of *Prorichthofenia* is present in material from the lower Bone Spring formation of the Sierra Diablo. The fragmentary condition in which the genus is always represented suggests that the remains were washed into the area from some other environment. It is interesting to note that

the highly specialized and the primitive richthofenids existed at the same time and that the separation of the two stocks was apparently environmental.

FAMILY SCACCHINELLIDAE WILLIAMS, 1953

DIAGNOSIS: Aberrant Permian Productacea in which the pedicle valve is a deep cone; brachial valve operculiform and capping the cone; pedicle interior with a median septum; brachial interior with a large two-pronged cardinal process.

DISCUSSION: Licharew (1928) erected the subfamily Scacchinellinae for the reception of *Scacchinella*. He regarded the genus as a productid and placed it in the Productidae. Elevation of the Productidae to superfamily rank required the elevation of the Scacchinellinae to family rank. This has been recently given them by Williams.

The relationships of *Scacchinella* have sometimes been misunderstood, and it has been placed, as by Williams (1953), with the Orthotetacea. Evidence indicating relationship to the Productacea rather than to the Orthotetacea is: the presence of spines; the presence of brachial ridges of productid type; the absence of a perideltidial area; the absence of radial ornamentation; and the absence of hinge teeth and sockets.

GENUS SCACCHINELLA GEMMELLARO, 1896

GENOTYPE: *Scacchinella variabilis* Gemmellaro.

DEFINITION: Medium- to large-sized, aberrant Permian Productacea. Pedicle valve a deep cone, flattened on one side by a broad, high interarea which is longitudinally striated and bears a low, indistinct deltidium; valve attached to the substratum by direct cementation at the beak and by stout anchoring spines; fine, anteriorly directed spines also present; irregular growth wrinkles abundant. Brachial valve slightly to moderately convex; ornamented with short, blunt spines and forming a lid to the cone of the pedicle valve.

Pedicle interior with a strong, high, median septum; tabulae may be present, especially in large shells, near the base of the cone; muscular insertions located on the septum. Brachial interior with a large, two-pronged cardinal process; anterior to each prong is a

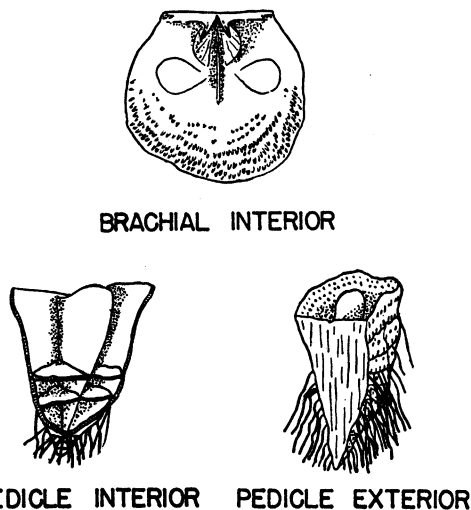


FIG. 40. *Scacchinella*.

raised and medially inclined muscle platform bearing the adductor scars; median septum low and rising between the muscle platforms near their anterior ends; low brachial ridges of productid type are present.

COMPARISONS: A well-preserved specimen of *Scacchinella* would be difficult to confuse with any other known genus. In poorly preserved material the shells might be mistaken for genera belonging to several groups of brachiopods. It may be distinguished from the Orthotetacea by its lack of radial ornamentation, absence of a distinct deltidium, presence of spines, and in most cases the deeper pedicle valve. It is separated from the Richthofenidae by the presence of the broad interarea and by the position of the brachial valve at the top rather than deep within the pedicle cone. It differs from the Gemmellaroidae by the absence of a raised, angular ridge on the outside of the pedicle valve and by the absence of the peculiar longitudinal partitioning of the shell wall.

DISCUSSION: The stratigraphic range of *Scacchinella* seems to be limited in North America to the Wolfcampian and lower Leonardian. In Eurasia, however, it has been reported from the upper Permian. Its geographic range is wide but erratic, with the genus occurring in Texas, Sicily, the Caucasus, the Carnic Alps, the Urals, and Japan.

These animals were evidently adapted for life in areas of considerable current, but do

not seem to have been primarily reef dwellers. They are frequently found attached to large shells and show a preference for somewhat conglomeratic rocks including those composed largely of organic debris. They are quite strongly gregarious and form large clumps when growing in advantageous locations.

***Scacchinella americana* Stehli, new species**

Plate 23, figures 15, 16; plate 24, figures 1-4

DIAGNOSIS: Small Wolfcampian and Leonardian *Scacchinella* bearing a row of spines along the margin of the interarea; pedicle interior with tabulae; brachial interior with a median septum.

TYPES: Syntypes: A.M.N.H. Nos. 27311/1:1, 27311/1:2, 27311/1:3, and 27311/1:4; paratypes: A.M.N.H. Nos. 27311/1, 27311/2, and 27311/3; from localities 625, 628, and 631.

DEFINITION: Shell of small to moderate size for the genus; shape variable, usually somewhat asymmetrical owing to attachment. Pedicle valve a rapidly expanding cone; interarea one-half to two-thirds of the width of the shell; numerous growth wrinkles present along which the spines are placed in a faintly concentric pattern; heavy anchoring spines predominate near the base of the cone, but persist to the top where hair-like, anteriorly directed spines are more common; margins of the interarea usually ornamented with one, or sometimes more, rows of stout spines. Brachial valve usually convex but with a tendency, especially in large shells, towards concavity near the front; surface wrinkled by concentric growth lines and bearing numerous short spines which are irregularly distributed; brachial interarea obsolete.

Pedicle interior with the median septum attached to the posterior wall of the cone and free of the anterior side except at the base; septum often higher than the valve so that it rises into the hollow of the brachial valve; apex of the cone progressively sealed by tabulae. Brachial interior with a very strong cardinal process composed of two long, divergent prongs with muscle grooves along their posterior faces; inclined platforms bearing sculptured adductor scars arise near the base of the cardinal process and run forward

one-fourth to one-third of the length of the valve; median septum low and extending to mid length; low spines present along the anterior margin of the valve; posterolateral extremity of the valve grooved so as to form a shallow articular fossette.

Measurements (in mm.) of *Scacchinella americana* are as follows:

Length, hinge to front	32	30	31
Width	37	42	30
Thickness	26	35	39

COMPARISONS: The preservation of the specimens in the present collection is superior to that of material previously described, and adequate comparison has not been possible. For this reason the writer believes it better to establish a new species based on this excellent material than to attempt reference to described species.

DISCUSSION: Robert E. King (1930) first recognized *Scacchinella* in the Texas Permian and referred his specimens to *S. gigantia* Schellwein. King's specimens may in part belong to *S. americana*, but they also consist in part of an exceptionally large species found in the Glass Mountains. That none is *S. gigantia* is likely on theoretical grounds alone, as that species is found in the Carnic Alps. Unfortunately specimens of that species examined by the writer are decorticated and cannot be adequately compared with the Texas material.

Scacchinella americana occurs in the Bone Spring formation of the Sierra Diablo and in the Wolfcampian of the Chinati Mountains. It is probably present in the Glass Mountains as well.

SUPERFAMILY RHYNCHONELLACEA SCHUCHERT, 1896

DIAGNOSIS: Impunctate, middle Ordovician to Recent Brachiopoda with recurved crura; hinge short; shell usually costate.

FAMILY CAMAROTOECHIIDAE SCHUCHERT, 1929

GENUS WELLERELLA DUNBAR AND CONDRA, 1932

DIAGNOSIS: Upper Paleozoic Camarotoechiidae in which the hinge plate is supported by a short median septum or in which a septum is lacking; costae not reaching the umbo.

GENOTYPE: *Wellerella tetrahedra* Dunbar and Condra.

DEFINITION: Shell uniplicate and small to medium in size. Pedicle valve moderately to strongly convex; beak usually elongate but not strongly incurved; sulcus generally strong but highly variable. Brachial valve convex; fold variable but usually strong. Both valves are costate at the front and tend to become smooth towards the umbones.

Pedicle interior with strong dental plates supporting small hinge teeth; placement of the muscles unknown. Brachial interior with the hinge plate entire and bounded laterally by a deep socket and socket plates; median septum located in the apex of the valve but variable in its development; long recurved crura descend into the pedicle valve from the front of the hinge plate; anterior ad-

especially in gerontic individuals. It is probable that the genus is polyphyletic.

Wellerella was apparently a very successful genus in the Pennsylvanian and Permian and is represented by a host of species, most of which are small forms, though a few attained considerable size. Unfortunately many of the Permian forms have not been adequately described or figured, and little emphasis has been accorded to the extreme variability of many species. For this reason many of the species now recognized will probably eventually be relegated to synonymy.

The habitat and life requirements of *Wellerella* are unknown, but it seems probable that it lived in sheltered places between or under boulders and in pockets in the reefs. Its distribution in reefy as well as reefless strata make it clear that it inhabited the reef environment only casually.

Wellerella elgans ? (Girty)

Plate 25, figures 13-17

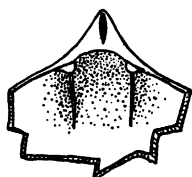
DEFINITION: Shell large for the genus, subtriangular to subpentagonal, very much wider than long, with the greatest width at or forward of mid length. Pedicle valve with the beak relatively short, pointed and inflated, not incurved; sulcus strong, developing near mid length and projected upward at the front as a tongue; valve strongly and evenly convex from the beak to the front along the sulcus but only slightly convex to nearly flat from the beak to the front at either side of the sulcus. Brachial valve with the beak hidden beneath that of the other valve; umbo flattened and sometimes slightly depressed medially; fold strong, beginning near mid length and becoming increasingly prominent towards the front. Both valves are ornamented with strong costae; fold and sulcus with two to five high, angular costae; lateral slopes with two to four rather low and rounded costae; umbones smooth, with the costae of the fold and sulcus approaching them more closely than those of the lateral slopes.

Pedicle interior characteristic of the genus. Brachial interior with a minute median septum or none at all.

Measurements (in mm.) of *Wellerella elgans* ? are as follows:



PROFILE



BRACHIAL INTERIOR

PEDICLE INTERIOR

FIG. 41. *Wellerella*.

ductors large and oval; posterior adductors small, elongate, and diagonally placed.

COMPARISONS: *Wellerella* is distinguished from other late Paleozoic Rhynchonellacea by its smooth umbones, undivided hinge plate, and short or obsolete median septum.

DISCUSSION: Dunbar and Condra (1932, p. 287) have noted the presence in *Wellerella* of a low median septum in the apex of the brachial beak. In specimens here assigned to the genus this character is variable and there may be no median septum, a minute one, or a low, rounded ridge representing the septum,

Length	15	14	13	18	17
Width	20	19	15	26	21
Thickness	11	12	9	17	16

COMPARISONS: This species differs from most others available for comparison in being much larger. It is distinguished from *W. mesocostalis* (Girty), which approaches it in size, by the normal development of the median costa of the fold. It differs from *W. shumardiana* (Girty) in being more strongly transverse in adult shells, in the flattening of the umbo of the brachial valve, and in its deeper sulcus.

DISCUSSION: This species is similar to the types of *W. elegans* but differs in being of larger size and in having more and stronger costae on the lateral slopes. It is considered probable that the present specimens are ecological variants of *W. elegans*.

This is a highly variable species. There is considerable range in the number of costae present in the fold and sulcus which causes individuals to have very diverse appearances. Shells having only two costae in the fold are relatively narrow, while those with five are often strongly transverse. Immature shells are far narrower than mature ones, for the earlier growth stages are concerned principally with forward growth.

Wellerella ? *elegans* is abundant in the lower part of the Bone Spring formation in the Sierra Diablo. It is common at locality 629 and is found sparingly at the other three localities.

***Wellerella nanas* Stehli, new species**

Plate 25, figures 18–22

DIAGNOSIS: Very small Leonardian *Wellerella* in which the fold and sulcus contain, respectively, three and two costae which do not extend to the umbones.

TYPES: A.M.N.H. No. 27318; from locality 629.

DEFINITION: Shell small for the genus, subcircular to subtriangular in outline; usually a little wider than long. Pedicle valve with the beak rather short but sharp and not incurved; sulcus broad, moderately deep, developing near mid length and projected upward as a tongue at the front; valve evenly curved from beak to the margin at either

side of the sulcus. Brachial valve slightly convex; umbo broadly and evenly rounded; beak very blunt and hidden beneath the other valve; fold arising at about mid length and becoming quite high near the front. Both valves are ornamented with costae which are strong and angular in the fold and sulcus which invariably contain, respectively, three and two; lateral slopes bearing two to three rounded and often faint costae; umbones smooth, with costae appearing a little posterior to mid length.

Pedicle interior characteristic for the genus. Brachial interior with the median septum either very minute or completely absent.

Measurements (in mm.) of *Wellerella nanas* are as follows:

Length	6
Width	7
Thickness	5

COMPARISONS: This species is very small for the genus, and its size readily differentiates it from most of the other Permian species. It most closely resembles *W. longicosta*, new species, from which it differs in having coarser costae, fewer costae on the lateral slopes, and smooth umbones.

DISCUSSION: *Wellerella nanas* is fairly common at locality 629 but has not been found elsewhere. The valves are almost invariably disarticulated and suggest transportation. The life requirements of the animal are completely unknown.

***Wellerella longicosta* Stehli, new species**

Plate 25, figures 23–27

DIAGNOSIS: Very small Leonardian *Wellerella* in which the costae extend almost to the beak.

TYPES: A.M.N.H. No. 27319; from locality 629.

DEFINITION: Shell very small for the genus; subtriangular in outline; about as long as wide. Pedicle valve with the beak short, sharp, but not incurved and formed by the intersection of the straight posterolateral margins of the shell without any elongation; sulcus arising a little posterior to mid length and projected upward as a tongue at the front. Brachial valve rather strongly convex, with the fold arising near mid length and

becoming quite high towards the front; beak hidden by the other valve; umbo transversely evenly rounded. Both valves are costate, with the fold bearing three strong, angular costae and the sulcus two; lateral slopes with five somewhat fainter and more rounded costae; costae extending almost to the beak.

Pedicle interior characteristic of the genus. Brachial interior with the median septum a low, broad ridge.

Measurements (in mm.) of *Wellerella longicosta* are as follows:

Length	5.5
Width	5.5
Thickness	4.0

COMPARISONS: This species is distinguished by its small size from most others in the west Texas Permian. It most nearly resembles *W. nanas*, from which it differs in the greater convexity of the brachial valve, finer and more numerous costae on the lateral slopes, and the close approach of the costae to the beak.

DISCUSSION: *Wellerella longicosta* is known only from locality 629 where it is quite common but represented mostly by fragmentary material. The animal was evidently washed in from some near-by area but it was probably very close to the collecting locality.

***Wellerella magnisepta* Stehli, new species**

Plate 25, figures 10-12

DIAGNOSIS: Leonardian *Wellerella* in which the hinge plate is supported by a strong median septum.

TYPES: A.M.N.H. No. 27334; from locality 629.

DEFINITION: Shell of medium size, about as wide as long; widest slightly forward of mid length; subtriangular to subpentagonal in outline. Pedicle valve with the beak pointed and rather short but not incurved; umbo slightly rounded but with a low median elevation running towards the beak; sulcus deep, arising near mid length and projected upward as a tongue at the front; postero-lateral slopes somewhat flattened. Brachial valve with the blunt beak hidden beneath that of the pedicle valve; umbo rounded except for a slight median flattening; fold developing forward of mid length and low

even at the front. Both valves are costate; lateral slopes bearing five to six angular to slightly rounded costae which become obsolete near mid length; fold and sulcus with three to five angular costae which persist onto the umbo, especially in the fold.

Pedicle interior with low, oblong hinge teeth supported by stout dental plates. Brachial interior characteristic of the genus but with a small, well-developed median septum supporting the hinge plate for its entire extent.

Measurements (in mm.) of a brachial valve of *Wellerella magnisepta* are as follows:

Length	11
Width	14

COMPARISONS: This species is distinguished from others in the west Texas Permian by its finer, more abundant costation, large size, and larger median septum.

DISCUSSION: *Wellerella magnisepta* has been found only at locality 629, and even here it is very rare. The valves are disarticulated in most cases, and the life requirements of the animal are quite unknown.

The extreme development of the median septum is unusual for *Wellerella* and might be used as the basis for the establishment of a new genus, but material is so scarce that this is regarded as undesirable at the present time.

GENUS **TEREBRATULOIDEA** WAAGEN, 1883

DIAGNOSIS: Permian Rhynchonellacea in which the pedicle valve lacks dental plates.

GENOTYPE: *Terebratuloidea davidsoni* Waagen.

DEFINITION: Shell small to moderate in size; uniplicate; costae approaching nearly or quite to the beak.

Pedicle interior without dental plates. Brachial interior with a divided hinge plate; without a median septum.

DISCUSSION: *Terebratuloidea* has not previously been recognized in the Western Hemisphere but is known from a number of localities in Eurasia. A small rhynchonellid from locality 629 is tentatively assigned to the genus because of its lack of dental plates. The brachial valve of this species is unknown, and no brachials showing the characters of *Terebratuloidea* have been found.

Terebratuloidea ? lenumbona Stehli, new species

Plate 25, figures 28-30

DIAGNOSIS: Small Leonardian *Terebratuloidea* ? in which the costae become obsolete on the umbo.

TYPES: A.M.N.H. No. 27320; from locality 629.

DEFINITION: Shell small, subtriangular in outline; about as wide as long, with the greatest width near mid length. Pedicle valve with a shallow sulcus which is hardly more than a median flattening but is projected upward as a tongue at the front; beak elongate but not incurved. Brachial valve unknown. The ornamentation consists of strong, but rather fine costae which number three in the sulcus and two to five on the lateral slopes; costae becoming obsolete on the umbo.

Pedicle interior without dental plates, but with the rostral cavity filled by large depressed muscle scars.

Measurements (in mm.) of pedicle valves of *Terebratuloidea* ? *lenumbona* are as follows:

Length	8	7	8
Width	8	7	8

COMPARISONS: This species is distinguished from other rhynchonellids in the west Texas Permian by the absence of dental plates. It differs from other species of *Terebratuloidea* in its smaller size and in the failure of the costae to reach the beak.

DISCUSSION: *Terebratuloidea* ? *lenumbona* is known from four pedicle valves from locality 629. The brachial valve is unknown, and without it the generic identification is considered tentative. There are brachial valves in the collection for which the pedicles are unknown but none of them show the characters of *Terebratuloidea*. The absence of dental plates is so unusual a feature among late Paleozoic rhynchonellids that it seems best to refer this species to *Terebratuloidea* despite some doubts.

SUPERFAMILY STENOSCISMACEA SHROCK AND TWENHOFEL, 1953

GENUS **STENOSCISMA** CONRAD, 1839

DIAGNOSIS: Strongly costate Devonian to Permian Stenoscismacea; possessing a pedicle sulcus and brachial fold at all stages of growth.

GENOTYPE: *Terebratula schlotheimii* Buch.

DEFINITION: Small to very large Stenoscismacea. Pedicle valve triangular in outline, strongly convex and bearing a median sulcus; beak short; pedicle foramen small, oval, closed below by small deltidial plates. Brachial valve strongly convex and bearing a strong fold; beak short and completely hidden beneath the other valve. Both valves are costate and bear a strong projecting skirt at the margin.

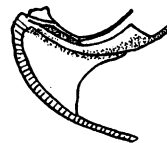
Pedicle interior with a spondylium supported at the front by a low median septum; muscles presumably inserted in the spondylium. Brachial interior with a spoon-shaped cruralium (camarophorium) bearing, in the middle of the anterior edge, a ventrally curved tongue; a strong, high, median septum supports the cruralium; a vertical plate arises from the posterior part of the cruralium (intercamarophorial plate) and supports the hinge plate from which two long curved crura descend into the pedicle valve; cardinal process low and posteriorly inclined. Along the margin of each valve are long tooth-like structures which probably interlocked to form a straining device.



BRACHIAL PROFILE



INTERIOR



BRACHIAL INTERIOR

FIG. 42. *Stenoscisma*.

COMPARISONS: This genus is very striking when specimens are obtained with the recurved skirt intact, and there are few brachiopods with which it might be confused. In specimens in which the skirt is absent the genus might be confused with *Nantanella* Grabau, from which it may be distinguished

by the presence in that genus of a median depression on the umbo of the brachial valve, which in adults is replaced by a fold.

DISCUSSION: *Stenosisma* enjoyed a world-wide distribution during the Permian. In west Texas it is represented by a large number of species and is found throughout the section.

Licharew (1936, p. 63) has separated the subgenus *Camarophorinella* from the typical stock, on the basis of the absence of the intercamarophorial plate in *Camarophorinella*. In all specimens from west Texas examined in the course of this study the intercamarophorial plate was present.

The development of so striking a feature as the marginal skirt of *Stenosisma* invites speculation as to its function. It probably enabled the animal to rest lightly on the surface of even very soft bottoms and at the same time would be of great value in improving the efficiency of incurrent and excurrent water streams.

***Stenosisma multicosta* Stehli, new species**

Plate 25, figures 7-9

DIAGNOSIS: Large Leonardian *Stenosisma* in which the shell is ornamented with a very large number of costae.

TYPES: A.M.N.H. No. 27316; from locality 629.

DEFINITION: Shell large for the genus, strongly triangular in outline, very much wider than long, with the greatest width near mid length. Pedicle valve with a very strong sulcus taking up about one-third of the width of the valve and becoming very deep towards the front where it is prolonged upward as a tongue; sulcus often causing slight emargination of the front and giving the shell a bilobate appearance; curvature of the valve from beak to anterior margin, in the sulcus, strong and even but along the sides the curvature is low; beak rather short and not strongly incurved. Brachial valve strongly and evenly convex, with a fold arising near one-third of the length and becoming very high towards the front. Both valves are ornamented with strong angular costae, six to nine in the fold and sulcus and about the same number on each lateral slope, though the last few are usually faint; costae of the fold and sulcus extending rather near the beak, while those of

the lateral slopes die out nearer the front; costae occasionally increasing by bifurcation; marginal skirt present on both valves, but its shape and size are unknown.

The interior of the shell, in so far as it is known, seems to be quite characteristic of the genus.

COMPARISONS: This species is easily recognized by its large size, abundant and relatively fine costation, high fold and deep sulcus, and the slight emargination of the front. The abundance of costae is especially useful in separating the species from *S. venusta*.

DISCUSSION: *Stenosisma multicosta* is present in the Sierra Diablo only in collections from locality 629, and even here all specimens are fragmentary. The species has also been noted in collections from the west facies of the Hess formation in the Glass Mountains. The species is apparently limited to the Leonardian.

***Stenosisma kala* Stehli, new species**

Plate 25, figures 1-6

DIAGNOSIS: Leonardian *Stenosisma* with abundant, very fine costae; size moderate; front not emarginate.

TYPES: A.M.N.H. No. 27315; from locality 629.

DEFINITION: Shell of moderate size for the genus; subtriangular to transversely suboval in outline; wider than long, with the greatest width near mid length. Pedicle valve moderately and evenly convex except at the front where the tongue-like projection of the sulcus is geniculated upward; sulcus wide and shallow, originating near mid length; beak short, somewhat inflated and not significantly incurved. Brachial valve very strongly convex, especially towards the beak; fold wide and low, originating a little in front of the beak. Both valves are ornamented with fine angular costae which number seven to nine in the fold and sulcus and eight to nine on the lateral slopes, with the last few commonly faint; costae sometimes increasing by bifurcation; each valve with a strong marginal skirt approximately parallel to the plane of commissure but slightly upturned anteriorly.

The interior of both valves is characteristic for the genus except that in the pedicle valve the spondylium does not arise directly from the hinge teeth as a discrete plate but is anky-

losed with the wall of the rostral cavity for some distance.

The approximate measurements (in mm.) of a brachial valve of *Stenosisma kala* are as follows:

Length	18
Width	29

COMPARISONS: This species is distinguished by its fine angular costae, and by the unusually large number of costae on the lateral slopes. It differs from *S. multicosta* in its smaller size and finer costation. It may be distinguished from *S. hueconiana* by its greater size and more abundant costae.

DISCUSSION: *Stenosisma kala* is a very rare shell and has so far been found only at locality 629. No complete specimens are known, though the collection includes a good brachial valve and several less perfect pedicle valves.

Stenosisma hueconiana (Girty)

Plate 24, figures 14-17

Camarophoria hueconiana GIRTY, 1929, Jour. Washington Acad. Sci., vol. 19, p. 412, figs. 14-21.

Camarophoria deloi R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 110, pl. 34, figs. 24-27.

Camarophoria deloi STAINBROOK AND MADERA, 1941, Jour. Paleont., vol. 15, pp. 376-383.

DIAGNOSIS: Small, strongly costate, lower Permian *Stenosisma* in which the costae are relatively few in number.

DEFINITION: Shell small for the genus, subtriangular in outline; wider than long, with the greatest width slightly anterior to mid length. Pedicle valve with a very broad, rather shallow sulcus which arises at or slightly before mid length and occupies a little more than half the width; valve rather strongly convex, with the beak somewhat inflated but short and strongly incurved. Brachial valve highly convex; fold arising near mid length but remaining low even near the front. Both valves are ornamented with strongly angular costae which become obsolete at the umbo; lateral slopes with three to four rather faint costae while the fold and sulcus bear four to six; marginal skirt present but of unknown size and shape.

The interiors of both valves, in so far as they are known, are characteristic of the genus.

Measurements (in mm.) of a pedicle valve of *Stenosisma hueconiana* are as follows:

Length	10
Width	12

COMPARISONS: *Stenosisma hueconiana* is distinguished from other species in the west Texas Permian by its small size and few, strong costae.

DISCUSSION: Robert E. King (1930, p. 110), unaware of Girty's publication of *S. hueconiana* (1929, p. 412) based on specimens from the Cerra Alto, erected *S. deloi* for the reception of what seems to be the same species from the near-by Hueco Mountains. *Stenosisma hueconiana* is widespread in the lower Permian of Texas and adjoining areas. In the present collections it was found only at locality 629 and was represented by more or less fragmentary material.

SUPERFAMILY SPIRIFERACEA WAAGEN, 1883

DIAGNOSIS: Middle Silurian to Jurassic Brachiopoda in which the hinge is usually greatly extended; shell impunctate; ornament consisting of costae or costellae; spires directed towards the cardinal extremities.

FAMILY SPIRIFERIDAE KING, 1846

DIAGNOSIS: Derived Spiriferacea in which the crura are directly continuous with the bases of the primary lamellae situated between the laterally directed spiralia; jugum simple and complete or incomplete.

GENUS NEOSPIRIFER FREDERICKS, 1919

DIAGNOSIS: Pennsylvanian and Permian Spiriferidae in which the costae are fasciculate.

GENOTYPE: *Spirifer fasciger* Keyserling.

DEFINITION: Medium- to large-sized shells, generally of transverse outline. Pedicle valve of variable convexity; beak rather short and incurved; interarea high and broad; sulcus highly variable. Brachial valve with a low interarea; variably convex; beak low; fold variable. Both valves are typically ornamented with fasciculate costae.

Pedicle interior with the hinge teeth supported by dental plates; median septum absent; muscle scars located between the dental plates and extending forward as an oval de-



PEDICLE EXTERIOR



PEDICLE INTERIOR BRACHIAL INTERIOR

FIG. 43. *Neospirifer*.

pression. Brachial interior with the crural plates suspended from the palintrope; muscle placement uncertain.

DISCUSSION: *Neospirifer* ranges through the Pennsylvanian and Permian, attaining a world-wide distribution. In west Texas it is present throughout the Permian section. It is poorly represented in the collections studied, however, and no complete specimens have been found.

Neospirifer has been used to include a great variety of forms, and it is now gradually being clarified by the transfer of some of the more extreme species into new genera.

Neospirifer sp.

DISCUSSION: None of the fragmentary remains of *Neospirifer* in the collections studied is sufficiently complete to permit specific assignment. The material is always badly worn and broken, and it seems likely that representatives of the genus lived at some distance from the collecting areas. *Neospirifer* is very abundant in the Victorio Peak member of the Bone Spring formation which seems to represent a great bank deposit, and this type of environment may have been that favored by the animal.

SUBFAMILY AMBOCOELIINAE GEORGE, 1931

DIAGNOSIS: Generally small Spiriferidae of plano-convex shell form in which the spiralia consist of a few widely spaced coils; jugum much reduced or absent; shell smooth or possibly ornamented with minute spines.

GENUS *CRURITHYRIS* GEORGE, 1931

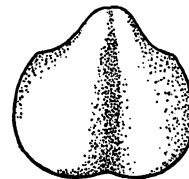
DIAGNOSIS: Upper Paleozoic Ambocoeliinae in which the hinge is less than the greatest width; cardinal process simple; muscle scars elongate.

GENOTYPE: *Spirifer urei* Fleming.

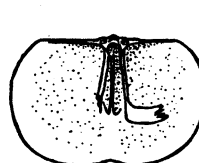
DEFINITION: Small, plano-convex shells which are generally wider than long. Pedicle valve strongly convex; beak strongly incurved; interarea high, sharply separated from the lateral slopes; delthyrium bounded by low plates which do not close it; with or without a faint sulcus. Brachial valve slightly convex to nearly flat; a shallow sulcus is frequently present; interarea low; notothyrium open but bounded by low ridges. Both valves probably finely spinose, but usually appearing smooth.

Pedicle interior without dental plates or a median septum; adductor scars very narrow and elongate; position of the diductors uncertain, but possibly they were also narrow, elongate scars posterolateral to the adductors. Brachial interior with deep, tubular sockets between which, in the apex of the notothyrium, lies the low, triangular cardinal process; crura arising from the anterior margin of the socket plates and posteriorly attached to the floor of the valve while anteriorly they run forward into the descending lamellae of the spires; jugum absent; spires complex; muscle scars elongate.

COMPARISONS: *Crurithyris* resembles *Ambo-*



PEDICLE EXTERIOR



BRACHIAL INTERIOR PEDICLE INTERIOR

FIG. 44. *Crurithyris*.

coelia Hall but differs in its narrower hinge, elongate muscle scars, simple cardinal process, and more complex spires. It differs from *Attenuatella*, new genus, in its shorter beak and in the absence of a median ridge in the pedicle valve.

DISCUSSION: *Crurithyris* ranged from the Devonian to the Permian and achieved a world-wide distribution. In the west Texas Permian it is present throughout the section and is represented by several species. Its preferred environment is unknown, but it is doubtful that it was an habitual reef dweller.

***Crurithyris sulcata* Stehli, new species**

Plate 26, figures 1-6

DIAGNOSIS: Leonardian *Crurithyris* of transverse outline which characteristically bear a sulcus in both valves.

TYPES: A.M.N.H. No. 27322; from locality 629.

DEFINITION: Shell of moderate size for the genus; suboval to subquadrate in outline and often somewhat emarginate; hinge equal to about two-thirds of the greatest width. Pedicle valve strongly convex; beak incurved; interarea somewhat broader than high; sulcus usually beginning near the beak and becoming wider towards the front; delthyrium about one-fourth of the width of the interarea; cardinal extremities rounded. Brachial valve very slightly convex, subcircular to transversely elliptical; sulcus or median flattening present anteriorly; interarea low, slightly curved and lying at slightly less than 90 degrees to the plane of commissure. The surface of both valves is probably finely spinose, though spines are not preserved on the present material. The shape of the shell is highly variable. It may be strongly emarginate if both valves bear a deep sulcus, or rarely may be almost smoothly rounded at the front when neither valve has a pronounced sulcus.

The interiors of both valves are characteristic of the genus.

Measurements (in mm.) of *Crurithyris sulcata* are as follows:

Length	10	11	8
Width	11	12	9
Thickness	5	5	4

COMPARISONS: *Crurithyris sulcata* differs

from *C. guadalupensis* (Girty) in being generally more transverse. It differs from both that species and from *C. plano-convexa* (Shumard) in the possession, in all but a very few specimens, of a sulcus in the pedicle valve. It differs from *C. inflata*, new species, in the presence of sulci and in the absence of a depressed muscle area in the pedicle valve.

DISCUSSION: *Crurithyris sulcata* is fairly common at locality 629 but has not been found elsewhere. The specimens are mostly disarticulated and are probably not in their life habitat.

***Crurithyris inflata* Stehli, new species**

Plate 26, figures 7-11

DIAGNOSIS: Large Leonardian to Guadalupean *Crurithyris* in which a sulcus is absent; muscle scars depressed in the floor of the pedicle valve.

TYPES: Holotype: A.M.N.H. No. 27323/1:1; from locality 629; paratype: A.M.N.H. No. 27323/2:1; from locality 512.

DEFINITION: Pedicle valve strongly and evenly convex; beak highly inflated and strongly incurved; interarea about two-thirds of the width of the shell and limited by sharp beak ridges; delthyrium one-fourth of the width of the interarea, open but bounded by low ridges; front evenly rounded, without a sulcus; cardinal extremities obtusely angular. Brachial valve subsemicircular, slightly and evenly convex; interarea low, nearly at right angles to the plane of commissure; notothyrium open but bounded by low ridges; without a fold or sulcus. The surface of both valves smooth but in life perhaps finely spinose.

The interiors of both valves are characteristic for the genus except that in the pedicle valve the elongate muscle scars form a shallow depression in the floor of the valve.

Measurements (in mm.) of the pedicle valve of *Crurithyris inflata* are as follows:

Length	16
Width	14

COMPARISONS: *Crurithyris inflata* is distinguished from other members of the genus by its large size and its distinctive shape as well as the depression of the muscle scars in the floor of the pedicle valve.

DISCUSSION: This species is represented, in the present collections, by a single pedicle valve from locality 629. The characters of the brachial valve are drawn from additional material from the Getaway formation of the Guadalupe Mountains where it also occurs. Nothing is known of the life preferences of the animal. The species is very thin shelled and as a result the margins of the shell are frequently broken away so that it is often difficult to recognize.

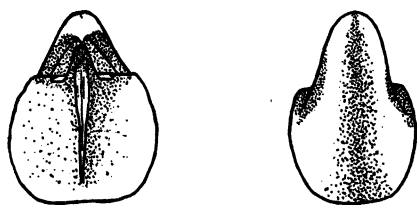
ATTENUATELLA STEHLI, NEW GENUS

DIAGNOSIS: Small, attenuated Ambocoeliinae of the lower Permian in which the pedicle valve bears a median ridge.

GENOTYPE: *Attenuatella texana* Stehli, new species.

DEFINITION: Pedicle valve narrow and long; strongly convex; beak greatly attenuate and strongly incurved; interarea high; beak ridges sharp; delthyrium probably bounded by low plates. Brachial valve subcircular, nearly flat; interarea low. The surface of both valves is smooth or possibly finely cancellated. It may be finely spinose though spines have not been observed.

Pedicle interior with a strong, broad, flat-topped median ridge which was evidently the site of muscle insertion; adductor scars very long and narrow, occupying a median position and extending far forward; diductor scars



PEDICLE INTERIOR PEDICLE EXTERIOR

FIG. 45. *Attenuatella*.

narrow, elongate, posterolateral to the adductors. Brachial interior unknown.

COMPARISONS: *Attenuatella* is distinguished from both *Crurithyris* and *Ambocoelia* by its greatly attenuated pedicle valve and by the median ridge of the pedicle interior.

DISCUSSION: The genotype is known from a single excellently preserved pedicle valve from

locality 629. Cloud (*in* King, R. E., Dunbar, Cloud, and Miller, 1944, pp. 62–63) described under the name *Crurithyris attenuata* an additional species belonging to the genus which he found in material from Las Delicias, Coahuila, Mexico. Should better and more abundant material be discovered the Mexico and Texas species might prove to be the same. This is now uncertain because of the difference in mode of preservation. Cloud's material shows the external features of the shell but does not show the interior. Material in the collections studied shows the interior of the pedicle valve but no surface ornamentation. The brachial interior remains unknown. The generic definition given above is drawn from both the Mexico and Texas specimens.

***Attenuatella texana* Stehli, new species**

Plate 25, figures 31–33

TYPES: Holotype: A.M.N.H. No. 27321; from locality 625.

DEFINITION: Pedicle valve strongly convex and very attenuated; length from the hinge to the front about equal to the width; length from the beak to the front about 1.3 times the width; hinge equal to a little more than one-half of the width of the shell; beak ridges sharp; cardinal extremities obtusely angular; interarea about as wide as high, initially perpendicular to the plane of commissure but strongly incurved; delthyrium open and about one-third of the width of the interarea; an indistinct sulcus runs from the beak to the anterior margin. Brachial valve unknown. The surface ornamentation is not preserved on the specimen but may be similar or identical to that described by Cloud (*in* R. E. King, Dunbar, Cloud, and Miller, 1944) for *A. attenuata*.

Pedicle interior as described for the genus.

Measurements (in mm.) of the pedicle valve of *Attenuatella texana* are as follows:

Length	10.2
Width	9.0
Length, hinge to front	7.8

DISCUSSION: This species is known from a single pedicle valve. Preservation of the specimen does not permit comparison with the only other known species, *A. attenuata*.

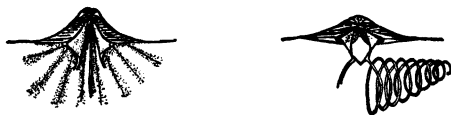
SUPERFAMILY PUNCTOSPIRACEA COOPER, 1944

DIAGNOSIS: Upper Silurian to Jurassic Brachiopoda with an endopunctate test and calcareous spires.

DISCUSSION: This superfamily is retained in the sense in which it was proposed, although it seems that some restriction will be necessary in the future. The shells to which the name "*Spiriferina*" has generally been applied together with the cyrtinoids seems to form a natural grouping to which the term Punctospiracea might be given. *Hustedia* and its near allies seem far beyond the limits of such a group.

FAMILY SPIRIFERINIDAE DAVIDSON, 1884

DIAGNOSIS: Devonian to Jurassic, spinose Punctospiracea in which the pedicle interior



PEDICLE INTERIOR BRACHIAL INTERIOR

FIG. 46. Spiriferinidae

bears strong dental plates and a high median septum, but lacks a spondylium.

DISCUSSION: This stock retains a remarkable uniformity in internal structures throughout its long range. In contrast the external features of the shell show considerable variation. Spines have been noted in most of the species studied, and it is probable that they were present throughout the group. Because of their delicate nature in most genera they are seldom preserved. The arrangement of spines is highly variable and is of importance in the recognition of genera.

The spines of the Spiriferinidae are hollow but generally do not open into the interior of the shell except at the margins. They were formed at the growing edge by deposition of shell material around a caecum of the mantle; however, this caecum was withdrawn after a short time and the spine base sealed by deposition of material on the inside of the shell.

The puncta seem to have a similar origin, and they too fail to penetrate the inner sur-

face of the shell except at the growing margin. Puncta and spines in this group seem identical except that the puncta ended blindly just beneath the surface, while the spine-building caeca passed through the shell and formed protective walls about themselves. The spines do not disturb the regular arrangement of the puncta. In certain genera such as *Crenispirifer* the spines are so closely and regularly packed as to suggest that every punctal caecum penetrated the shell and formed a spine. The function of the spines and puncta is unknown.

There is considerable variation in the shape of the shell, character of costation, and type of surface ornamentation within the Spiriferinidae. These characters supplement the spine pattern in the recognition of generic units.

A rather considerable number of generic names have been proposed for various members of the Spiriferinidae, but many of them are inadequately defined and have consequently been slow to find general usage. It has in fact, until recently, been general practice to refer all members of the group to *Spiriferina* D'Orbigny. This procedure is unsound, especially for the Paleozoic species, in view of the fact that *Spiriferina*, *sensu stricto*, is a Jurassic genus bearing little resemblance to any of the known Paleozoic genera.

Spiriferina D'Orbigny is based on *S. rostrata*. It is either smooth or only incipiently costate. The hinge is much less than the greatest width of the shell. The cardinal extremities are rounded. The crural plates reach the floor of the valve. The jugum is said to be a simple transverse band. The surface bears few spines, the pattern of which has not been determined.

For upper Paleozoic members of the group the following names are available: *Reticularina* Fredericks, *Spiriferellina* Fredericks, *Punctospirifer* North, *Spiriferinaella* Fredericks, *Callispirina* Cooper and Muir-Wood, *Paraspiriferina* Reed, and *Crenispirifer* and *Altiplecus*, the two new names proposed in this paper.

Specimens of most of these genera have not been available for study; however, listed below in abbreviated form are what seem to be the important features of those genera not diagnosed.

RETICULARIINA FREDERICKS

Greatest width at the hinge; beak ridges sharp; surface smooth except for long, stout, marginally inclined spines which are scattered over the shell except between the costae, though they are present in the sulcus. In so far as is now known the genus is confined to the Mississippian. References to it in the Permian by Reed (1944, p. 251) and Chronic (*in* Newell, Chronic, and Roberts, 1949, pp. 105–106) are apparently based simply on the presence of spines.

CALLISPIRINA COOPER AND MUIR-WOOD

About as wide as long; hinge much less than the greatest width; cardinal extremities rounded; beak ridges indistinct; spine pattern unknown. The genus is known only from the Permian. Fredericks originally gave it the name *Maia*, which proved to be a homonym and was replaced by Reed by *Mansuyella*, which also was a homonym and has been replaced by Cooper and Muir-Wood by *Callispirina*.

PARASPIRIFERINA REED

Shell finely and regularly lamellose; hinge less than the greatest width; beak ridges rounded; shell more or less globose, with the brachial valve highly convex. The genus is monotypic and known only from the Permian.

SPIRIFERINAELLA FREDERICKS

Shell ornamented with regular imbricating lamellae; hinge equal to the greatest width; fold bearing at its crest a small reverse plication. The genus has been reported only from the Permian.

The foregoing discussion by no means represents a complete study of the genera mentioned. It is an attempt to clarify, in so far as is possible at this time, some of the confusion that has surrounded the group. Much more study is needed, including a comprehensive restudy of the genera proposed by Fredericks.

GENUS PUNCTOSPIRIFER NORTH, 1920

DIAGNOSIS: Strongly transverse Spiriferinidae in which the surface is ornamented by fine, regular, imbricating lamellae; fold and sulcus much larger than the lateral plications.

GENOTYPE: *Punctospirifer scabricostatus* North.

DEFINITION: Shell small, semicircular in outline; biconvex, with the pedicle valve the more so. Pedicle valve with a strong, broad sulcus; lateral slopes with numerous relatively fine, low, rounded plications; sulcus about as wide as three plications on the lateral slopes; interarea moderately high; beak slightly incurved; beak ridges sharp. Brachial valve of low convexity; fold prominent and as wide as three lateral plications; interarea very low. Both valves are ornamented by very fine, imbricating lamellae which are a feature of only the extreme outer part of the shell and are frequently worn away near the umbo; spines very fine and lying flat against the shell, but their pattern is unknown.

Pedicle interior with strong dental plates and a high median septum to which the muscles were attached; the septum and the dental plates are joined in the beak by a callous deposit. Brachial interior with a low median ridge bisecting the muscle field.

COMPARISONS: *Punctospirifer* shares with *Spiriferinaella* and *Paraspiriferina* a regular ornamentation of imbricating lamellae. It differs from *Spiriferinaella* in lacking the reverse plication in the fold, and from *Paraspiriferina* in having the greatest width at the hinge and sharp beak ridges.

DISCUSSION: The preceding definition has been drawn up from the original description and from examination of species of the genotype in the collections of the United States National Museum. These specimens show certain details not mentioned by North such as the presence of spines and the callus in the beak of the pedicle valve which he considered to be absent. Regarding the interior of the brachial valve, North states that the jugum is posteriorly directed. In this he is probably mistaken. In all the Paleozoic genera of the Spiriferinidae which have been available for this study and which showed the jugum, it is anteriorly directed. North himself compares the interior of *Punctospirifer scabricostus* to that of *Spirifer kentuckyensis* Shumard as it is figured in Hall and Clarke (1892). The figure to which he referred, however, clearly shows the jugum in that species to be anteriorly directed.

Punctospirifer has been pressed into service

to include a great many forms which probably do not belong to it. There is a real need for a comprehensive restudy of the genus, to discover the features of the brachial interior and the pattern of spine arrangement. Until this is done any assignment to the genus must be considered somewhat questionable. This is especially true for Permian forms as the genotype is lower Carboniferous.

***Punctospirifer* ? *irenae* Stehli, new species**

Plate 26, figures 12-15

DIAGNOSIS: Leonardian *Punctospirifer* ? in which the imbricate lamellae are coarse and widely spaced.

TYPES: A.M.N.H. No. 27324; from locality 629.

DEFINITION: Shell small, biconvex, wider than long; semicircular to subtriangular in outline. Pedicle valve strongly convex; beak incurved; interarea moderately high; beak ridges sharp; delthyrium large, probably closed by a deltidial covering; sulcus broad and bordered by three to four progressively fainter plications. Brachial valve moderately convex; fold strong and bordered by three to five plications. Both valves are ornamented with strong and very regular, imbricating growth lamellae; spines have not been noted, but this is probably because of the wear of the shells.

Pedicle interior with strong hinge teeth supported by abbreviated dental plates in the beak; median septum strongly developed, rising to a crest and then abruptly terminated anteriorly; median septum and dental plates joined by an adventitious deposit in the beak; muscle scars located on the septum. Brachial interior with strong sockets bounded by socket plates; cardinal process low and joined to the crural plates by a narrow shelf; crura springing from the anterior end of this shelf; remainder of the brachial apparatus unknown; muscular area bounded by low ridges and usually bisected by an insignificant ridge.

Measurements (in mm.) of pedicle valves of *Punctospirifer* ? *irenae* are as follows:

Length	11	9	11	8	9
Width	17	18	18	15	18

COMPARISONS: *Punctospirifer* ? *irenae* is distinguished from most other Spiriferinidae of

the west Texas Permian by its imbricate-lamellose ornament. A possible exception is *Spiriferina pyramidalis* Girty from which it differs in the absence of a very high interarea.

DISCUSSION: This species is tentatively referred to *Punctospirifer* because of its lamellose ornamentation. It is possible that it is incorrectly placed here, but in the absence of information on the spine pattern of either this species or the genotype its proper placement cannot be ascertained. In the genotype the imbricating lamellae affect only the surface layer of the shell. In *Punctospirifer* ? *irenae* they are deeply impressed upon the shell.

The species is very rare and has been found only at locality 629. Its life requirements are unknown.

GENUS **SPIRIFERELLINA** FREDERICKS, 1919

DIAGNOSIS: Permian Spiriferinidae in which the fold and sulcus are somewhat flattened; sulcus often bearing a minute median elevation.

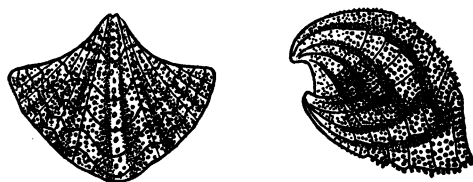
GENOTYPE: *Terebratulites cristatus* Schlotheim.

DEFINITION: Shell of moderate size, wider than long, with the greatest width at the hinge; more or less semicircular in outline. Pedicle valve markedly more convex than the brachial; beak moderately to strongly incurved; interarea moderate to high; delthyrium large, with a deltidial covering (which is seldom preserved); sulcus strong, much deeper than the lateral plications and usually containing a small median elevation towards the front. Brachial valve with the beak and interarea very low; fold much elevated above the lateral plications and usually somewhat flattened on top. Both valves are ornamented with fine, closely spaced, erect, short spines which are present on the crests and sides of the plications but are absent in the troughs excepting the sulcus which bears one or more rows of spines along the top of its median elevation; irregular concentric growth lines are also present.

Pedicle interior with abbreviated dental plates in the beak; a strong median septum is present, rising to a crest and terminating abruptly anteriorly; dental plates and median septum united by a small platform of adventitious material in the beak; muscle insertions

probably on the median septum. Brachial interior with strong sockets bounded by socket plates; cardinal process low, united with the crural plates by a narrow shelf; crura spring from the anterior end of this shelf and converge until they are joined by an anteriorly directed jugum; the descending lamellae diverge from the jugum and give rise to the spires; muscle scars elongate, bounded by low lateral ridges and sometimes divided by an insignificant median ridge.

COMPARISONS: *Spiriferellina* may be distinguished by the general irregularity of the



PEDICLE EXTERIOR

PROFILE

FIG. 47. *Spiriferellina*.

imbricating lamellae, by its spine pattern, and by the low elevation in the sulcus. It differs from *Crenispirifer*, new genus, in spine pattern and in the rounding of the plications. It is distinguished from *Altiplecus*, new genus, by its spine pattern and by the normal development of the lateral plications.

DISCUSSION: *Spiriferellina* has been recognized in the Permian of Eurasia for some time, but has only recently been noted in North America. In west Texas it is known from several horizons and is apparently rather widespread. It is also present in the Permian of Mexico.

Specimens in the present collection agree closely with specimens from the Salt Range of India, referred by Waagen (1883, p. 499) to *Spiriferina cristata*, and the two are undoubtedly congeneric. No specimens definitely identified as *Spiriferina cristata* from Europe have been available for comparison.

***Spiriferellina newelli* Stehli, new species**

Plate 26, figures 22-27

DIAGNOSIS: Moderate-sized Leonardian *Spiriferellina* bearing enlarged spines on the crests of the plications and in the sulcus.

TYPES: Syntypes: A.M.N.H. Nos. 27326/1:1 and 27326/1:2; paratypes:

A.M.N.H. Nos. 27326/1 and 27326/2; from localities 625 and 629.

DEFINITION: Shell somewhat wider than long; biconvex; semicircular to subtriangular in outline. Pedicle valve with the beak usually strongly incurved; interarea moderately high, usually at an angle of less than 90 degrees to the plane of commissure but highly variable; interarea about one-fourth as high as wide; delthyrium about one-fifth of the width of the interarea and closed by a deltidial covering which is seldom preserved; sulcus very strong and bearing a median plication; four to six lateral plications are present, but if more than four, the last few are often faint. Brachial valve much less convex than the pedicle; fold strong and generally somewhat flattened on top at least near the front; lateral plications three to five in number; interarea very low and lying nearly in the plane of commissure. Both valves are ornamented with close-packed, fine spines the distribution of which is that described for the genus; there are very stout spines on the crest of the fold and occasional large ones in the sulcus; concentric growth lines are frequent and pronounced but irregularly placed.

Pedicle interior with the median septum running about one-third of the length of the valve; remainder essentially as described for the genus. Brachial interior with well-developed ridges bounding the muscle area.

Measurements (in mm.) of pedicle valves of *Spiriferellina newelli* are as follows:

Length	16	15	17
Width	21	21	19

COMPARISONS: *Spiriferellina newelli* is distinguished from other species of the genus by the enlarged spines on the crests of the costae and in the sulcus.

DISCUSSION: This species has been found at localities 625 and 629 but is unknown outside the Bone Spring formation in the Sierra Diablo. The life requirements of the species are completely unknown.

CRENISPIRIFER STEHLI, NEW GENUS

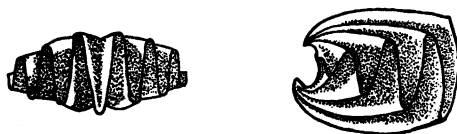
DIAGNOSIS: Pennsylvanian and Permian Spiriferinidae in which the plications are very angular and the spines exceedingly fine and close spaced.

GENOTYPE: *Spiriferina angulata* King.

DEFINITION: Front of the shell strongly plicate, with the median plication nearly equal to the thickness of the shell. Pedicle valve with the interarea moderately high; beak somewhat incurved; plications acutely angular; valve slightly to moderately convex. Brachial valve of low to medium convexity; interarea low. Both valves are ornamented throughout with minute, closely packed, erect spines in regular rows.

Pedicle interior with short dental plates; median septum high, rising to a crest and abruptly truncated anteriorly; muscle scars on the septum. Brachial interior with the sockets bounded by socket plates; crural plates curved so as to form a platform at either side of the cardinal process; adductor scars bounded by a low ridge, while a minute median ridge may bisect the muscle area; crura arising from the crural plates and converging until they are joined by the forward-directed jugum; from this point the descending lamellae diverge, giving rise to the spires.

COMPARISONS: *Crenispirifer* is distinguished from *Spiriferellina* by its acute plications and by the close-packed, fine spines. It differs from *Aliiplecus*, new genus, in its larger num-



FRONT

PROFILE

FIG. 48. *Crenispirifer*.

ber of plications and in their angular nature and in the nature of the spine pattern. It is distinguished from *Punctospirifer* by the absence of regularly arranged, imbricating lamellae.

DISCUSSION: This genus occurs in the upper Pennsylvanian and Permian of the western United States. It is not yet known to be represented in other areas. In the west Texas Permian it is known to range from the Leonardian through the Guadalupian. Its preferred environment is unknown.

Crenispirifer angulatus (King)

Plate 26, figure 28; plate 27, figures 1-7

Spiriferina angulata R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 122, pl. 42, figs. 12-13.

DIAGNOSIS: Large Leonardian *Crenispirifer*.

DEFINITION: Shell large, wider than long, with the greatest width at or very near the hinge; semicircular in outline; slightly to moderately convex; plications very high and acutely angular; front deeply serrate, with the median plication nearly as high as the entire thickness of the shell. Pedicle valve with a deep, angular sulcus bounded on either side by four to five progressively smaller plications; interarea about one-fourth as high as wide and rather sharply distinct from the lateral slopes; beak somewhat incurved; delthyrium about one-fifth as wide as the hinge and probably closed by calcareous plates. Brachial valve with a sharp median fold and a series of progressively smaller lateral plications; convexity low to moderate; interarea very low, lying about in the plane of commissure. The surface of both valves is ornamented by fine, erect spines about 1 mm. long and crowded so closely together that there are 20 to 30 in a square millimeter; spines largest and most strongly developed on the crests and slopes of the plications but occurring in the troughs as well; concentric growth lines are frequently present but are irregularly spaced.

The interiors of both valves are characteristic of the genus.

Measurements (in mm.) of *Crenispirifer angulatus* are as follows:

Length	10	8	16	14	19	16	15
Width	16	15	18	19	28	20	20
Thickness	8	8	11	11	14	14	14
Height of median plication	7	7	7	7	11	10	11

COMPARISONS: *Crenispirifer angulatus* is the only described species of the genus, but there is another, much smaller species in the Pinery formation of the Guadalupe Mountains.

DISCUSSION: *Crenispirifer angulatus* is found in the Hess and Leonard formations of the Glass Mountains and is abundant in the Bone Spring formation of the Sierra Diablo. It occurs at all of the collecting localities studied and is very common at 625 and 629.

It was also noted on weathered surfaces throughout the Sierra Diablo. It was apparently much less restricted environmentally than the other species of the family.

ALTIPLECUS STEHLI, NEW GENUS

DIAGNOSIS: Permian Spiriferinidae in which the fold and sulcus are deep and the lateral plications weak; spines strong and concentrically arranged.

GENOTYPE: *Altiplecus cooperi* Stehli, new species.

DEFINITION: Shell small to medium sized; much wider than long; triangular in outline; biconvex, with the pedicle valve far more strongly convex than the brachial; plications acute, few in number. Pedicle valve with the beak usually somewhat incurved; interarea moderately high; valve with a deep sulcus sometimes bearing a faint median elevation; plications of the lateral slopes few and faint; accretion of shell material with a minimum of forward growth causes flattening of the front. Brachial valve of rather low convexity, with a very strong fold and several weak lateral plications; front flattened as in the other valve. Both valves are ornamented with strong spines which usually appear as one or two concentric rows on the frequent, irregular growth lamellae; plications irregularly knobby.

Pedicle interior with a high median septum rising to a crest and then abruptly terminating; septum bearing muscle scars; dental plates apically united with the median septum by a callous deposit. Brachial interior with the sockets bounded by strong socket plates; cardinal process low and united to the crural plates by a narrow shelf; crura converging to the point at which they are united by the anteriorly directed jugum, here the descending lamellae arise and diverge into the valve giving rise to the spires; muscle

area bounded by a low lateral ridge and sometimes bisected by a low median ridge.

COMPARISONS: *Altiplecus* is distinguished from both *Crenispirifer* and *Spiriferellina* by its triangular outline, few costae, and distinctive spine pattern.

DISCUSSION: *Altiplecus* has been found at locality 625 in the Sierra Diablo and in the Hess of the Glass Mountains. *Spiriferina mongolica* Grabau from the Permian of Mongolia appears to belong to the genus, but the writer has not had the opportunity of examining specimens of the species. *Altiplecus* is a rare fossil, and its life requirements are unknown.

Altiplecus cooperi Stehli, new species

Plate 26, figures 16-21

TYPES: A.M.N.H. No. 27325; from locality 625.

DEFINITION: Shell small and triangular in outline; widest at the hinge. Pedicle valve strongly convex; beak incurved; interarea about one-fourth as high as wide, usually standing at about 90 degrees to the plane of commissure, though there is considerable variation; delthyrium about one-fifth as wide as the interarea and closed by a deltidial covering which is seldom preserved; sulcus somewhat deeper than the two, rarely three, lateral plications, and sometimes bearing a slight median elevation towards the front; anterior margin more or less flattened. Brachial valve with a very small beak; interarea very low, lying in the plane of commissure; fold strong, with two, occasionally three, lateral plications at each side; anterior margin flattened. Both valves bear frequent, irregular growth varicies which give the plications a knobby appearance; spines stout and arranged in concentric rows.

The interiors of both valves are as described for the genus.

Measurements (in mm.) of *Altiplecus cooperi* are as follows:

Length	12	10
Width	18	17
Thickness	8	8

DISCUSSION: This species is rare in the present collections, having been found only at locality 625. It is known, however, from the

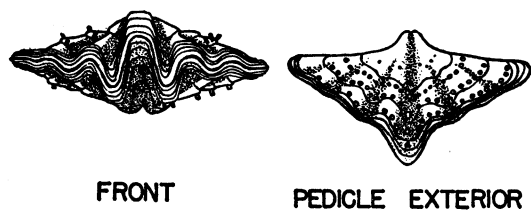


FIG. 49. *Altiplecus*.

Hess of the Glass Mountains as well. The animal seems to have grown irregularly. During its resting phase there was accretion of shell at the margin without forward growth, so that the margin appears flattened. This was followed by a period of renewed forward growth. This method of growth results in very knobby plications and in flattening of the front.

CYRTINIDAE STEHLI, NEW FAMILY

DIAGNOSIS: Silurian to Jurassic Punctospiracea in which the dental lamellae join to form a spondylium which is penetrated by the median septum.

DISCUSSION: Concomitant with the emendation of the Spiriferinidae, set forth above, the cyrtinoids are given family rank. The group has not as yet been well studied but includes such diverse genera that it will probably be found to include several groups of subfamily rank.

PUNCTOSPIRACEA OF UNCERTAIN POSITION

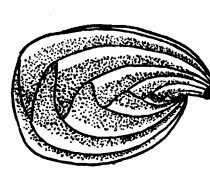
GENUS *HUSTEDIA* HALL AND CLARKE, 1892

DIAGNOSIS: Small, strongly costate Mississippian to Permian Punctospiracea with a rostrate pedicle beak and a flat symphytium.

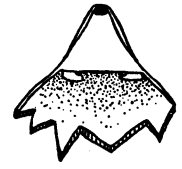
GENOTYPE: *Terebratula mormoni* Marcou.

DEFINITION: Shell subtriangular to ovate in outline. Pedicle valve convex, rostrate, with the beak often somewhat incurved; pedicle foramen round; hinge short; symphytium flat. Brachial valve subcircular; beak low. Both valves are ornamented with strong rounded to angular costae originating at the beak.

Pedicle interior without dental lamellae; an incomplete pedicle collar is present in the beak. Brachial interior with an erect hinge plate bearing a small cardinal process, in front of which is a long recurved process descending into the pedicle beak; at either side the hinge plate gives rise to a crural process, bounding the sockets and descending into the pedicle valve, then turning sharply upward and giving rise to the laterally directed spires; primary lamellae joined by a V-shaped, forward-directed, spinose jugum which bears at its apex a posteriorly pointing, spinose process; a low median septum is present.



PROFILE



PEDICLE INTERIOR

FIG. 50. *Hustedia*.

COMPARISONS: *Hustedia* is not likely to be confused with any other Permian genus, and is easily recognized by its punctate shell structure, strong and abundant costation, rostration of the pedicle beak, and its flat symphytium.

DISCUSSION: The relationships of *Hustedia* and its close allies to other genera of the Punctospiracea are uncertain. It seems doubtful that they are closely related to either the Spiriferinidae or the Cyrtinidae, and their inclusion in the Punctospiracea on a permanent basis is open to question.

Hustedia is the most abundant brachiopod in the west Texas Permian and occurs virtually everywhere that fossils are found. This abundance suggests either that the animal itself had an extremely wide distribution or that the shell was uniquely adapted for transport by currents. The former was probably the case, as the shells are usually in very good condition as found and often contain the brachidium partly or wholly intact. The animal seems to have been able to compete successfully in almost any area of relatively shallow water, yet the presence of several distinct species indicates that there were at least some isolating factors in operation which limited the habitats of these specific groups.

Hustedia hessensis King

Plate 27, figures 8-14

Hustedia hessensis R. E. KING, 1930, Univ. Texas Bull., no. 3042, p. 125, pl. 42, figs. 43-46.

DIAGNOSIS: Large Leonardian *Hustedia* in which a slight fold and sulcus are visible at the front.

DEFINITION: Shell large for the genus; proportions variable but usually about as wide as long, with the greatest width forward of mid length. Pedicle valve with the beak of moderate length, slightly incurved; adult

shells with a pronounced sulcus containing two costae; anterior margin truncated across the sulcus. Brachial valve subcircular in outline; beak low, fold visible at the front and containing three costae. Both valves are strongly and angularly costate; costae 10 to 14 in number, with the last few at either side small; well-preserved specimens sometimes show a more or less regular concentric ornamentation.

The interiors of both valves are character-

istic for the genus, except that the margins of the valves bear minute teeth which presumably interlocked to form a straining device.

COMPARISONS: *Hustedia hessensis* is distinguished from other species in the west Texas Permian by the presence of a fold and sulcus.

DISCUSSION: *Hustedia hessensis* occurs in the Hess formation of the Glass Mountains and in the Bone Spring formation of the Sierra Diablo. Its life requirements are unknown, but the species was apparently unable to survive the close of the Leonardian.

The fold and sulcus of the species do not appear until relatively late in ontogeny, and in juveniles the median costa of the brachial valve is lower than the rest, giving the shell a bipartite appearance. Should the juveniles and adults be found separately they would almost certainly be assigned to different species.

SUPERFAMILY ROSTROSPIRACEA SCHUCHERT, 1929

DIAGNOSIS: Ordovician to Jurassic Brachio-
poda bearing calcareous spires of the athyroid type.

FAMILY ATHYRIDAE PHILLIPS, 1841

SUBFAMILY ATHYRINAE WAAGEN, 1883

GENUS COMPOSITA BROWN, 1849

DIAGNOSIS: Mississippian to Permian smooth-shelled terebratuliform Athyrinae.

GENOTYPE: *Spirifer ambiguus* Sowerby.

DEFINITION: Pedicle valve strongly convex; with or without a sulcus; beak prominent, incurved; pedicle foramen large, oval, and opening posteriorly on the delthyrium which is largely filled by the beak of the brachial valve; interarea obsolete. Brachial valve with or without a fold; subcircular in outline. Both valves are smooth but often with numerous concentric growth lines.

Pedicle interior with the hinge teeth supported by dental plates, often partly ankylosed with the outer shell wall, and defining the rostral cavity which was the site of adductor muscle insertion; adductors together forming an elongate heart-shaped scar which is bounded laterally and anteriorly by the larger diductors; muscle area often deeply depressed in the floor of the valve. Brachial

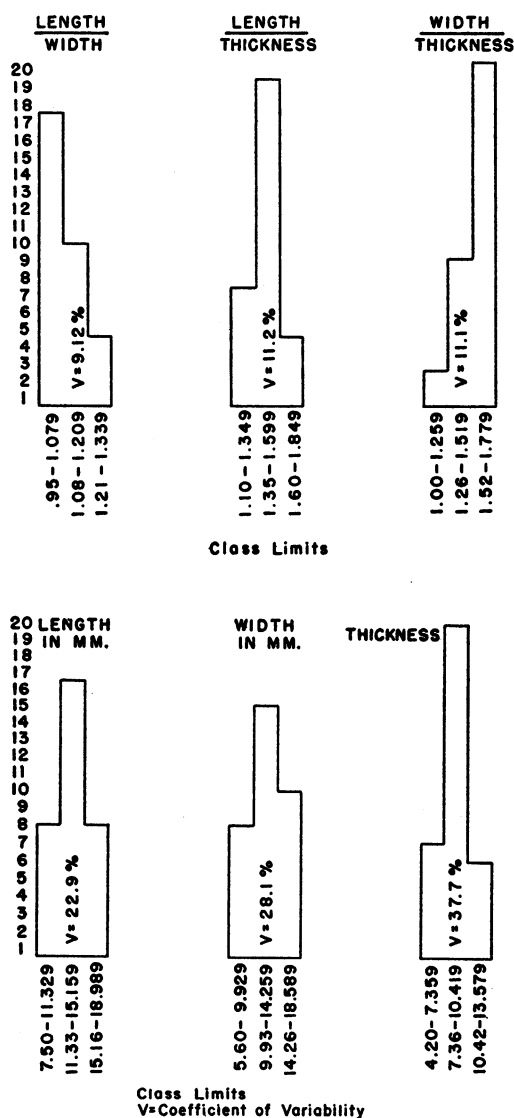


FIG. 51. Individual variation in *Hustedia hessensis* King.

interior with deep sockets bounded by socket plates which outline the distinctive subquadrate hinge plate; hinge plate acting as a cardinal process and anteriorly giving rise to the crura; posterior adductor scars small, oval, and separated by a low ridge; anterior

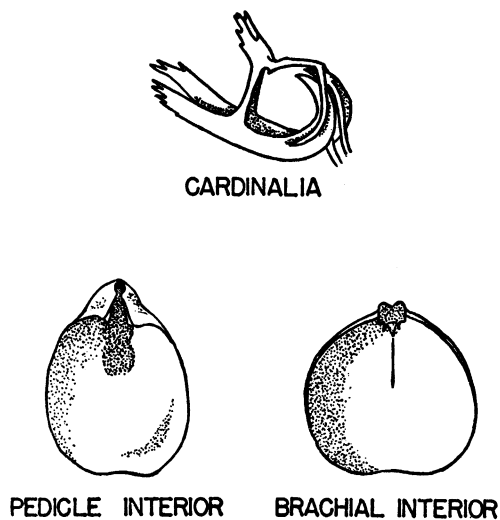


FIG. 52. *Composita*.

adductor scars in contact and together forming an oval depression.

COMPARISONS: *Composita* is of distinctive form and is not readily confused with contemporary genera. It may be distinguished from the Dielasmatidae by the absence of deltidial plates and punctation.

DISCUSSION: *Composita* is a common fossil in a great many areas where rocks of Mississippian to Permian age outcrop, and it is unfortunate that the determination of species is so difficult. The problems connected with the identification of species have been summarized by Weller (1914, p. 485). It is possible to make specific distinctions in most cases, if adequate series of specimens are available, for each species seems to have a characteristic growth form; however, there is great overlap.

***Composita emarginata affinis* Girty**

Plate 27, figures 15-18

Composita emarginata affinis GIRTY, 1908, Prof. Papers U. S. Geol. Surv., no. 58, p. 389, pl. 15, figs. 6-7b.

Composita emarginata affinis R. E. KING, 1930,

Univ. Texas Bull., no. 3042, p. 128, pl. 43, figs. 12-17.

Composita emarginata affinis CLOUD, in King, R. E., Dunbar, Cloud, and Miller, 1944, Special Papers Geol. Soc. Amer., no. 52, p. 65, pl. 18, figs. 20-22.

DIAGNOSIS: Permian *Composita* of medium size, with a strongly uniplicate anterior commissure.

DEFINITION: Pedicle valve strongly convex; sulcus seldom strong but the anterior margin very strongly uniplicate; beak of moderate length, slightly incurved; valve ovate to subpentagonal in outline; slightly longer than wide. Brachial valve subcircular to ovate in outline; beak short, low, and incurved; fold evident only at the anterior edge of the shell; valve moderately to strongly convex. Concentric growth lines form the only ornamentation and are generally limited to the front of the shell.

The interiors of both valves are apparently characteristic of the genus, but the brachidia are unknown.

Measurements (in mm.) of pedicle valves of *Composita emarginata affinis* are as follows:

Length	24	22
Width	20	21

COMPARISONS: Hard and fast lines are difficult to draw in *Composita* and, as specimens are insufficient in the present collection for a growth habit to be discerned, reference to this species is made on a basis of its similarity to illustrated specimens. Little can be said of the differences between this and other species that has not been said by Girty (1908) and King (1930).

SUPERFAMILY TEREBRATULACEA WAAGEN, 1883

DIAGNOSIS: Upper Silurian to Recent, punctate, terebratuliform shells in which the lophophore is supported by a calcareous loop.

FAMILY DIELASMATIDAE SCHUCHERT, 1929

DIAGNOSIS: Silurian to Permian (at least), smooth to costate Terebratulacea in which the cardinal plate is free or sessile and in which normal crural plates are absent; dental plates present or not.

DISCUSSION: The Dielasmatidae have not

been well studied, and the group would benefit from an extension of Cloud's studies of Silurian and Devonian forms into the upper Paleozoic.

SUBFAMILY **DIELASMATINAE** SCHUCHERT,
1913

DIAGNOSIS: Upper Paleozoic Dielasmatidae in which the cardinal plate is composed of two separate plates which join the floor of the valve independently or unite above the floor and are supported by a median septum; dental plates present.

DISCUSSION: This subfamily was originally proposed by Schuchert in the sense in which the name Dielasmatidae is now used, and was later rejected. It is here revived to include those genera which resemble the genotype of *Dielasma* more or less closely in the nature of the cardinalia. It includes *Dielasma*, *sensu stricto*, *Girtyella*, *Dielasmoides*, and at least two undescribed Permian genera from the Guadalupe Mountains.

GENUS **DIELASMA** KING, 1859

DIAGNOSIS: Permian Dielasmatinae in which the anterior commissure is rectimarginate or uniplicate; cardinal plates extending freely from the sockets to the floor and bearing the crura.

GENOTYPE: *Dielasma elongata* King.

DEFINITION: Small to medium-sized Permian terebratuliform shells with a rectimarginate to uniplicate anterior commissure.

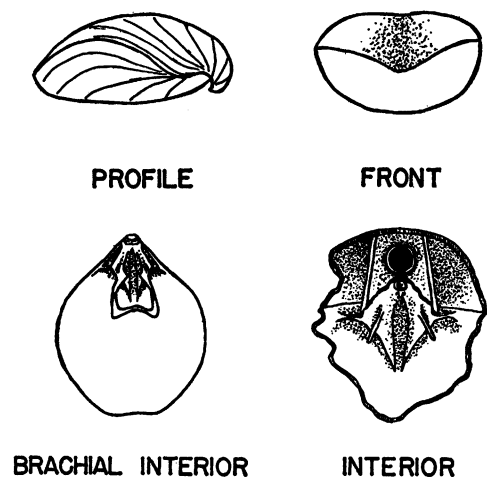


FIG. 53. *Dielasma*.

Pedicle valve usually with a broad rounded or angular sulcus unopposed at the front by a brachial fold; beak slightly incurved; foramen epithyrid often with a groove running posteriorly to the apex of the beak; longitudinally convex. Brachial valve of low longitudinal convexity, but transversely highly convex; front sometimes slightly emarginate.

Pedicle interior with hinge teeth supported by dental plates; beak with a short tubular pedicle sheath; muscle placement not well known. Brachial interior with deep sockets bounded by socket ridges borne on the cardinal plates which extend unattached to the floor; crura arising from the cardinal plate below the sockets; loop short; extreme apex of the beak modified to serve as a cardinal process.

COMPARISONS: *Dielasma* is distinguished from other Dielasmatinae of similar external appearance by the nature of the cardinalia and the presence of dental plates. It most nearly resembles the Mississippian genus *Dielasmoides* Weller but differs from it in that the front is uniplicate or rectimarginate rather than sulcinate.

DISCUSSION: *Dielasma* is a common genus among the Dielasmatinae of the west Texas Permian. Several, or perhaps all, of the species of "*Dielasma*" described by Girty (1908) from the Guadalupe Mountains belong to the genus, but generic assignments cannot be made from his types.

There has been considerable confusion surrounding the genus *Dielasma*, though it was well figured in several early reports. The internal structures of the brachial valve seem to have been misinterpreted by both Weller (1914) and Dunbar and Condra (1932) who applied the name *Dielasma* to shells possessing the cardinalia of "*Dielasma*" *bovidens* Morton. This latter type should be separated from *Dielasma* as a separate genus. It is distinguished from *Dielasma*, *sensu stricto*, by the failure of the cardinal plate to develop between the socket plates and the crura, and by the attachment of the cardinal plate to the wall of the shell.

Because of its pediculate attachment *Dielasma* was washed about after death, and its ecological preferences have not been determined. Like modern shells of similar form, it

probably lived in such sheltered places as crannies between rocks or in pockets in the reef.

***Dielasma diabloense* Stehli, new species**

Plate 27, figures 19–22

TYPES: Syntypes: A.M.N.H. Nos. 27330/1:1 and 27330/1:2; paratypes: A.M.N.H. Nos. 27330/1 and 27330/2; from localities 625 and 629.

DEFINITION: Shell large for the genus, longer than wide, widest near mid length; proportions highly variable. Pedicle valve longitudinally strongly convex; sulcus appearing faintly near mid length and becoming deeper and more angular towards the front (in young individuals the sulcus is shallow and rounded; in mature shells it is deeper and more angular) and often prolonged as a tongue at the front; beak slightly to moderately incurved. Brachial valve only slightly convex transversely; no fold is distinguishable apart from the general curvature of the valve; front usually somewhat emarginate.

Pedicle interior with the dental plates variably inclined so that they converge, diverge, or are parallel; a very low median ridge may be developed near mid length. Brachial interior characteristic for the genus but variable so that the two parts of the cardinal plate may approach each other closely or be widely separated; crura arising close to the sockets or at some distance from them.

Measurements (in mm.) of *Dielasma diabloense* are as follows:

Length	26	19
Width	22	13
Thickness	13	9

COMPARISONS: The relationship of this species to the several species of "*Dielasma*" proposed by Girty (1908) is uncertain. It seems probable that Girty named as species several extreme variations of a single species, but his material is too poor to permit adequate comparison with the present material, and it is felt that it is better to give a new name to the present excellent specimens.

DISCUSSION: This species is known definitely only from the lower part of the Bone Spring formation in the Sierra Diablo. Concomitant with its external variability is con-

siderable variation in the details of the cardinalia. Larger series of specimens than are presently available are necessary before the true range of variation can be adequately determined.

SUBFAMILY CRYPTONELLINAE THOMPSON, 1926

DIAGNOSIS: Devonian to Permian (at least), smooth or costate Dielasmatidae in which the anterior commissure is sulcate or uniplicate; cardinal plate sessile or free; loop cryptonelliform; dental plates present.

GENUS HETERELASMA Girty, 1908

DIAGNOSIS: Permian Cryptonellinae with a uniplicate to sulcinate anterior commissure and a median septum in the pedicle valve.

GENOTYPE: *Heterelasma shumardianum* Girty.

DEFINITION: Small to moderate-sized Permian terebratuliform shells. Pedicle valve longitudinally convex, transversely convex to slightly concave; beak short, with angular shoulders, slightly incurved; foramen small; valve usually with a strong sulcus. Brachial valve longitudinally flat to mildly concave; transversely convex; fold seldom distinguishable from the general curvature of the valve; a small sulcus is often present at the front.

Pedicle interior with dental plates and a low, broad, median septum; position of the



BRACHIAL INTERIOR



PROFILE



FRONT

FIG. 54. *Heterelasma*.

muscle insertions unknown. Brachial interior with the hinge plate entire or apically perforate; cardinal plate unsupported by crural plates; sockets bounded by high socket plates from the anterior ends of which spring the crura; loop cryptonelliform; muscle placement unknown.

COMPARISONS: Externally *Heterelasma* is so distinctive that there is little chance of confusion with other genera from the North American Permian. *Heterelasma* Licharew from the Permian of Sicily is of similar appearance, but the anterior commissure is episulcate and the loop short.

DISCUSSION: Girty established the genus *Heterelasma* for the reception of terebratuloids having a median septum in both valves and a sulcinate anterior margin. In his diagnosis Girty does not state the nature of his evidence for the presence of a brachial median septum. However, one of his paratypes shows a strong septum. This specimen is not a *Heterelasma* but belongs to the genus *Glossothyropsis*. Silicified specimens of the genotype of *Heterelasma* from the Guadalupe Mountains do not show a brachial median septum.

Both of the species originally described by Girty were sulcinate, but this does not seem to be an invariable feature of the genus and is absent in certain species from the Leonardian and Wordian of west Texas and Mexico. In most species the cardinal plate is apically perforate, but in the genotype it is entire. Further study may indicate that one or more new genera are necessary for the reception of species now included in *Heterelasma*.

Heterelasma is known only from the Permian. In west Texas the genus is represented by a number of species, two of which are described below. The various species are generally rather distinctive, and it is possible that with further study they will be found to be valuable stratigraphic guides because of their easy recognition.

Like most pediculate brachiopods *Heterelasma* can seldom be shown to have lived where it is found. Its probable habitat was sheltered places near the reefs.

***Heterelasma geniculata* Stehli, new species**

Plate 27, figures 30-33

DIAGNOSIS: Sulcinate, Leonardian *Heter-*

elasma with a sharply geniculate pedicle valve.

TYPES: A.M.N.H. No. 27333; from locality 629.

DEFINITION: Shell of moderate size for the genus, longer than wide; anterior commissure sulcinate. Pedicle valve sharply geniculate near mid length; sulcus appearing shortly forward of the beak and becoming deep and angular at the geniculation, then flattening at the front which is strongly notched; beak short, slightly incurved; lateral slopes strongly flattened, especially near the geniculation. Brachial valve not well known, but with a reverse plication in the fold.

The pedicle interior is characteristic of the genus. Brachial interior poorly known but with an apically perforate cardinal plate.

Measurements (in mm.) of two pedicle valves of *Heterelasma geniculata* are as follows:

Length	9	10
Width	6	8

COMPARISONS: This species is so distinctive as to be easily distinguished from any described species of the genus.

DISCUSSION: *Heterelasma geniculata* is rare and only seven specimens are known. All were obtained in the lower Bone Spring formation at locality 629. Six specimens are more or less perfect pedicle valves while the seventh is a complete juvenile shell.

***Heterelasma lenticularia* Stehli, new species**

Plate 27, figures 27-29

DIAGNOSIS: Sulcinate Leonardian *Heterelasma* of lenticular longitudinal profile.

TYPES: Holotype: A.M.N.H. No. 27332; from locality 629.

DEFINITION: Shell small, lenticular, pentagonal in outline; anterior commissure sulcinate; shell about as wide as long. Pedicle valve longitudinally of low convexity, transversely nearly flat; beak short, not incurved; sulcus reduced to a median flattening. Brachial valve slightly convex, with a low, broad fold having concave lateral slopes; anteriorly depressed by a small median sulcus.

Interior characters are not well known but are seemingly characteristic of the genus; cardinal plate apically perforate.

Measurements (in mm.) of *Heterelasma lenticularia* are as follows:

Length	8.7
Width	9.2
Thickness	3.7

COMPARISONS: The extremely thin lenticular form of this species is distinctive, and it is easily distinguished from other known species.

DISCUSSION: *Heterelasma lenticularia* is known from a single specimen collected in the Bone Spring formation of the Sierra Diablo at locality 629. It is so far beyond the known range of variation of other species that there can be little doubt that it is new.

GENUS *GLOSSOTHYROPSIS* GIRTY, 1934

DIAGNOSIS: Permian Cryptonellinae with a sulcate anterior commissure and a sessile, entire cardinal plate.

GENOTYPE: *Cryptocanthia* ? *robusta* Girty.

DEFINITION: Small to medium-sized terebratuliform shells of pentagonal outline having a sulcate anterior commissure. Pedicle valve strongly convex longitudinally and transversely; beak short and strongly incurved, with a minute, oval pedicle foramen limited below by deltidial plates; beak ridges sharply angular; fold often indistinguishable from the general curvature of the valve except near the front. Brachial valve transversely almost flat or medially flat with the margins geniculated sharply; sulcus deep and rounded.

Pedicle interior with the hinge teeth supported by dental plates; adductor scars small, elongate, and mostly enclosed by the larger diductors. Brachial interior with a strong median septum; sockets open anteriorly, triangular, bounded laterally by socket plates which give rise to the crura; cardinal plate massively united with the floor of the valve; loop cryptonelliform, descending lamellae spinose, transverse band broad; adductor scars elongate, one on either side of the septum.

COMPARISONS: *Glossothyropsis* differs from most other late Paleozoic Terebratulacea in having a sulcate anterior commissure. It differs from the externally similar *Cryptocanthia*

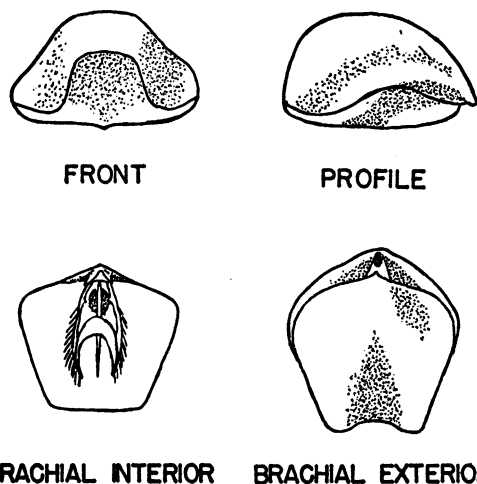


FIG. 55. *Glossothyropsis*.

White and St. John in having a sessile and entire cardinal plate, while in the latter the cardinal plate is raised above the floor of the valve and apically perforate.

DISCUSSION: The sulcate anterior commissure is a feature which occurs sparingly in many groups of brachiopods including a few living genera. Unfortunately its significance is not yet known.

If the rules of nomenclature were strictly interpreted it is doubtful that *Glossothyropsis* would be valid because of the manner in which Girty proposed it; however, names similarly proposed have been accepted in the past. There seems little purpose in rejecting it.

Glossothyropsis is widespread in the Permian of Texas and Mexico, and there is considerable variety of species. The genus seems to range throughout the Permian section here but is unknown in other parts of the world.

Glossothyropsis sinuata Stehli, new species

Plate 27, figures 23–26

DIAGNOSIS: Small Leonardian *Glossothyropsis* with sinuous anterior commissure; fold with concave slopes; brachial valve rather flat.

TYPES: Holotype: A.M.N.H. No. 27331; from locality 629.

DEFINITION: Shell small, pentagonal in

outline, more or less plano-convex; about as wide as long; widest near mid length. Pedicle valve with a high, flat-topped fold having slightly concave lateral slopes which cause the fold at the front to be flanked by two shallow sulci; beak moderately long, somewhat incurved, with very angular lateral slopes; pedicle foramen small and oval. Brachial valve almost flat but with a deep, flat-bottomed sulcus towards the front.

The interior is not well known but seemingly is as described for the genus.

Measurements (in mm.) of *Glossothyropsis sinuata* are as follows:

Length	9.2
Width	8.7
Thickness	5.6

COMPARISONS: This species differs from most others in its very small size. It most closely resembles *G. robusta*, from which it is distinguished by its much flatter brachial valve, the concave lateral slopes of the fold, its longer, less incurved beak, and its more sinuous anterior commissure.

DISCUSSION: *Glossothyropsis sinuata* is known only from the holotype, but it differs in so many respects from *G. robusta* that it is certainly a new species.

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PLATE 17

1-6. *Rhipidomella hessensis* King. 1. Pedicle exterior, A.M.N.H. No. 27282/1:1. 2. Pedicle interior, A.M.N.H. No. 27282/1:2, showing characteristic muscle scars. 3. Pedicle interior, A.M.N.H. No. 27282/1:3, showing hinge teeth which are frequently broken. 4. Brachial exterior, A.M.N.H. No. 27282/1:4, showing pore-like openings of hollow costellae. 5. Brachial interior, same specimen, showing cardinal process and brachiophores. 6. Profile, A.M.N.H. No. 27282/1:1.

7-12. *Orthotichia hueconiana* (Girty). 7. Pedicle exterior, A.M.N.H. No. 27283/1:1. 8. Profile, same specimen. 9. Interior of same pedicle valve, showing strong median septum and dental plates. 10. Profile, brachial valve, A.M.N.H. No. 27283/1:2. 11. Brachial exterior, same specimen. 12. Brachial interior, same specimen, showing brachiophores and supporting plates, as well as low median ridge and minute cardinal process.

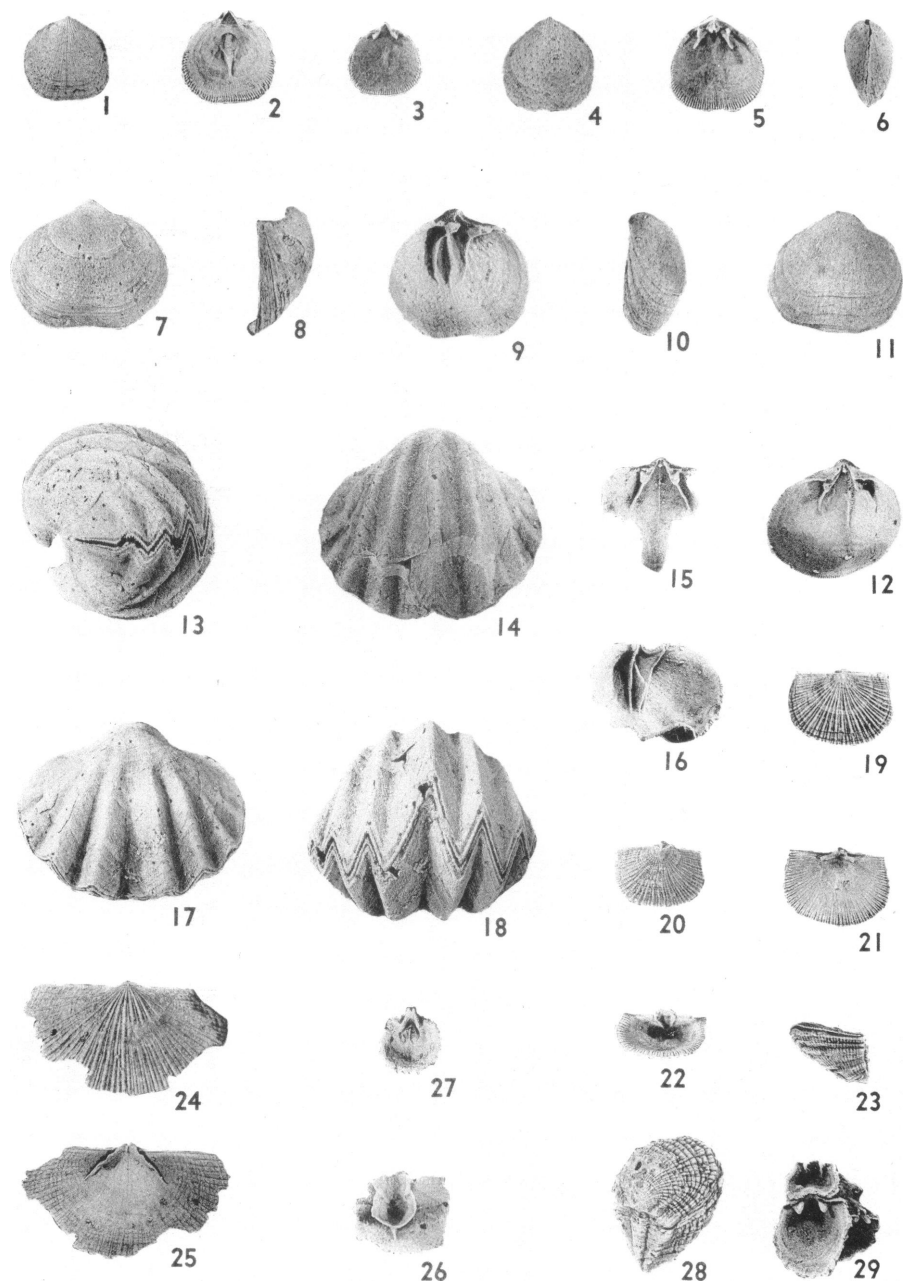
13-18. *Enteleles dumblei* Girty. 13. Profile, A.M.N.H. No. 27284/1:1. 14. Brachial exterior, same specimen. 15. Brachial interior, A.M.N.H. No. 27284/2:2, showing brachiophores and supporting plates and minute cardinal process. 16. Pedicle interior, A.M.N.H. No. 27284/2:1, showing dental plates and very high median septum. 17. Pedicle exterior, A.M.N.H. No. 27284/1:1. 18. Front, same specimen.

19-23. *Schuchertella permiana* Stehli, new species. 19. Brachial exterior, A.M.N.H. No. 27285/1:1. 20. Pedicle exterior, A.M.N.H. No. 27285/1:3. 21. Brachial interior, A.M.N.H. No. 27285/1:1, showing low cardinal process and crural plates. 22. Pedicle interior, A.M.N.H. No. 27285/1:3, showing absence of dental plates and presence of a low ridge, indicating trace of growth of hinge teeth. 23. Profile, A.M.N.H. No. 27285/1:2.

24-26. *Orthotetella wolfcampensis* King. 24. Exterior of fragmentary brachial valve, A.M.N.H. No. 27287/1:1. 25. Interior, same specimen, showing low cardinal process and long crural plates. 26. Fragment of pedicle interior, A.M.N.H. No. 27287/1:2, showing characteristic conical spondylium of the genus and supporting median septum.

27-29. *Diplanus lamellatus* (King). 27. Brachial interior, A.M.N.H. No. 27286/1:1, showing high cardinal process, recurved crural plates, and adductor muscle scars. 28. A.M.N.H. No. 27286/1:2, showing characteristic ornamentation of the genus as well as interarea of brachial valve. 29. A.M.N.H. No. 27286/1:3, showing pedicle interior of several individuals in a clump.

All figures natural size.



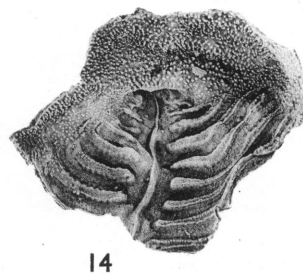
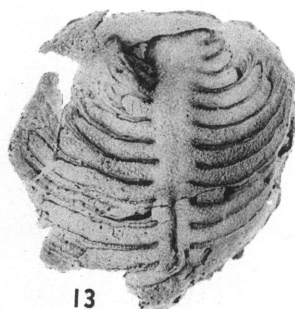
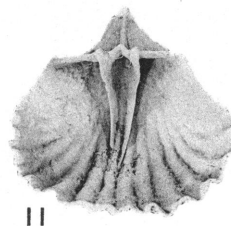
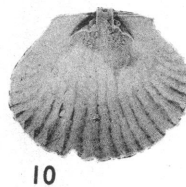
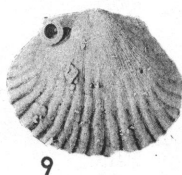
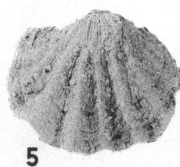
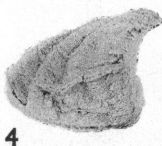
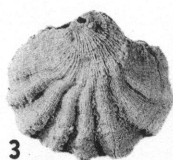
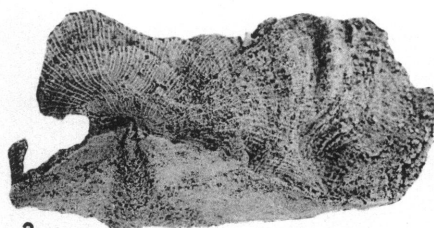
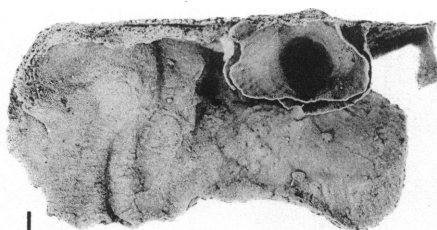


PLATE 18

1, 2. *Orthotetella wolfcampensis* King. 1. Pedicle interior of fragmentary individual of large size, A.M.N.H. No. 27287/1:3, showing spondylium. 2. Exterior, same specimen, showing interarea and ornamentation.

3-5. *Meekella hessensis* King. 3. Pedicle exterior, A.M.N.H. No. 27288/1:1. 4. Profile, same specimen. 5. Brachial exterior, same specimen.

6-11. *Meekella attenuata* Girty. 6. Profile, A.M.N.H. No. 27289/1:1. 7. Profile, A.M.N.H. No. 27289/1:2. 8. Pedicle exterior, A.M.N.H. No. 27289/1:1. 9. Brachial exterior, A.M.N.H. No. 27289/1:2. 10. Interior, same specimen, showing high cardinal process, crural plates, and socket ridges. 11. Interior, A.M.N.H. No. 27289/1:1, showing hinge teeth and long, subparallel dental plates.

12-14. *Leptodus ? diabloensis* Stehli, new species. 12. A.M.N.H. No. 27290/1:1, showing fragmentary pedicle exterior. 13. Interior, same specimen, showing pinnate brachial valve in place, and hood-like posterior wall of cone. 14. Pedicle interior, A.M.N.H. No. 27290/1:2, showing lateral ridges and median ridge and papillose nature of inside of hood.

All figures natural size.

PLATE 19

1-3. *Leptodus* ? *marshalli* Stehli, new species. 1. Fragment of pedicle valve, A.M.N.H. No. 27291/1:1, showing attachment to a crinoid stem. 2. Fragment of pedicle valve, A.M.N.H. No. 27291/1:2, showing rolled back posterolateral margins and hinge. The valve is attached to several brachial valves of *Leptodus* ?. 3. Fragment of pedicle valve, A.M.N.H. No. 27291/1:3, showing attachment to a platycerid snail, which frequented crinoids.

4. *Poikilosakos* ? *petaloides* Watson. Pedicle interior of small individual, A.M.N.H. No. 27292, attached to exterior of a brachial valve of *Cancrinella altissima*, and showing characteristic asymmetrical muscle development.

5-8. *Lissochonetes sinesulcus* Stehli, new species. 5. Pedicle exterior, A.M.N.H. No. 27293/1:1, showing slight median flattening. 6. Interior, same specimen. 7. Brachial exterior, A.M.N.H. No. 27293/1:2. 8. Brachial interior, same specimen, showing cardinal process, brachiophores, and median septum.

9-12. *Dyoros consanguineus* (Girty). 9. Brachial exterior, A.M.N.H. No. 27294/1:1. 10. Brachial interior, A.M.N.H. No. 27294/1:2, showing raised papillose rim around visceral disc, spine bearing median septum, brachiophores, cardinal process, and socket ridges. 11. Pedicle interior, A.M.N.H. No. 27294/1:3. 12. Pedicle exterior, showing smooth surface and fold at either side of sulcus in same specimen.

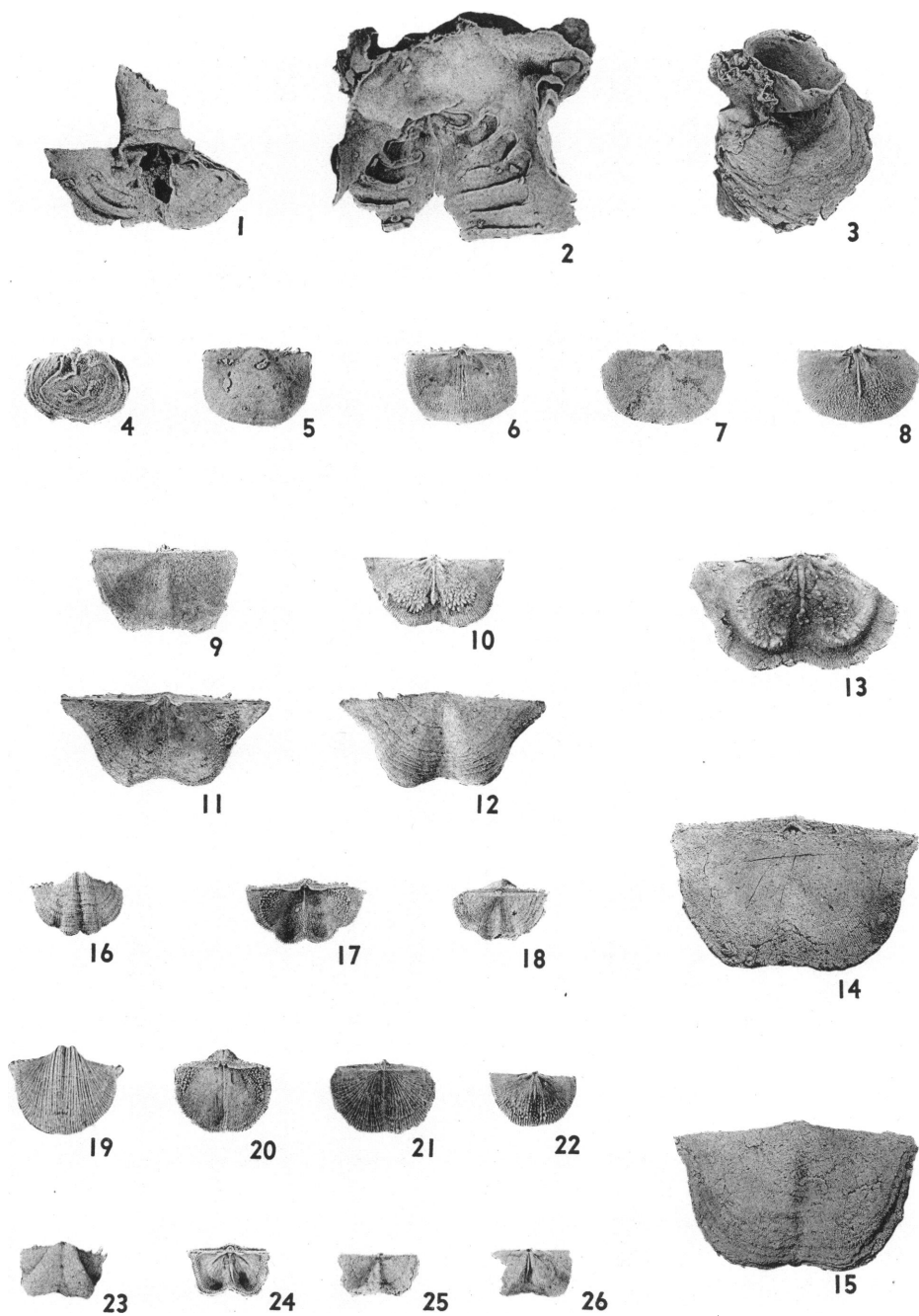
13-15. *Dyoros* ? *magnus* Stehli, new species. 13. Brachial interior, A.M.N.H. No. 27295/1:1, showing raised, papillose rim around visceral disc, spine bearing median septum, brachiophores, and flattened rim of valve. 14. Brachial exterior, A.M.N.H. No. 27295/1:2, showing faint radial ornamentation which may or may not be a surface feature of shell. 15. Pedicle exterior, same specimen.

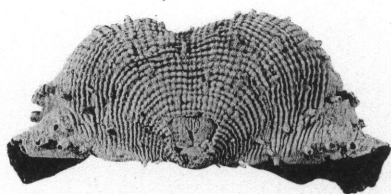
16-18. *Chonetinella biplicata* (King). 16. Pedicle exterior, A.M.N.H. No. 27296/1:1, showing strong fold at either side of sulcus and fine costellae. 17. Pedicle interior, A.M.N.H. No. 27296/1:2. 18. Brachial exterior, A.M.N.H. No. 27296/1:1, showing double sulcus.

19-22. *Chonetinella victoriana* (Girty). 19. Pedicle exterior, A.M.N.H. No. 27297/1:1, showing fasciculate costellae. 20. Pedicle interior, A.M.N.H. No. 27297/1:2. 21. Brachial exterior, A.M.N.H. No. 27297/1:3. 22. Brachial interior, A.M.N.H. No. 27297/1:4, showing radiating papillae, median septum, and cardinal process.

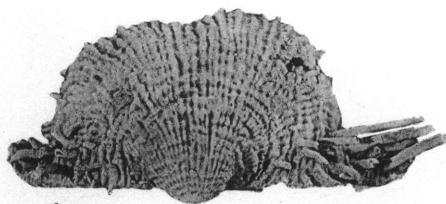
23-26. *Quadrochonetes girtyi* Stehli, new species. 23. Pedicle exterior, A.M.N.H. No. 27298/1:1, showing angular nature of folds. 24. Pedicle interior, A.M.N.H. No. 27298/1:2, showing muscle scars. 25. Brachial exterior, A.M.N.H. No. 27298/1:3. 26. Brachial interior, A.M.N.H. No. 27298/1:4, showing low median septum and virtual absence of radiating rows of papillae.

All figures natural size.

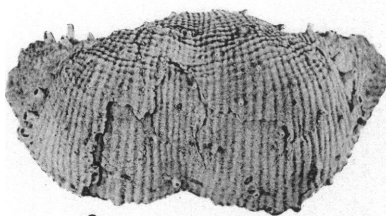




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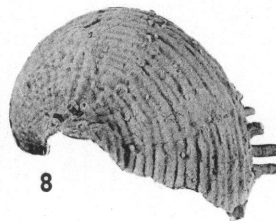
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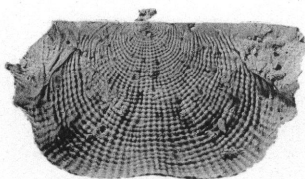
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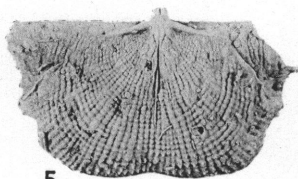
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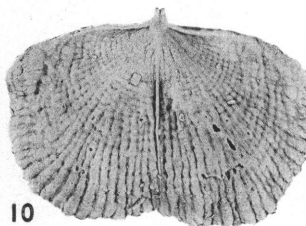
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PLATE 20

1-5. *Antiquatonia planumbona* Stehli, new species. 1. Posterior, A.M.N.H. No. 27299/2:1, showing row of cardinal spines and row above ears. 2. Pedicle exterior, same specimen. 3. Profile, same specimen, showing spine-bearing ridge above ears and flattened posterior slope of shell. 4. Brachial exterior, A.M.N.H. No. 27299/2:2. 5. Brachial interior, same specimen.

6-10. *Spinifrons quadratus* Stehli, new species. 6. Posterior, A.M.N.H. No. 27300/1:1, showing strong spines on ears. 7. Pedicle exterior, same specimen, showing ear spines and bases of spines in middle of anterior slope. 8. Profile, A.M.N.H. 27300/1:2, showing spines in middle of anterior slope. 9. Brachial exterior, A.M.N.H. No. 27300/1:3. 10. Brachial interior, same specimen.

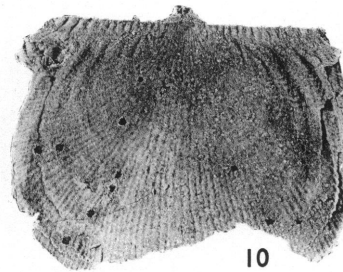
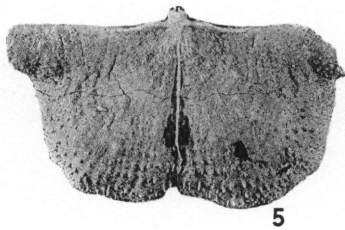
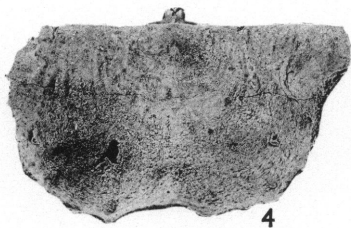
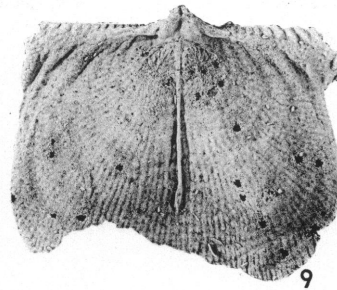
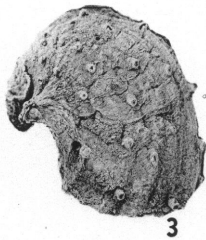
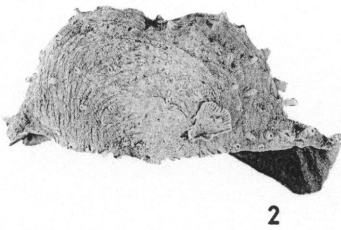
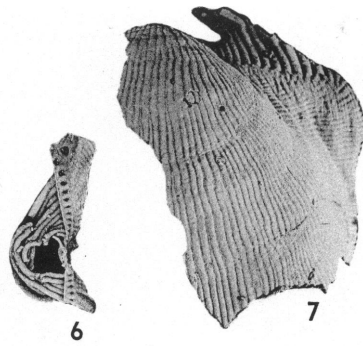
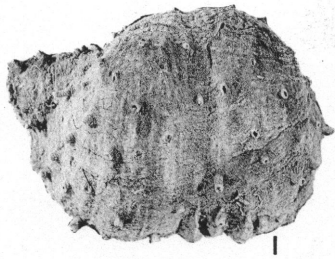
All figures natural size.

PLATE 21

1-5. *Nudauris diabloensis* Stehli, new species. 1. Pedicle exterior, A.M.N.H. No. 27301/1:1, showing single row of cardinal spines on ears. 2. Posterior, same specimen. 3. Profile, same specimen, showing spine pattern. 4. Brachial exterior, A.M.N.H. No. 27301/1:2, showing absence of spines. 5. Brachial interior, same specimen.

6-10. *Linoproductus philocrinus* Stehli, new species. 6. Attachment spines as they were used for grasping a crinoid stem, A.M.N.H. No. 27302/1:1. 7. Fragment of pedicle valve, A.M.N.H. No. 27302/1:2, showing absence of spines except at hinge. 8. Interior, same specimen, showing cicatrix of attachment at beak and strong spine bases at hinge. 9. Brachial interior, A.M.N.H. No. 27302/1:3, showing seeming denticulation of hinge and cardinal process and median septum. 10. Brachial exterior, same specimen.

All figures natural size.



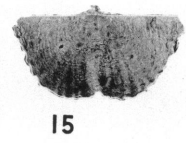
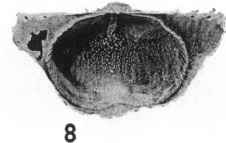
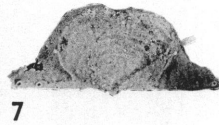
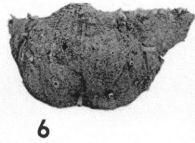
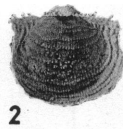


PLATE 22

1-5. *Cancrinella altissima* King. 1. Pedicle exterior, A.M.N.H. No. 27303/1:1. 2. Pedicle interior, same specimen. 3. Profile, A.M.N.H. No. 27303/1:2. 4. Brachial exterior, A.M.N.H. No. 27303/1:3. 5. Brachial interior, same specimen.

6-11. *Kozłowska kingi* Stehli, new species. 6. Pedicle exterior, A.M.N.H. No. 27304/1:1. 7. Posterior, A.M.N.H. No. 27304/2:1. 8. Pedicle interior, same specimen, showing ridge around visceral area and raised muscle scars. 9. Brachial exterior, A.M.N.H. No. 27304/1:2, showing fringe of old trails around edge of valve. 10. Brachial interior, A.M.N.H. No. 27304/2:2, showing marginal ridge, parallel spines, brachial ridges, median septum, muscle scars, and cardinal process. 11. Profile of specimen, A.M.N.H. No. 27304/3:1, retaining most of spines.

12-16. *Psilonotus transversalis* Stehli, new species. 12. Pedicle exterior of specimen, A.M.N.H. No. 27305/2:1, showing many spines intact. 13. Pedicle exterior, A.M.N.H. No. 27305/1:1, with spines broken. 14. Profile, same specimen. 15. Brachial exterior, A.M.N.H. No. 27305/1:2, showing absence of spines and faintness of costation. 16. Brachial interior, A.M.N.H. No. 27305/1:3, showing absence of marginal ridge, presence of spines, and brachial ridges and median septum.

17-19. *Psilonotus minimus* Stehli, new species. 17. Pedicle exterior, A.M.N.H. No. 27306/1:1. 18. Brachial exterior, A.M.N.H. No. 27306/1:2, showing strong costation of spines. 19. Profile, A.M.N.H. No. 27306/1:1.

20-22. *Alexenia* ? *parvispinosa* Stehli, new species. 20. Profile, A.M.N.H. No. 27307/1:1. 21. Pedicle exterior, A.M.N.H. No. 27307/1:2, showing ear spines. 22. Fragment of pedicle exterior, A.M.N.H. No. 27307/1:3, showing spines.

All figures natural size.

PLATE 23

1, 2. *Alexenia* ? *parvispinosa* Stehli, new species. 1. Brachial exterior, A.M.N.H. No. 27307/1:4. 2. Brachial interior, same specimen, showing partial marginal ridge broken by spines at front.

3, 4. *Ramavectus diabloensis* Stehli, new species. 3. Brachial exterior, A.M.N.H. No. 27308/1:1. 4. Fragment of brachial interior, A.M.N.H. No. 27308/1:2, showing elongate cardinal process with its four buttressing ridges.

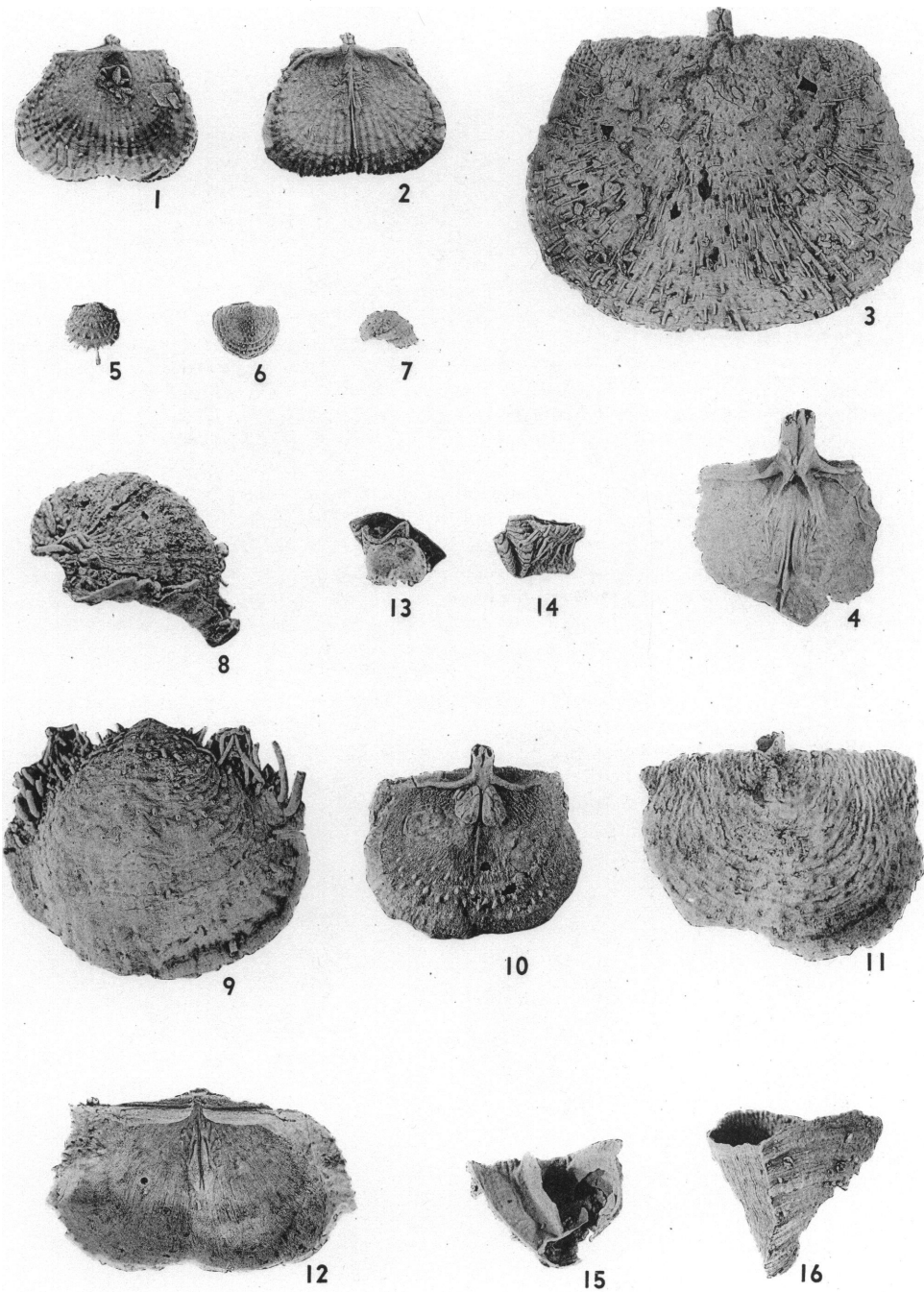
5-7. *Overtonia plummeri* King. 5. Pedicle exterior, A.M.N.H. No. 27309/1:1, showing pattern of single rows of spines. 6. Brachial exterior, A.M.N.H. No. 27309/1:2, showing same spine pattern on this valve. 7. Profile, A.M.N.H. No. 27309/1:3.

8-12. *Limbella victorioensis* Stehli, new species. 8. Profile, A.M.N.H. No. 27310/1:1, showing recurved skirt. 9. Pedicle exterior, A.M.N.H. No. 27310/1:1, showing skirt and spine tufts on ears. 10. Brachial interior, A.M.N.H. No. 27310/1:2, showing elongate cardinal process and raised muscle platforms. 11. Brachial exterior, A.M.N.H. No. 27310/1:3, showing wrinkled and pitted ornamentation. 12. Pedicle interior, A.M.N.H. No. 27310/1:4, showing muscle scars and interarea.

13, 14. *Heteralosia* sp. 13. Pedicle interior, A.M.N.H. No. 27324/1:2, showing hinge teeth. 14. Front, same specimen, showing its attachment to brachial valve of *Punctospirifer* ? *irenae*.

15, 16. *Scacchinella americana* Stehli, new species. 15. Fragment of pedicle interior, A.M.N.H. No. 27311/1:1, showing median septum and a single horizontal platform sealing off base of cone. 16. Pedicle valve, A.M.N.H. No. 27311/1:2, showing general shape of valve and its broad, flat interarea.

All figures natural size.



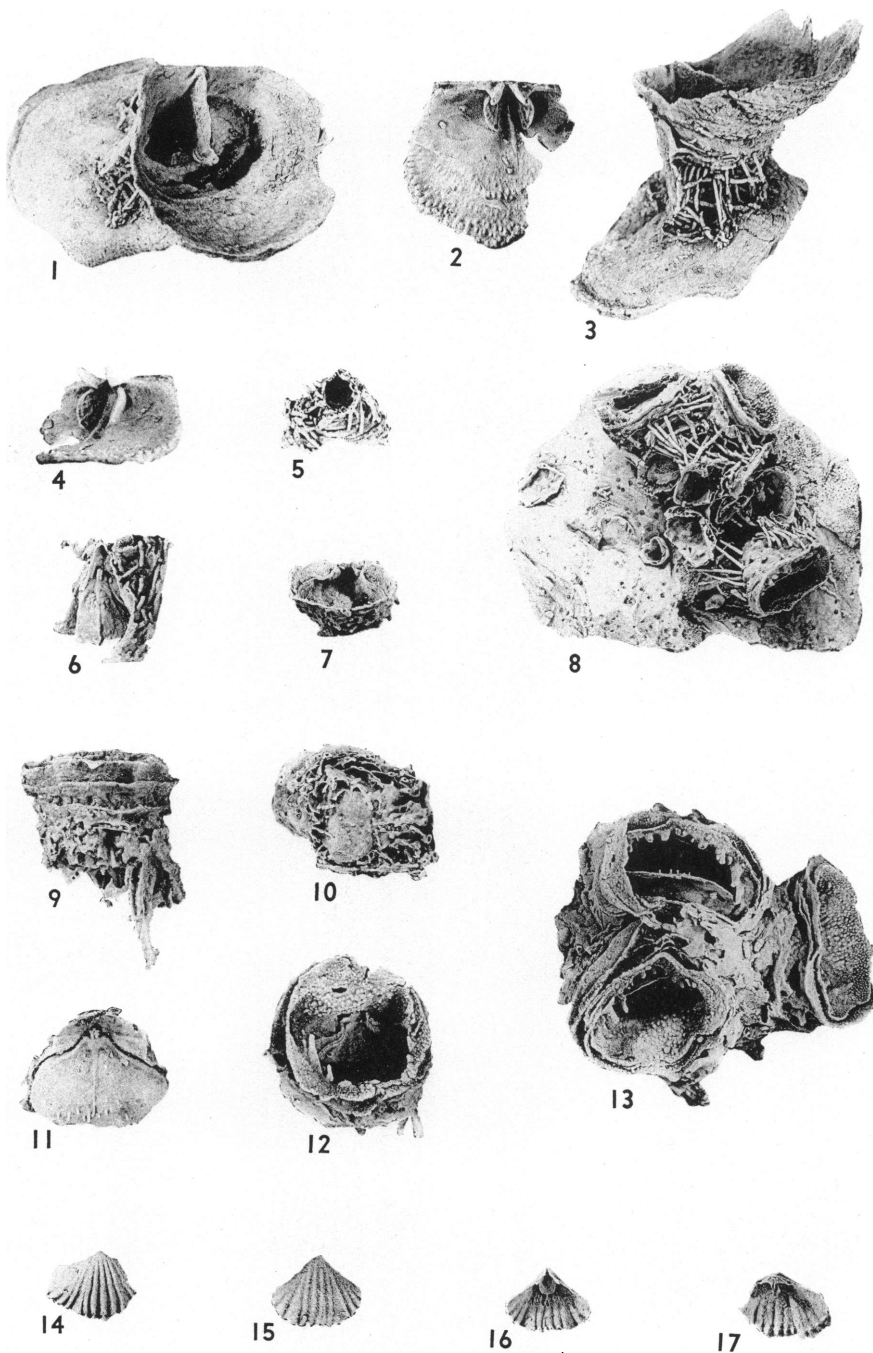


PLATE 24

1-4. *Scacchinella americana* Stehli, new species. 1. Large pedicle valve, A.M.N.H. No. 27311/1:3, attached by anchoring spines to a brachial valve of same species; note strong median septum. 2. Brachial interior, A.M.N.H. No. 27311/1:4, showing raised and inclined muscle platforms, median septum, strong, two-pronged cardinal process, and articular fossette at extremity of hinge. 3. Same specimen as in 1, showing anchoring spines. 4. Same specimen as in 2, showing two-pronged cardinal process.

5-8. *Teguliferina* ? *teguliferoides* (King). 5. Pedicle valve, A.M.N.H. No. 27312/1:1, showing attachment of spines to crinoid stem. 6. Brachial interior, A.M.N.H. No. 27312/1:2, showing cardinal process, muscle scars, and median ridge. 7. Same specimen as in 5, showing small internal "area." 8. A.M.N.H. No. 27312/1:3, a clump of individuals in growth position on fragment of shell of *Leptodus* ?.

9-13. *Planispina conida* Stehli, new species. 9. Profile, A.M.N.H. No. 27313/1:1, showing nested cones characteristic of the species, and flattened spines. 10. Same specimen, showing base of cone and flattened spines. 11. Brachial interior, A.M.N.H. No. 27313/1:2, showing cardinal process, median ridge, and marginal spines. 12. Pedicle interior, A.M.N.H. No. 27313/1:3, showing small internal "area" and marginal ridge which supports brachial valve. 13. A.M.N.H. No. 27313/1:4, a clump of individuals in growth position.

14-17. *Stenosisma hueconiana* (Girty). 14. Fragment of brachial exterior, A.M.N.H. No. 27314/1:1. 15. Pedicle exterior, A.M.N.H. No. 27314/1:2. 16. Interior, same specimen, showing spondylium. 17. Interior of branchial valve, A.M.N.H. No. 27314/1:1.

All figures natural size.

PLATE 25

1-6. *Stenosisma kala* Stehli, new species. 1. Brachial exterior, A.M.N.H. No. 27315/1:1, with marginal skirt still partially intact. 2. Profile, pedicle valve, A.M.N.H. No. 27315/1:2. 3. Profile, brachial valve, A.M.N.H. No. 27315/1:1. 4. Interior, pedicle valve, A.M.N.H. No. 27315/1:2, showing spondylium. 5. Pedicle exterior, same specimen. 6. Brachial interior, A.M.N.H. No. 27315/1:1, showing teeth at margin of valve, hinge plate, cardinal process, and cruralium.

7-9. *Stenosisma multicosta* Stehli, new species. 7. Fragment of brachial interior, A.M.N.H. No. 27316/1:1, showing cardinal process, hinge plate, cruralium, and several pallial trunks. 8. Fragment of pedicle interior, A.M.N.H. No. 27316/1:2, showing spondylium and supporting median septum. 9. Slightly broken pedicle exterior, A.M.N.H. No. 27316/1:3, showing nature of costation.

10-12. *Wellerella magnisepta* Stehli, new species. 10. Interiors of both valves, A.M.N.H. No. 27334/1:1, showing strong median septum of species. 11. Pedicle exterior, A.M.N.H. No. 27334/1:2. 12. Brachial exterior, A.M.N.H. No. 27334/1:3.

13-17. *Wellerella elgans* ? (Girty). 13. Pedicle interior, A.M.N.H. No. 27317/1:3, showing dental plates. 14. Profile, A.M.N.H. No. 27317/1:1. 15. Brachial exterior, same specimen. 16. Brachial interior, A.M.N.H. No. 27317/1:2, showing hinge plate, low median septum, and muscle scars. 17. Pedicle exterior, A.M.N.H. No. 27317/1:1.

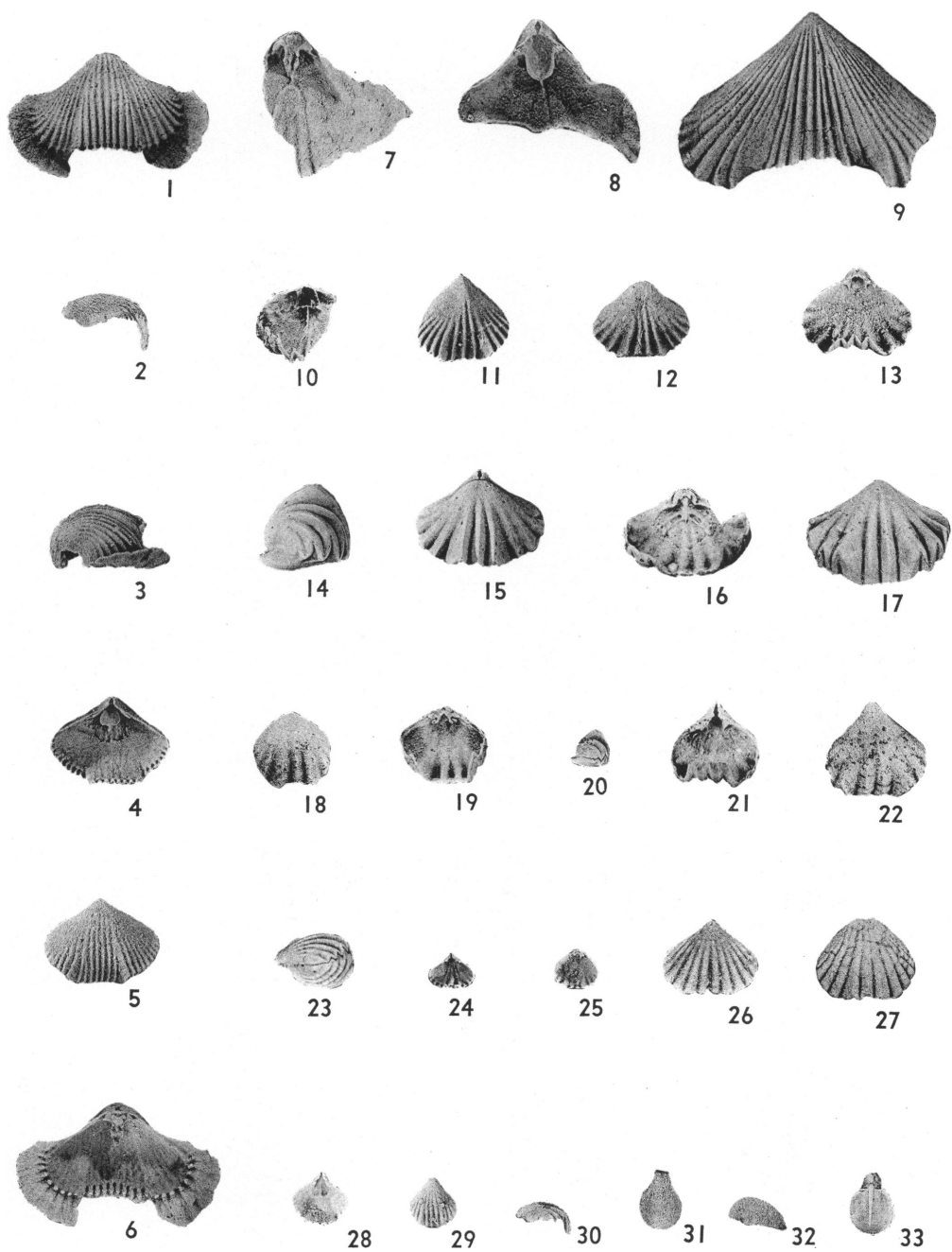
18-22. *Wellerella nanas* Stehli, new species. 18. Brachial exterior, A.M.N.H. No. 27318/1:1. 19. Interior, same specimen. 20. Profile, A.M.N.H. No. 27318/1:2. 21. Pedicle interior, A.M.N.H. No. 27318/1:3, showing dental plates. 22. Pedicle exterior, same specimen.

23-27. *Wellerella longicosta* Stehli, new species. 23. Profile, A.M.N.H. No. 27319/1:1. 24. Pedicle interior, A.M.N.H. No. 27319/1:2. 25. Brachial interior, A.M.N.H. No. 27319/1:3. 26. Pedicle exterior, A.M.N.H. No. 27319/1:2, showing manner in which costae approach the umbo. 27. Brachial exterior, A.M.N.H. No. 27319/1:3.

28-30. *Terebratuloides ? lenumbona* Stehli, new species. 28. Pedicle interior, A.M.N.H. No. 27320/1:1, showing muscle scars. 29. Pedicle exterior, A.M.N.H. No. 27320/1:2. 30. Pedicle profile, same specimen.

31-33. *Attenuatella texana* Stehli, new species. 31. Pedicle exterior, A.M.N.H. No. 27321, showing greatly attenuated beak. 32. Pedicle profile, same specimen. 33. Pedicle interior, same specimen, showing strong median ridge.

1-17, 20, 24, 25, and 28-33 are natural size; 18, 19, 21-23, 26, and 27 are twice natural size.



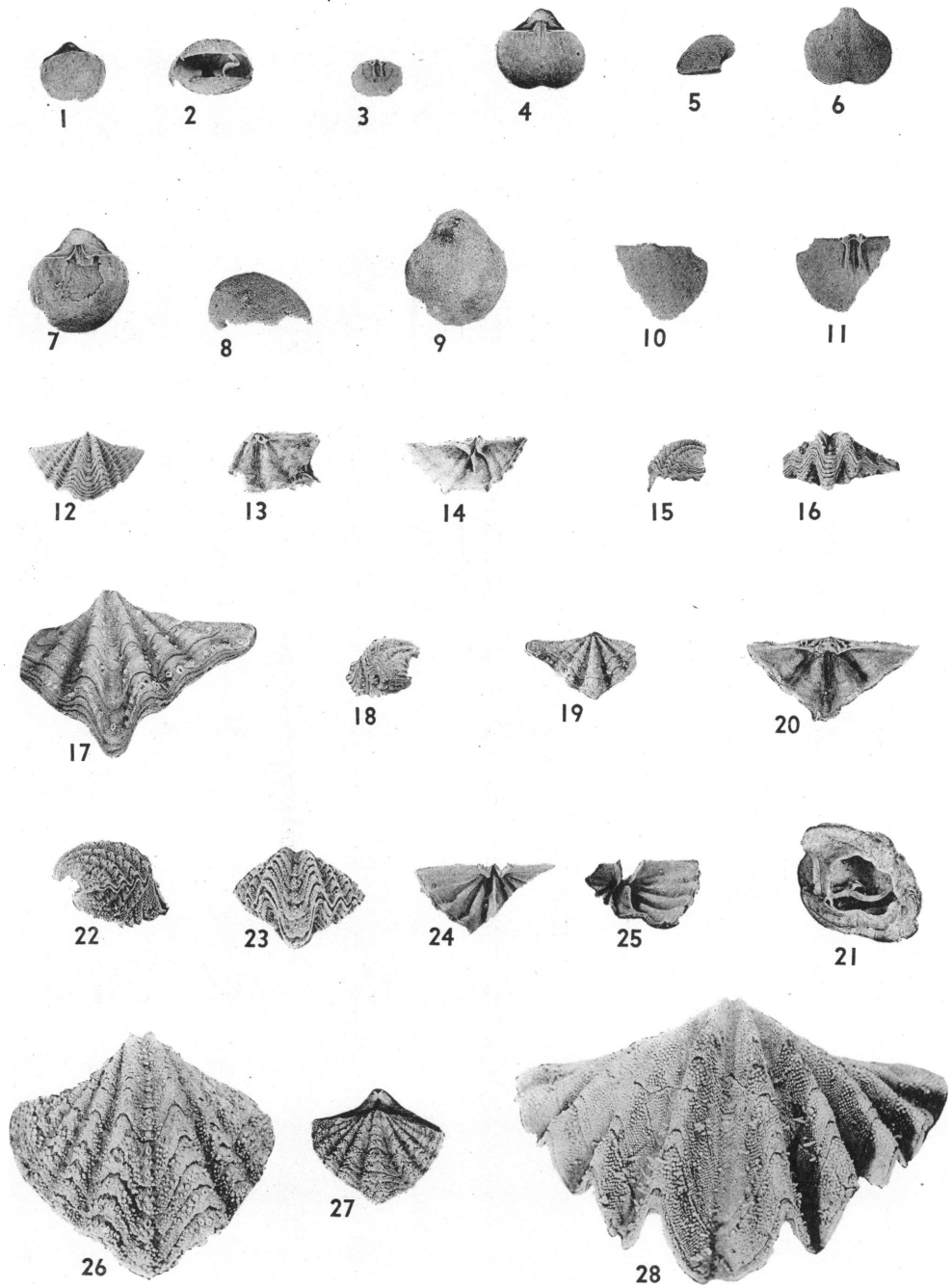


PLATE 26

1-6. *Crurithyris sulcata* Stehli, new species. 1. Brachial exterior, A.M.N.H. No. 27322/1:1, showing slight emargination of front. 2. Interior, A.M.N.H. No. 27322/1:2, showing initial part of spire. 3. Brachial interior, A.M.N.H. No. 27322/1:3, showing crura and sockets. 4. Pedicle interior, A.M.N.H. No. 27322/1:4. 5. Profile, A.M.N.H. No. 27322/1:1. 6. Pedicle exterior, A.M.N.H. No. 27322/1:4, showing characteristic sulcus.

7-11. *Crurithyris inflata* Stehli, new species. 7. Pedicle interior, A.M.N.H. 27323/1:1. 8. Pedicle profile, same specimen. 9. Pedicle exterior, same specimen. 10. Brachial exterior, A.M.N.H. No. 27323/2:1. 11. Brachial interior, same specimen, showing crura and sockets.

12-15. *Punctospirifer ? irenae* Stehli, new species. 12. Pedicle exterior, A.M.N.H. No. 27324/1:1, showing regular, imbricating lamellae. 13. Brachial interior, A.M.N.H. No. 27324/1:2. 14. Pedicle interior, A.M.N.H. 27324/1:1, showing dental lamellae and median septum. 15. Pedicle profile, same specimen.

16-21. *Altipecus cooperi* Stehli, new species. 16. Front, A.M.N.H. No. 27325/1:1, showing flattened nature of front. 17. Pedicle exterior, same specimen, showing strong, concentrically arranged spines. 18. Profile, same specimen. 19. Brachial exterior, same specimen, showing strong fold and relatively weaker lateral plications. 20. Brachial interior, A.M.N.H. No. 27325/1:2. 21. Interior, A.M.N.H. No. 27325/1:3, showing crura, jugum, and descending lamellae.

22-27. *Spiriferellina newelli* Stehli, new species. 22. Profile, A.M.N.H. No. 27326/1:1. 23. Front, same specimen. 24. Pedicle interior, A.M.N.H. No. 27326/1:2, showing dental plates and median septum. 25. Pedicle interior, same specimen. 26. Pedicle exterior, A.M.N.H. No. 27326/1:1, showing spine pattern. 27. Brachial exterior, same specimen.

28. *Crenispirifer angulatus* (King). Pedicle exterior, A.M.N.H. No. 27327/1:4, showing spine pattern.

All figures natural size, except 17, 21, 26, and 28 which are twice natural size.

PLATE 27

1-7. *Crenispirifer angulatus* (King). 1. Brachial interior, A.M.N.H. No. 27327/1:1, showing crura and descending lamellae. 2. Interior, A.M.N.H. No. 27327/2:1, showing crura, descending lamella, and half of jugum. 3. Brachial exterior, A.M.N.H. 27327/1:2. 4. Brachial interior, A.M.N.H. No. 27327/1:3, showing cardinal process, sockets, and ridges bounding muscle field. 5. Front, A.M.N.H. No. 27327/1:2, showing height and angularity of plications. 6. Pedicle interior, A.M.N.H. No. 27327/1:4, showing dental lamellae, median septum, and callus in beak. 7. Profile, A.M.N.H. No. 27327/1:2.

8-14. *Hustedia hessensis* King. 8. Pedicle exterior, A.M.N.H. 27328/1:1. 9. Brachial exterior, A.M.N.H. No. 27328/1:2. 10. Profile, A.M.N.H. No. 27328/1:1. 11. Front, A.M.N.H. No. 27328/1:1, showing fold and sulcus. 12. Pedicle interior, A.M.N.H. No. 27328/1:3, showing symphytium and hinge teeth. 13. Brachial interior, A.M.N.H. No. 27328/1:4, showing nearly entire spires. 14. Interior, A.M.N.H. No. 27328/1:5, showing cardinalia.

15-18. *Composita emarginata affinis* Girty. 15. Pedicle exterior, A.M.N.H. No. 27329/1:1. 16. Brachial exterior, A.M.N.H. No. 27329/1:2. 17. Pedicle interior, A.M.N.H. No. 27329/1:1, showing depressed muscle area and hinge teeth. 18. Brachial interior, A.M.N.H. No. 27329/1:2, showing quadrate hinge plate.

19-22. *Dielasma diabloense* Stehli, new species. 19. Pedicle exterior, A.M.N.H. No. 27330/1:1. 20. Profile, same specimen, showing incurved beak. 21. Interior, A.M.N.H. No. 27330/1:2, showing dental plates and pedicle sheath of pedicle valve and sockets, socket plates, cardinal plates, and crura of brachial valve. 22. Brachial exterior, A.M.N.H. No. 27330/1:1.

23-26. *Glossothyropsis sinuata* Stehli, new species. 23. Pedicle exterior, A.M.N.H. No. 27331, showing fold. 24. Brachial exterior, same specimen, showing sulcus. 25. Profile, same specimen. 26. Front, same specimen, showing sinuous anterior margin, with shallow sulci bounding fold.

27-29. *Heterelasma lenticularia* Stehli, new species. 27. Brachial exterior, A.M.N.H. No. 27332. 28. Profile, same specimen, showing thinness of shell. 29. Pedicle exterior, same specimen.

30-33. *Heterelasma geniculata* Stehli, new species. 30. Pedicle profile, A.M.N.H. No. 27333/1:2. 31. Anterior slope of pedicle valve, A.M.N.H. No. 27333/1:2. 32. Posterior slope of pedicle valve, A.M.N.H. No. 27333/1:1. 33. Pedicle interior, A.M.N.H. No. 27333/1:1.

All figures natural size.

