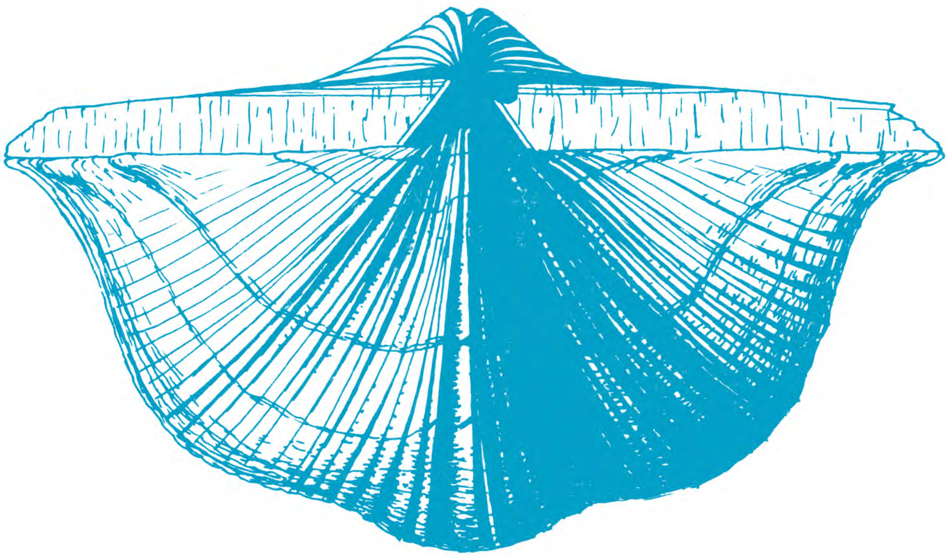
Pennsylvanian Brachiopods and Biostratigraphy in Southern Sangre de Cristo Mountains, New Mexico

by PATRICK K. SUTHERLAND and FRANCIS H. HARLOW



MEMOIR 27 New Mexico Bureau of Mines & Mineral Resources 1973

A DIVISION OF

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Pennsylvanian Brachiopods and Biostratigraphy
in Southern Sangre de Cristo Mountains,
New Mexico

DALTON BLUFF—*The most important Pennsylvanian stratigraphic sequence in the Sangre de Cristo area (measured section 36).*

Memoir 27

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Abstract

Pennsylvanian marine strata are exposed extensively in the southern Sangre de Cristo Mountains of north-central New Mexico. The area studied extends from Santa Fe and Lamy in the south to Taos in the north. The Pennsylvanian strata show marked lateral changes in thickness and lithology from a thin, predominantly carbonate shelf facies in the south to a thick, predominantly terrigenous trough facies in the north. The combined thickness of the La Pasada and Alamitos Formation is 2,200 feet in the south; the Flechado and Alamitos Formations are greater than 6,500 feet in the north. The Morrow, Atoka, and Des Moines Series are particularly well represented.

Analysis of the regional Pennsylvanian stratigraphy of the area would have been impossible without a detailed study of the brachiopod faunas that form the most common element in the megafaunas of the Pennsylvanian System. Correlations in the middle and upper parts of the Pennsylvanian (upper Atokan to Virgilian) were aided by detailed information provided by the fusulinids, where they occur, and in the lower part of the section (Morrowan) by the conodonts.

This study provides a better understanding of the evolutionary relationships of the brachiopod faunas in the lower parts of the Pennsylvanian System. It documents for the first time the marked evolutionary changes that occur in many brachiopod groups between the Morrow and lower Des Moines Series, and to some extent between the Morrowan and Atokan. In contrast, rates of change are comparatively slow in most brachiopod groups higher in the Pennsylvanian, in the Des Moines, Missouri, and Virgil Series.

Ninety-four species belonging to 42 genera of brachiopods are described. Three new generic names are proposed, *Sandia*, *Tesuquea* and *Zia*. Twenty-nine new species and subspecies are described: *"Orbiculoidea" youngi*, *Rhipidomella trapezoida*, *Derbyia bonita*, *Neochonetes henryi*, *Neochonetes whitei*, *Mesolobus profundus*, *Kozlowskia montgomeryi*, *Desmoinesia nambeensis*, *Sandia brevis*, *Sandia santafeensis*, *Pulchratia? pustulosa*, *Pulchratia? picuris*, *Buxtonia grandis*, *Tesuquea formosa*, *Horridonia? daltonensis*, *Linoproductus devargasi*, *Linoproductus pumilus*, *Zia novamexicana*, *Composita umbonata*, *Cleiothyridina milleri*, *Neospirifer tewaensis*, *Anthracospirifer curvilateralis tanoensis*, *Anthracospirifer curvilateralis chavezae*, *Anthracospirifer mcalesteri*, *Spiriferellina ceres*, *Punctospirifer morrowensis*, *Beecheria daltonensis*, *Beecheria stehlii*, and *Beecheria gerberi*.

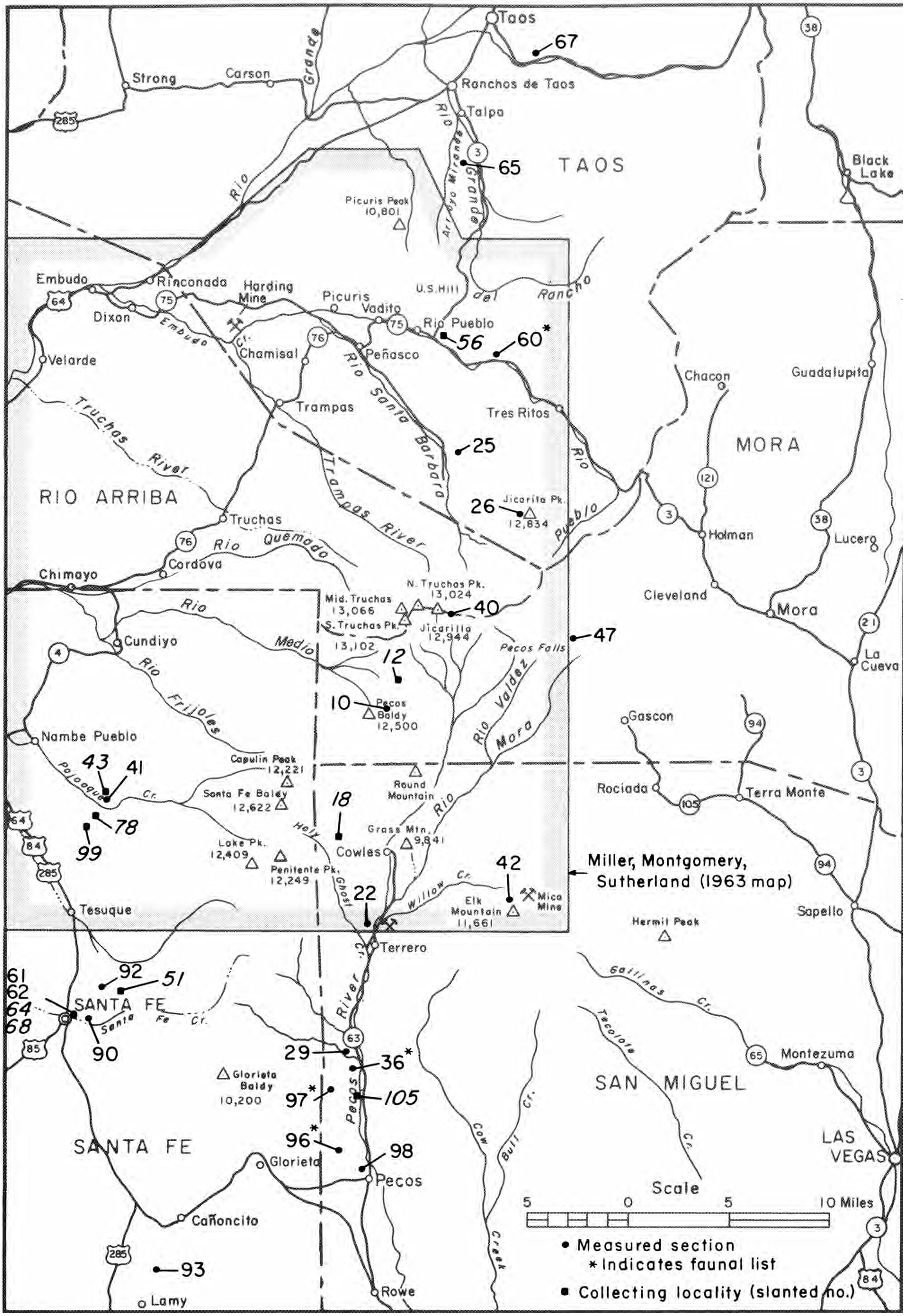

FIGURE 2-*Index and locality map.*

Introduction

SCOPE OF INVESTIGATION

The Pennsylvanian brachiopod faunas of the southern Sangre de Cristo Mountains provide significant evidence for correlating the Pennsylvanian System within northern New Mexico and to the Midcontinent. Brachiopods form the most common element in the megafaunas of the Pennsylvanian System in northern New Mexico, commonly occurring to the virtual exclusion of other faunal elements. Analysis of the regional stratigraphy of the area would have been impossible without a detailed study of the brachiopods, particularly in the Morrowan, Atokan, and lower part of the Desmoinesian (fig. 1) . Correlations in the middle and

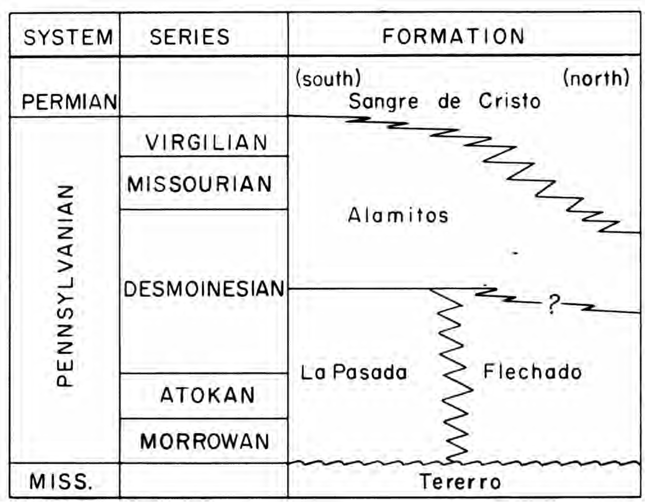

FIGURE 1—*Table of stratigraphic sequence.*

upper parts of the Pennsylvanian (Atokan to Virgilian) were greatly aided by detailed information on fusulinids, and in the lower part of the Pennsylvanian (Morrowan) by the conodonts.

The study has also provided a new understanding of the evolutionary relationships of brachiopod faunas in the Morrowan with those in the Desmoinesian. The often-quoted, classic study by Dunbar and Condra (1932) of the Desmoinesian to Virgilian brachiopods in the Midcontinent demonstrates the very striking similarities between the brachiopod faunas of the upper Desmoinesian, Missourian, Virgilian and Lower Permian. Slow rates of evolution are inferred for most brachiopod generic stocks during the Middle and Late Pennsylvanian. Such is not the case in the Early Pennsylvanian. The present study documents, for the first time, the very marked changes in the brachiopods between the Morrowan and lower Desmoinesian, and to some extent even between the Morrowan and Atokan. The Morrowan brachiopod faunas in the southern Sangre de Cristo area are the largest, both in numbers of genera and numbers of species, yet reported from North America, and include most of the species of brachiopods described from the type region of the Morrow Series in northwestern Arkansas and northeastern Oklahoma.

The area studied (fig. 2) extends about 55 miles from north to south and is bounded on the north by Taos, on the west by Santa Fe and the Rio Grande Depression, and on the south by the towns of Lamy and Pecos. The general geology of this area was described by Miller, Montgomery, and Sutherland (1963). The area they mapped is shown on fig. 2. The present study is a companion work to that memoir; to a considerable extent the correlations of Pennsylvanian rocks proposed herein, document the preliminary correlations made in 1963 by Sutherland. Field work for this study was carried out in the summers of 1956 through 1960.

MARCOU'S 1853 SURVEY

Jules Marcou was the geologist on the expedition headed by Lt. Whipple (1856) that, in its search for a railway route near the 35th parallel, visited northern New Mexico in the fall of 1853. Marcou visited Pecos, Santa Fe, Albuquerque, climbed to the crest of the Sandia Mountains, and made notes on the geology of the region. He did not collect fossils at Santa Fe, but made sizeable collections at "Pecos village" and at "Tigeras Canon of San Antonio," east of Albuquerque. His localities are particularly significant because several of his species names are widely used throughout the continent. These type localities have not previously been redefined. Marcou incorrectly referred the strata he described to the Mountain Limestone or Lower Carboniferous.

When the expedition ended, Marcou had a major disagreement with the Secretary of War, Jefferson Davis, who wanted his detailed report prepared immediately. Marcou wished to return to Europe first, and wrote only a brief report (1856) before his departure, claiming illness. The Secretary of War required that his field notes and fossil collections be returned to Washington. His field notes were then translated and published by Blake (1856) and the fossil specimens that he returned were described and figured by Hall (1856). Later, Marcou (1858) published in Zurich his own account of his observations based on his "private journal" and letters written while on the expedition. In this report, he described fossils from the expedition based on specimens not returned to Washington, and which form a much larger collection than the specimens that were returned. Most of these specimens are now in the collections of the British Museum of Natural History in London.

PECOS VILLAGE

Marcou (1858) described the occurrence of several species of brachiopods as being from "Pecos village" without detailed locality information. Two new species are included, *Orthis pecosii* and *Terebratula rocky-montana.* Hall (1856) figured 7 species from the same locality, one being new, *Terebratula millepunctata.* Marcou's (1858, p. 21) only statement concerning the locality is as follows:

> Finally at the village of Pecos, where the valley is reduced to a deep gorge, giving passage only to the river and the road, the rocks of the *Mountain Limestone* are very much developed and extremely rich in fossils. On the left side of the river especially there are strata composed entirely of *Spirifer, Productus* and *Terebratula;* the most common species I found are the following: *Productus semi-reticulatus, P. Cora* and *P. scabriculus; Terebratula subtilita, T. Rockymontana; Spirifer triplicata, S. striatus; Orthis Pecosii; Myalina Apachesi; Amplexus coralloides.*

More specific information is provided in the translation of Marcou's field notes (Blake, 1856, p. 145), as follows:

> October 14. We saw on the left bank of the river, beween Old Pecos and Pecos, the beds of the superior carboniferous formation, and we encamped upon the inferior carboniferous. Near the bridge I found a quantity of fossils and a bed filled with *Terebratula biplicata, Productus giganteus* and *punctatus, Spirifer, Polypi* and *Crinoids.*

Marcou published a "Geological Map of New Mexico" with his 1858 paper on which he showed both his route and his camping sites. The part of this map covering the Pecos area is reproduced as fig. 3. His field notes and map indicate that Marcou spent the night of October 13, 1853, camped near the Pecos River northwest of the village of Pecos; and spent, at most, part of a day in the area.

Marcou's notes imply that his fossils came from a locality near the bridge on the "left" side of the river. Marcou's 1858 map (our fig. 3) shows his route crossing

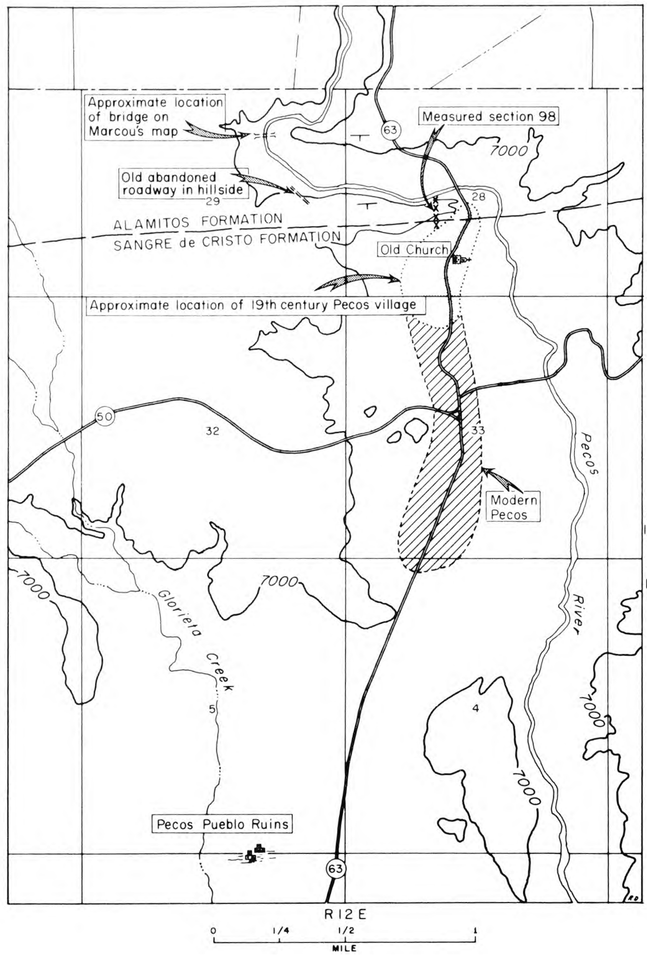

FIGURE 4—*Locality and geologic map of area around town of Pecos. Base taken from 7.5 minute topographic map series. Compare with fig. 3.*

the Pecos River at the very distinctive bend northwest of " Pecos village" (see modern map, our fig. 4), presumably the location of the bridge in 1853. Modern usage concerning direction on a river is to face down stream and call the bank on one's left the left bank. If this is the sense in which Marcou used the term, then his specimens must have been collected on the north side of the river near the site of the old bridge. However, the opposite is suggested by comparing his October 14 entry, quoted above, and his map. He states that he saw the beds of the "superior carboniferous formation" (most probably referring to the red beds of the Sangre de Cristo Formation) on the left bank of the river between Old Pecos and Pecos. His map (fig. 3), depicting his route between his campsites 19 and 20, shows that he was on the west side of the river at the time, suggesting he meant the left side of the river as he proceeded north towards Pecos. In either case, the map appears to indicate the location of the bridge near where he collected his specimens.

We have not examined the specific locality at the sharp bend in the river just discussed. During our earlier visits to the area we searched for fossils on the major east-west bluff on the south side of the river nearer the present bridge, which we assumed to be near Marcou's locality (fig. 4). Sutherland measured section 98 on the bluff about 200 ft west of the modern bridge.

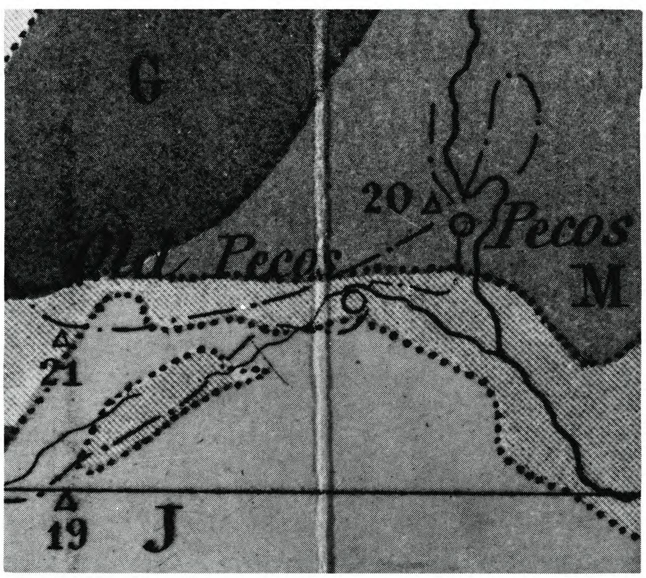

FIGURE 3—*Enlargement of area around town of Pecos from Marcou's 1858 geologic map of New Mexico. Compare with fig. 4. Triangles represent campsites; dash line, the route traversed. Old Pecos Pueblo is more nearly south of town of Pecos than shown by Marcou.*

Fossils are sparse in this exposure but some brachiopods were found and Virgilian fusulinids were collected in unit 98-3. Marcou's specimens from this immediate area are Virgilian in age.

TIGERAS CANON

Marcou was more specific in discussing his locality near " Tigeras village" east of Albuquerque. (The modern spelling for this place name is Tigeras.) This is the type locality for *Spirifer Rocky-montani.* In his 1858 paper, Marcou gives approximately the same information three times, the most complete is as follows (p. 56):

> Camp No 16. From Albuquerque to Tigeras the first twelve miles are on the alluvium of the Rio del Norte valley, then the road enters the Canon of San Antonio and is on granite for three miles, until near a very narrow pass, where the granite is replaced by a sort of serpentine trap. These last rocks appear to be metamorphic and are only two hundred feet thick; masses of limestone strata of the age of the Mountain Limestone are superposed upon them. Fossils are common, and I found in this Lower Carboniferous limestone the following species: *Productus semi-reticulatus, P. Cora, P. Flemingii, P. punctatus, P. pustulosus, P. pyxidiformis; Terebratula plano-sulcata, T. subtilita; Spirifer lineatus, Sp. striatus, Sp. Rocky-montani; Amplexus coralloides* and *Zaphrentis Stansburyi.* The strata are upheaved, dipping to the east, at an angle of 35 degrees. The limestone is bluish-gray, sometimes black, very hard and about four hundred feet thick.

On page 21 he adds:

> In going from Albuquerque to San Antonio, in the middle of the Pass or Canon of San Antonio, ten minutes from the village of Tigeras, there is a bluff of *Mountain Limestone on* the right *of* the road, forming a grand perpendicular wall. Fossils abound in the strata of this bluff, and I collected . . ." (same list given as quoted above, including *Spirifer Rocky-montani).*

This statement is particularly important because he states specifically that he collected specimens of *Spirifer Rocky-montani* from this bluff. The precise spot described by Marcou can be located. His green "serpentine trap" (Precambrian), located 3 miles east of the canyon entrance, can be clearly seen as can his "grand

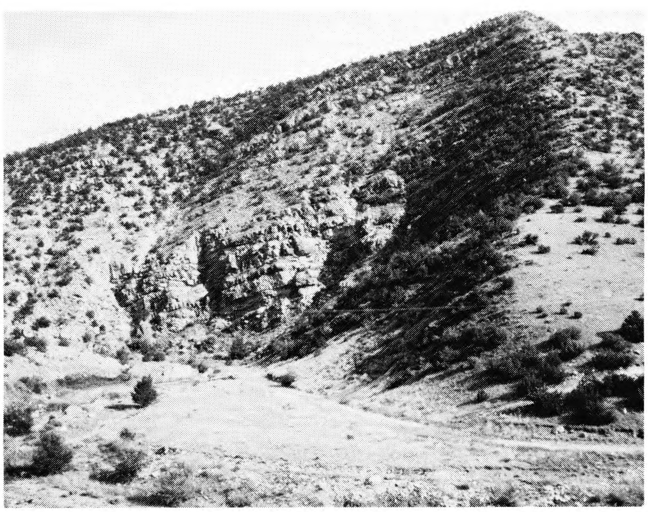

PHOTO 2—*Marcou's `grand perpendicular wall, " seen in middle of photo, is composed of limestones of Desmoinesian age. Grassy hill to right (west) exposes strata in lower part of the Pennsylvanian, probably Atokan. Possibly Marcou traversed old road at base of hill. Compare with fig. 5.*

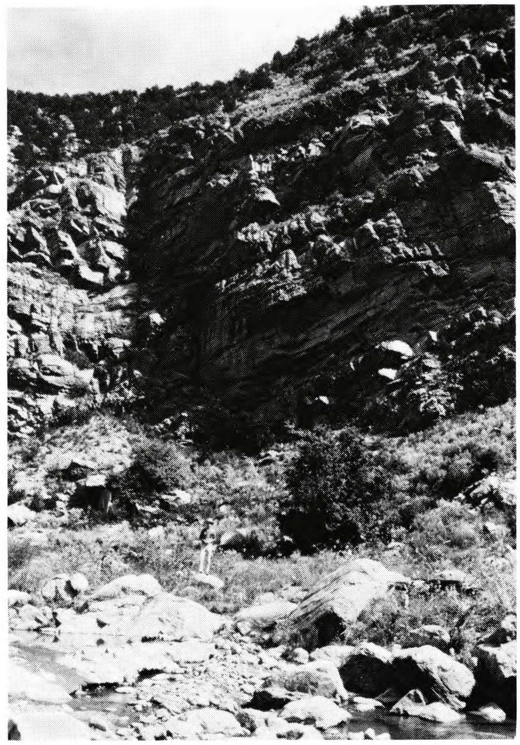

PHOTO 3—*Marcou's "grand perpendicular wall."*

perpendicular wall." We have made a brief examination of this locality but have not measured a stratigraphic section, and did not find *Spirifer rockymontanus.* We conclude that Marcou's specimens most probably came from the great cliff, which, while poorly fossiliferous, contains fusulinids and brachiopods including *Neospirifer cameratus* and *Buxtonia* n. sp. B of this paper, indicating a Desmoinesian age.

Marcou included with his field notes (Blake, 1856, p. 142) a sketch of the bluff as he observed it from Camp No. 16 (our fig. 5). He correctly shows a more thin-bedded lower sequence overlain by thick-bedded cliff-forming limestones. Szabo (1953, p. 28) records at this locality 44 ft of sandstones interbedded with shales at the base of the Pennsylvanian, overlain by 73 ft of interbedded shales and thin limestones, followed by cliff-forming limestones. These lowermost Pennsylvanian rocks are not exposed at river level but crop out on a steep hillside just west of the great cliff. The lowest limestones in this sequence are poorly fossiliferous, but we collected specimens of *Sandia santafeensis,* suggesting an Atokan age. Fossils of definite Morrowan age are lacking.

Marcou's field notes (Blake, 1856, p. 142) indicate that he traveled from Albuquerque to Camp No. 16, slightly west of Tigeras, on October 8, 1853. The next day, he traveled from Tigeras northeastward to Antonito, an airline distance of about 6 miles. Time spent at the Tigeras locality could not have been more than a few hours, and yet his map (our fig. 6) indicates that he, or members of his party, climbed both the steep valley side to the south as well as to the north.

A detailed stratigraphic section is needed at Marcou's locality, from which careful collections have been made of both brachiopods and fusulinids from all fossiliferous layers, to establish the occurrence and range of *Spirifer*

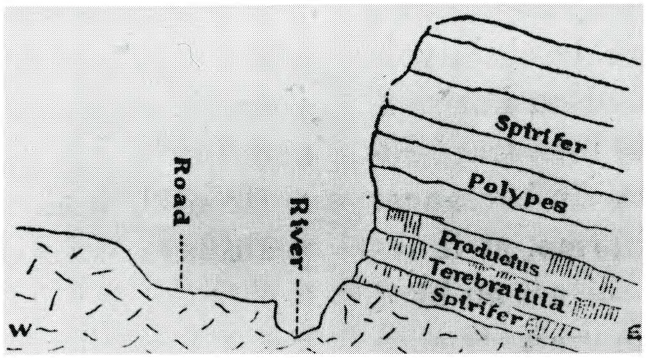

FIGURE *5—Sketch of bluff at Marcou's camp 16 (see fig. 6) as reproduced by Blake (1856, p. 142).*

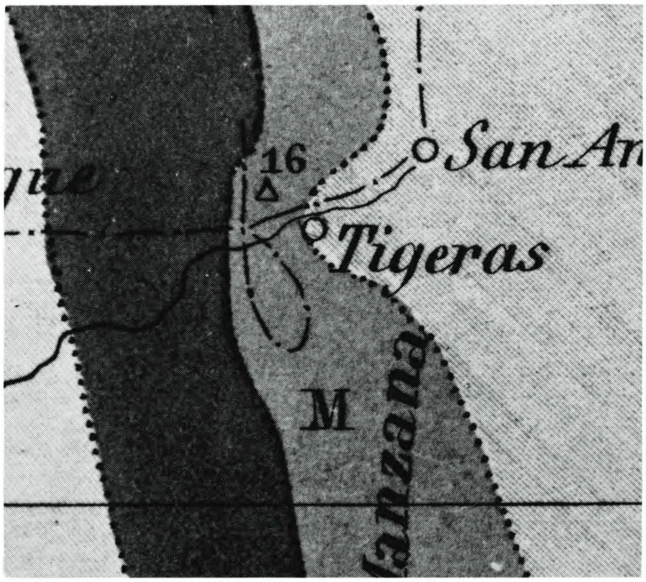

FIGURE *6-Enlargement of area near Tigeras village from Marcou's 1858 geologic map of New Mexico. Triangle represents campsite; dashed line, the route traversed.*

rockymontanus. We believe the type specimens came from the great cliff and are Desmoinesian in age.

EARLY SURVEYS IN SANTA FE AREA

The preceding section describes Marcou's (1858) collection and description of Pennsylvanian brachiopods from "Pecos village" (Virgilian age) and from "Tigeras Cañon" (Desmoinesian age). Marcou visited Santa Fe, but he did not collect fossils there. The Santa Fe area, however, later yielded sizable collections of brachiopods described by Newberry (1861, 1876) and by White (1874, 1877). Interestingly the brachiopod species they illustrated from the Santa Fe area came, not from the Middle or Upper Pennsylvanian, but from strata of Morrowan and Atokan age. These extremely fossiliferous rocks crop out in small areas of exposure, but form a striking contrast to the Precambrian granites and Cenozoic gravels that are so widely exposed in the area.

The Pennsylvanian exposures near Santa Fe are scattered in an area I to 4 miles east and northeast of the city (see map of Kottlowski and Baldwin, 1963). Most of these exposures are in rugged mountainous

PHOTO *4—Santa Fe. Looking southwest from Old Santa Fe Quarries.*

terrain 2 to 4 miles northeast of the Santa Fe Plaza, but three exposures were probably readily accessible to Santa Fe in the 19th century. The most accessible exposure consists of a $^1/_2$-mile diameter inlier in the Cenozoic gravels, located on the east edge of the city at the old Santa Fe Quarries (fig. 51 and measured sections 61 and 62). The second consists of several small exposures in and along the north side of the Santa Fe River valley, $1^1/_2$ to 3 miles east of the city (measured section 90). The third is at Bishop's Lodge, 4 miles northeast of the Plaza (measured section 92). Nambe Falls, located 11 miles north of Santa Fe (see fig. 50 and section 41), is the only additional exposure of Carboniferous strata present on the west slope of the Sangre de Cristo Mountains.

The first expedition to make sketchy observations about the rocks of the Santa Fe region was led, in 1846 and 1847, by Lieutenant Abert (1848). He did not collect fossils at Santa Fe, but he has the distinction of having illustrated the first Pennsylvanian brachiopod from New Mexico—a specimen of *Composita* collected from limestones at a copper mine at Tuerto on the north side of the Sandia Mountains about 30 miles south of Santa Fe.

The first person to decribe Pennsylvanian rocks in the Santa Fe area in any detail was Newberry (1861, 1876a), the geologist on two separate expeditions to the area in the years 1858 and 1859. Newberry correctly correlated the Pennsylvanian strata in the area with the "Coal measures" (Upper Carboniferous) of the Mississippi Valley; not with the lower Carboniferous, as Marcou had done. Both Newberry and Marcou recognized that the Carboniferous strata in the region rest directly on granites, indicating an absence of lower and middle Paleozoic strata.

Newberry (1876a) measured 3 stratigraphic sections in the Carboniferous strata of the Santa Fe area. He listed the occurrence in these sections of many different Carboniferous brachiopod species but he described and figured only one new species, *Productus nodosus* (= *Linoproductus nodosus* of this paper), a characteristic Morrowan brachiopod. Newberry (1876b) listed this species as being only from "Santa Fe, New Mexico." However, he (1876a, p. 43-46) gives 3 stratigraphic sections, 2 of which list the occurrence of *P. nodosus.* The first, his section No. 1, "in the hills immediately back of Santa Fe", is certainly the sequence at the Santa Fe Quarries (our sections 61 and 62); the second, his section No. 2, "in the gorge of the Santa Fe River," is believed to be near our section 90. The exposure at section 90 is the only one known to us where *L. nodosus* occurs commonly; therefore, we have designated 90-7 as the type locality for this species. Determining what other species are represented in Newberry's lists is impossible because none were illustrated.

In 1873, one of the survey parties under the supervision of Lt. Wheeler (1875) visited the Santa Fe area. One of Wheeler's assistants, Gilbert (1875, p. 520), states "the collection of Coalmeasure fossils made by Mr. Keasbey, near Santa Fe, is of value to the paleontologist, not for new forms, but for the exceptionally good condition of its specimens, which will enable an intimate and thorough knowledge of some species heretofore but partially described." The invertebrate fossils collected by the various field parties under Wheeler's direction, including those from Santa Fe, were subsequently described and illustrated by White (1874, 1877). White listed 13 brachiopod species as having been collected "near Santa Fe," and gave new names to 2 of them. Ten of the 13 can be identified from his illustrations with some degree of certainty. Of these 9 are Morrowan and 1 is an Atokan species. We have collected 7 of the 9 Morrowan species, including 1 of White's new species from one or more of our measured sections (61, 90, 92) in the Santa Fe area. The species names used in this paper are as follows, with the names used by White given in parentheses: *Spiriferellina campestris* (White) *(Spiriferina spinosa* var. *campestris,* 1874, and *Spiriferina octoplicata,* 1877); *Pulchratia? picuris* n. sp. *(Productus Nebrascensis); Rhipidomella trapezoida* n. sp. *(Orthis Pecosii); Punctospirifer morrowensis* n. sp. *(Spiriferina Kentuckensis); Hustedia gibbosa?* Lane *(Retzia Mormonii); Cleiothyridina milleri* n. sp. *(Spirigera planosulcata)* and *Beecheria stehlii* n. sp. *(Terebratula bovidens).* The only post-Morrowan species included is *Neospirifer cameratus* (Morton) *(Spirifer cameratus),* collected in the Santa Fe Quarries at the Atokan units 62-17 and 18.

An interesting question is raised by the fact that we did not find at Santa Fe two of the species figured by White as coming from "near Santa Fe", but collected great numbers of both from the same thin layer at Nambe Falls, 11 miles north of Santa Fe. These two species are White's new species *Chonetes platynota (Neochonetes? platynotus* of this paper) and a form White classified as *Productus longispinus* Sowerby *(Desmoinesia nambeensis* n. sp. of this paper). These species occur at Nambe Falls in unit 41-49 (unit no. 49 of section 41), in the La Pasada Formation, high in strata of Morrowan age. The 1873 survey party visited the Nambe Indian Pueblo (Wheeler, 1875), located 12 miles north of Santa Fe. We assume, from the fossil evidence, that this party could have been taken to see the beautiful Nambe Falls and collected fossils, later reported as being from "near Santa Fe."

The most likely explanation as to why these two species have not been found in the Santa Fe area is that both are apparently restricted to the upper part of the Morrow sequence. The exposures at Santa Fe (measured sections 61, 90 and 92) expose only the lower part of the strata of Morrowan age developed in this region (see fig. 7).

ACKNOWLEDGMENTS

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We are grateful to Charles J. Mankin for identifying the petrographic thin sections of the sedimentary rocks, to Dwight E. Waddell and George J. Verville, who identified the Pennsylvanian fusulinid faunas, to H. Richard Lane and Thomas W. Henry, who identified the conodont faunas from the Morrowan and Atokan intervals, to Roy Davis and the Oklahoma Geological Survey for drafting many of the illustrations, and to Thomas W. Henry for much assistance during the preparation of the manuscript. The several brachiopods sketches appearing on covers and chapter heads were done by Francis H. Harlow. A. Lee McAlester and Dean Gerber served as field assistants. We are indebted to Richard E. Grant for critically reading the manuscript and suggesting improvements.

Stratigraphy

INTRODUCTION

The Pennsylvanian stratigraphy of the southern Sangre de Cristo area was described by Sutherland (1963, 1972); only a short summary is included in the present re port.

The southern Sangre de Cristo area is a region of marked lateral changes in facies and thickness, from a thin shelf facies in the south (Pecos shelf) to a thick clastic trough facies in the north (Taos trough).

An attempt was made to use the formational names Sandia and Madera, but criteria could not be found for consistently delineating the Sandia Formation, and more specifically, the Sandia-Madera formational boundary in the area. The term Sandia has been widely applied to a basal clastic interval commonly, but not invariably, found in the lower part of the Pennsylvanian sequence in northern New Mexico. These basal sandstones are irregular in distribution and age.

The only consistent lithic break observed in the southern Sangre de Cristo Mountains coincides in the Pecos area with the boundary between the lower gray limestone and upper arkosic limestone members of the Madera Formation as used by Brill (1952). The beds above this horizon are marked either by a significant increase in the percentage of feldspar, as in the Pecos valley at Dalton Bluff, or by the first appearance of feldspar farther north at Pecos Baldy and Rio Pueblo. The Pennsylvanian rocks in the southern part of the area were divided on this basis by Sutherland (1963, p. 36) into two formations: 1) La Pasada Formation, 973 ft thick at Dalton Bluff in the Pecos valley and equivalent to the Sandia Formation plus the lower gray limestone member of the Madera Formation, as used by Brill (1952); and 2) the Alamitos Formation, approximately 1,275 ft thick in the Alamitos and Pecos valley areas near the town of Pecos, and equivalent to the upper arkosic limestone member of the Madera Formation.

The correlation of Pennsylvanian rocks northward from the Pecos area to the Rio Pueblo area, a distance of about 40 miles, is shown by Sutherland (1963, fig. 10). In the north, the facies changes abruptly to a dominantly clastic sequence with marked increase in thickness. In the Rio Pueblo area, two lithic units are recognizable: a lower, nonarkosic, and predominantly clastic unit named the Flechado Formation approximately 2,500 ft thick at Rio Pueblo; and an upper arkosic unit that includes limestones and is correlative with the Alamitos Formation. The latter is approximately 4,000 ft thick in the Rio Pueblo region, giving a total thickness in this area of about 6,500 ft for rocks that are definitely identifiable as Pennsylvanian. The highest limestones in the Rio Pueblo area are late Desmoinesian. In contrast, the highest limestones in the Pecos valley, where the total Pennsylvanian sequence is 2,250 ft thick, are Virgilian.

Sutherland (1963) gave descriptions of four Pennsylvanian stratigraphic sections (36, 60, 96, and 97). All additional stratigraphic sections to which references are made in this report are given in Appendix 1. Each brachiopod, fusulinid, and conodont collected is listed in its appropriate stratigraphic unit in each section. References to these occurrences in the text appear as double numbers, e.g. "unit 41-49" denotes unit 49 at measured section, or locality, 41.

LA PASADA FORMATION

At its type locality at Dalton Bluff (section 36; see also frontispiece), the La Pasada Formation is predominantly a cyclic carbonate unit that includes a variety of rock types. For the most part, the formation is characterized by sequences of highly fossiliferous interbedded limestones and shales. The more thick-bedded limestones form the great cliffs at Dalton Bluff. At that locality, a lower, more clastic sequence is dominated by shales, with subequal amounts of sandstone and limestone. This sequence is gradational upward with the predominantly carbonate sequence (fig. 7). Sandstone percentages average 23 percent of the rocks of Morrowan age, decreasing to 18 percent in the Atokan interval and to 9 percent in the Desmoinesian part of the formation. The percentage of limestones shows a marked increase upward from 20 percent in the Morrowan to 67 percent in the Desmoinesian interval. A lithologic basis for subdivision was not found.

The marked lateral facies changes that occur in the lower part of the La Pasada Formation demonstrate the infeasibility of separating the locally more clastic basal sequences as a separate formation or member (Sandia Formation). Westward from Dalton Bluff, the carbonate percentage in rocks of Morrowan age greatly increases; the sandstone percentage correspondingly decreases. At Nambe Falls (section 41), at Bishop's Lodge (section 92), and in the Santa Fe River valley east of Santa Fe (section 90), all located on the west slope of the Sangre de Cristo Mountains, the limestone content of the Morrowan outcrops is 41, 49, and 46 percent, respectively (fig. 7). At Nambe Falls, the lowest of many limestones occurs within 1 ft of the base of the Pennsylvanian. In contrast, north and northeast of Dalton Bluff the Morrowan rocks are much more clastic. At Terrero, in the Pecos valley 6 miles north of Dalton Bluff, the sandstone percentage in the Morrowan interval is at least twice that at Dalton Bluff, and the sandstones have a coarser texture.

The Desmoinesian part of the La Pasada Formation is lithologically recognizable as far north as the high

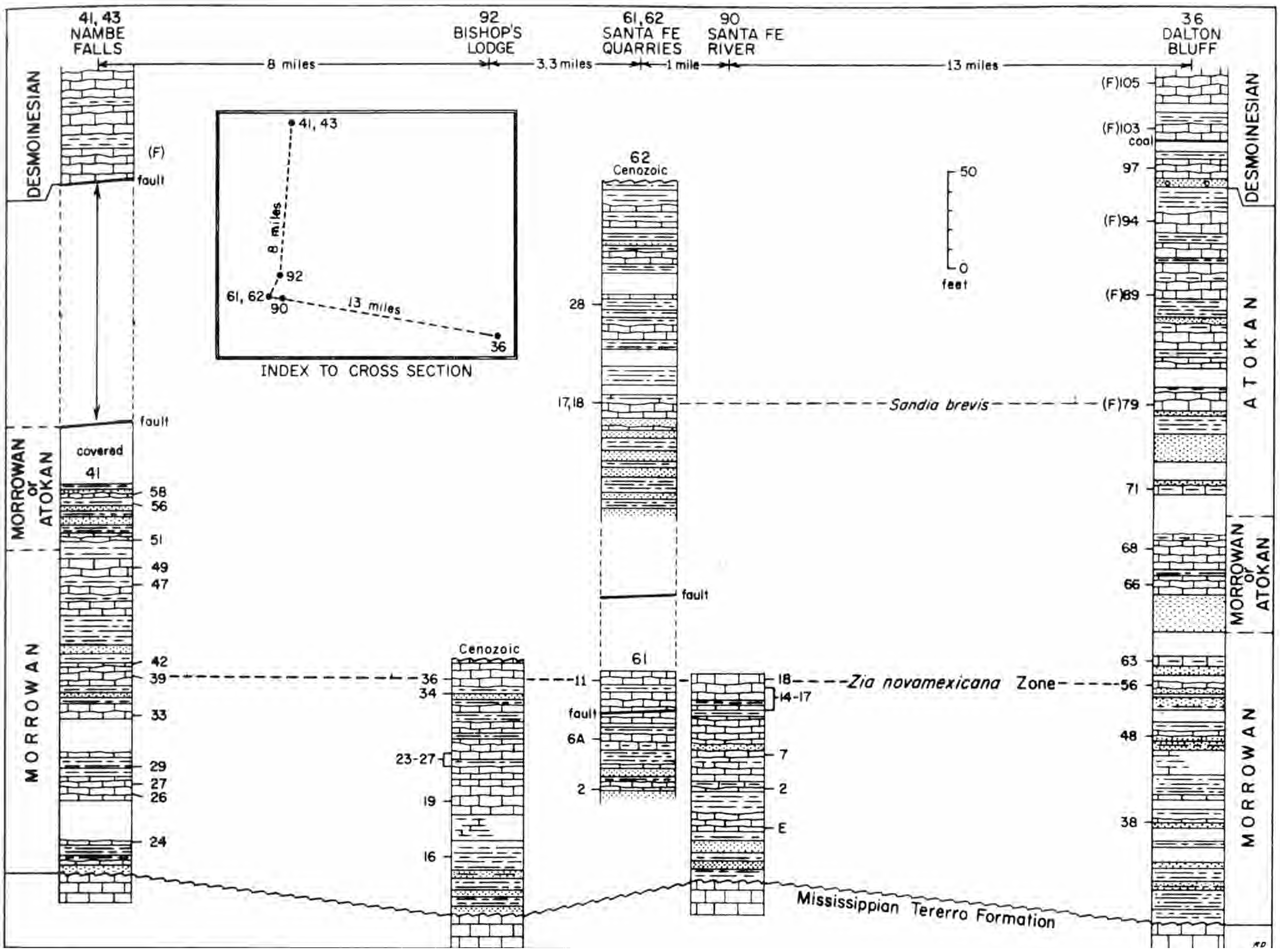


FIGURE 7—*Correlation of Lower and Middle Pennsylvanian sections from the Nambe and Santa Fe areas east to the Pecos valley. Datum is the Morrowan* Zia novamexicana *zone. Units from which brachiopods have been collected are numbered. Units marked "F" contain fusulinids. All strata are included in the La Pasada Formation.*

mountain exposures just east of the Truchas Peaks, about 23 miles north of Dalton Bluff. In this interval, a northward increase in the percentage of shale occurs as the limestones become less thick bedded and the percentage of limestone decreases. Detrital feldspar is absent in the formation in these northern exposures.

The lower Desmoinesian limestones have a finer texture, are darker in color, and are commonly spiculiferous at measured sections 42 and 47 (fig. 2) east of the Pecos valley. Fossils are also much less common here than in the localities in the Pecos valley. These conditions are in marked contrast to the lower Desmoinesian strata at measured sections 10, 22, 36, and 40. These characteristics may indicate deposition in deeper and/or quieter water eastward.

PHOTO 5—*La Pasada Formation measured section 10, faulted against Precambrian Ortega Quartzite at left (west). Ridge northeast of East Pecos Baldy.*

FLECHADO FORMATION

The type locality for the Flechado Formation is located in the Rio Pueblo valley 36 miles north of Dalton Bluff and about 18 miles south of Taos. The Flechado Formation ranges in age from Morrowan to middle Desmoinesian. This formation is the approximate northern equivalent of the La Pasada Formation. The south-north relationship of the two formations is illustrated by Sutherland (1963, fig. 10). The facies change abruptly in the interval 8 to 13 miles south of the Rio Pueblo valley from a predominantly carbonate sequence in the south (La Pasada Formation) to a predominantly clastic sequence in the north (Flechado Formation). These facies changes are accompanied by a marked increase in thickness northward.

The Flechado Formation is approximately 2,500 ft thick in the Rio Pueblo valley and is composed mainly

PHOTO *6—Orthoquartzitic sandstones of Flechado Formation, Rio Pueblo valley. Unit 60-134 forms the high cliff*

of sandstones, conglomerates, and shales. All sandstone and conglomerate layers sampled have less than 3 percent feldspar, a feature which readily permits the separation of this formation from the overlying Alamitos Formation in which all layers of terrigenous clastics contain more than 30 percent feldspar. The conglomerates commonly contain pebbles of Precambrian metaquartzite.

ALAMITOS FORMATION

The Alamitos Formation overlies the La Pasada and Flechado Formations and is, in turn, overlain by the red shales and arkoses of the Sangre de Cristo Formation. The Alamitos is approximately equivalent in the Pecos valley area to what has been called the arkosic limestone member of the Madera Limestone by Brill (1952). In the type area south of Dalton Bluff and in the Alamitos Canyon a short distance northwest of Pecos, coarse-grained clastic rocks are dominant in the lower two-thirds of the formation, and carbonate rocks are more important in the upper one-third. This general division into a lower clastic and an upper carbonate interval is neither sharp nor consistent laterally. All rock types show marked lateral and vertical variations.

The contact with the underlying La Pasada Formation is apparently conformable, but is placed at a marked lithic change from a sequence composed primarily of limestone in the upper half of the La Pasada Formation to a sequence with major percentages of sandstone and conglomerate in the lower half of the overlying Alamitos Formation. Even more striking is the corresponding increase in the percentage of feldspar from 1 to 20 percent in the upper sandstone layers of the La Pasada Formation to 30 percent, or more, in all of the sandstones and conglomerates examined in the Alamitos Formation. Fragments of granite are common in the higher formation.

Shales in the lower half of the Alamitos Formation in the Pecos area are gray. In the upper half of the formation, which includes rocks of Missourian and Virgilian age, the gray shales are interbedded with red shales that increase in percentage upward. In the upper 300 ft of the formation, all shales are red and many are closely interbedded with marine limestones. The boundary with the overlying Sangre de Cristo Formation in the Pecos region is gradational, and is arbitrarily placed at the highest well-developed limestone.

To the north, in the Rio Pueblo area, the Alamitos Formation is about 4,000 ft thick and has the overall character of a coarse-grained arkose. In this area, both the lower part of the Alamitos Formation and the upper part of the underlying Flechado Formation are coarse-grained clastic units. The separation is based on the abrupt increase in feldspar from less than 3 percent in the sandstones of the Flechado to more than 30 percent in those of the Alamitos Formation. The rate of sedimentation also appears to increase markedly at the beginning of deposition of the Alamitos Formation in the Taos trough. During the time interval no greater than middle to late Desmoinesian, 4,000 ft of rock,

PHOTO *7—Coarse arkosic sandstones and conglomerates (unit 96-17) of Alamitos Formation, Alamitos valley.*

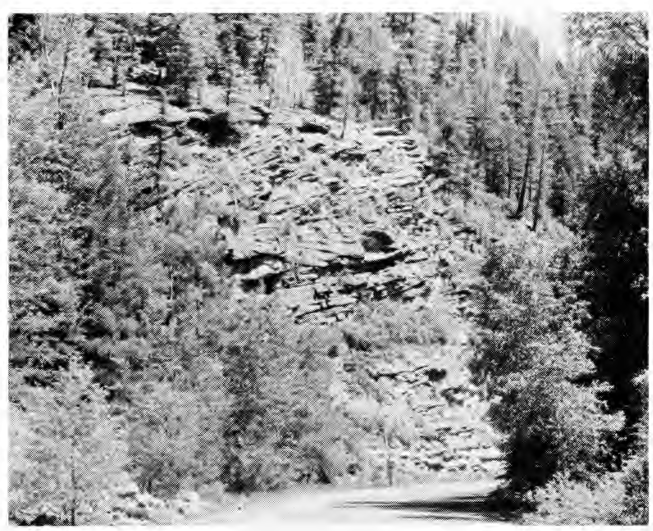


PHOTO *8-Highly cross-bedded arkosic sandstones and conglomerates (unit 60-171) of Alamitos Formation, Rio Pueblo valley.*

consisting principally of arkoses, were deposited. By contrast, the 2,500 ft of orthoquartzite in the underlying Flechado Formation was deposited over an interval spanning Morrowan, Atokan, and early to middle Desmoinesian time. The 4,000 ft of strata comprising the Alamitos Formation in the Rio Pueblo area is believed to be equivalent only to the lower 500 ft of the formation in the Pecos area 40 miles to the south. The Alamitos, ranging in age from upper Desmoinesian to Virgilian in the south, is interpreted to be the time equivalent of the Alamitos Formation in the north, which includes rocks only of middle and late Desmoinesian age, as well as the lower part of the overlying Sangre de Cristo red shale and arkose sequence.

SANGRE DE CRISTO FORMATION

Only the lower part of this formation has been studied. Direct faunal evidence concerning its age is lacking. In the Pecos area, the lower beds consist of coarse-grained, poorly sorted arkoses interbedded with red shales and siltstones, gradational with Virgilian limestones. To the north in the Rio Pueblo area, the Sangre de Cristo Formation overlies upper Desmoinesian limestones. This relationship is interpreted as representing a gradual offlap or withdrawal of the sea, resulting in an intertonguing of the upper part of the Alamitos Formation in the south with the Sangre de Cristo to the north.

Faunal Evaluation

INTRODUCTION

The main purposes of this investigation were to study the brachiopod faunas and their evolutionary development in the Sange de Cristo region and, to establish a biostratigraphic framework for correlating Pennsylvanian strata characterized by rapid lateral facies changes in this region.

Initial field collecting included all faunal elements, but brachiopods dominate most collections. Fusulinid samples were collected wherever observed. They are abundant locally but are absent or are rare in many sequences, particularly in the northern area of predominantly clastic deposition. Fusulinids were a primary basis for correlating in the upper Atokan and higher strata; brachiopods were almost equally important in the lower Desmoinesian. The brachiopods formed the primary basis of correlating Morrowan and lower Atokan, with conodonts secondary in 5 southern and southwestern sections.

Correlations suggested by the fusulinids and brachiopods did not conflict. Fig. 8 (pocket) shows the stratigraphic distribution by formation and age of fusulinids in relation to the brachiopods.

A conflict does arise, however, in arbitrarily delineating the Morrowan and Atokan boundary by means of brachiopods and conodonts. Typical Morrowan brachiopods occur in units 41-58 and 36-68 (figs. 7 and 8). In this report, these units mark the top of the Morrowan. Conodont correlations would place the base of the Atokan slightly lower in the section to include units 41-51 and 36-66.

FUSULINID OCCURRENCES

Fusulinids occur commonly at many horizons in the Pennsylvanian strata of the Pecos valley in the combined sequence formed by measured sections 36 and 97 (fig. 8, pocket). This sequence is a reference for the entire area.

A zonation of the fusulinids has been provided by Dwight E. Waddell who has correlated the fusulinids with the occurrences in the Ardmore basin in southern Oklahoma. The lower 5 of 7 zones proposed for New Mexico coincide with the lower 5 zones proposed by Waddell (1966) for the Ardmore basin.

The fusulinid zones recognized in the southern Sangre de Cristo area are as follows:

Zone I, upper A tokan. Specimens of *Profusulinella* have not been found in northern New Mexico or in the Ardmore basin. The zone is characterized by the occurrence of *Fusulinella prolifica* Thompson, *Fusulinella devexa* Thompson and *Fusulinella famula* Thompson. A similar fauna occurs in the Bostwick Limestone in southern Oklahoma.

Zone II, lowermost lower Desmoinesian. This zone is characterized by one of the most primitive *Fusulina* faunas and by the lowest occurrence of *Wedekindellina.* The zone is recognized by the presence of *Fusulina taosensis* Needham and *Fusulina pumila* Thompson. A similar fauna occurs in the Lester and Frensley Limestones in the Ardmore basin.

Zone III, lower Desmoinesian. Characteristic species are *Fusulina novamexicana* Needham, *Fusulina euryteines* Thompson, *Wedekindellina euthysepta* (Henbest), and *Wedekindellina excentricus* (Roth and Skinner). The zone occurs in the Pumpkin Creek and the Devils Kitchen Limestones in the Ardmore basin.

Zone IV, middle Desmoinesian. This zone is characterized by *Fusulina haworthi* (Beede), *Fusulina erugata* Waddell, *Fusilina* sp. A and sp. B of Waddell (1966, p. 8), and *Wedekindellina* sp. D of Waddell. The zone occurs in the Arnold Limestone in the Ardmore basin.

Zone V, upper Desmoinesian. In northern New Mexico this zone is characterized by the occurrence of *Fusulina cappensis* Stewart. In the Ardmore basin the comparable zone V occurs in the Camp Ground Limestone. In northeastern Oklahoma, this zone occurs also in the Marmaton Group.

Zone VI, Missourian. In the southern Sangre de Cristo area this zone is characterized by occurrence of *Triticites ohioensis* Thompson and *Triticites irregularis* (Schellwien and Staff). Fusulinids have not been found in the Missourian parts of sections 96 and 97 but the above-listed fusulinids have been collected from the same stratigraphic interval about 0.5 mile northeast of Rowe, New Mexico, about 6 miles southeast of section 96. Zone VI is approximately equivalent to the Ardmore basin zones VI and VII, both of which are Missourian in age.

Zone VII, Virgilian. Rocks of definite Virgilian age have been recorded only in the immediate vicinity of the town of Pecos. *Triticites* cf. *T. cullomensis* Dunbar and Condra occurs in unit 98-3 in the Pecos River Bluff. The same species occurs in the Deer Creek Limestone, in the lower Virgilian of Kansas. Fossiliferous strata of Virgilian age do not occur in the Ardmore basin.

CONODONT OCCURRENCES

Conodont samples were collected from the lower part of the La Pasada Formation in 4 areas in the southern and southwestern part of the Sange de Cristo region. To provide an independent means of evaluating the biostratigraphic framework based upon the brachiopods from this part of the section, samples were collected mostly from the pre-fusulinid, Morrowan and Atokan parts of the Pennsylvanian sequence from the following sections and localities: 41, 61, 62, 64, 90 and the lower part of section 36 (units 38 to 103), all shown on fig. 7.

The samples were collected by P. K. Sutherland and Thomas W. Henry in August, 1968, and the processed samples were examined and the conodonts identified by H. Richard Lane and Thomas W. Henry in August, 1969. Eighty-one samples were collected and all but five yielded identifiable conodont elements. The following discussion is based upon their information.

The most important result of the conodont study is that the Morrowan in the Sangre de Cristo area is equivalent to only the upper half of the type Morrowan sequence in northwestern Arkansas. In that area, Lane (1967) recognized 6 conodont zones in the Morrowan sequence. Only the upper 2 of these have been recognized in northern New Mexico. The conodonts suggest correlation of the lowest fossiliferous Pennsylvanian strata in northern New Mexico with the upper part of the Brentwood Limestone Member and the lower part of the overlying Woolsey Member of the Bloyd Formation. Morrowan strata equivalent to the Hale Formation have not been recognized.

The conodont faunas recognized in the Sangre de Cristo sections are:

Fauna 1 correlates with the upper part of the Brentwood Limestone Member and the lower part of the overlying Woolsey Member of the Bloyd Formation, characterized by the following faunal elements: *Idiognathoides corrugatus* (Harris and Hollingsworth), which occurs in unit 36-38; and *Idiognathodus* sp. (= Lane, 1967, pl. 119, fig. 11), which occurs in unit 90-E.

Fauna 2 is upper Morrowan in age, correlates with the Dye Shale and Kessler Limestone Members of the Bloyd Formation in northwestern Arkansas. The distinctive faunal element is *Idiognathodus* n. sp. A (Lane and Straka, 1971, p. 402), which occurs at units 36-46, 36-63, 41-31, 41-34, 41-39, 41-41, 61-11, 90-7, 90-10, 90-12, 90-14, and 90-18.

Fauna 3 is reported by Lane to be Atokan in age on the basis of the occurrence of *Neognathodus columbiensis* (Stibane), *Idiognathoides fossatus* (Branson and Mehl), *Gnathodus coloradoensis* (Murray and Chronic), and *Neognathodus* n. sp. At the type section of the Derryan (= Atokan) in southern New Mexico, *Neognathodus* n. sp. has its first occurrence at 13 ft above the base of the section, closely followed by *Gnathodus coloradoensis* and *Profusulinella* at 15 ft. In its type area, however, the Derryan rests unconformably upon Devonian strata; thus the lower ranges of these forms cannot be determined in that area. Lane (personal communication) reports that the lowest occurrence of *Gnathodus coloradoensis* and *Neognathodus* n. sp. is 204 ft below the lowest occurrence of *Profusulinella* in Arrow Canyon in Nevada. Therefore, *Gnathodus coloradoensis* and *Neognathodus* n. sp. may possibly range down into the upper Morrowan.

Fauna 4 is lower Desmoinesian in age, the distinctive element occurs immediately below the first occurrence of Desmoinesian fusulinids. Lane reports the occurrence of a new subspecies of *Gnathodus coloradoensis* in unit 36-103.

BRACHIOPOD CORRELATIONS

Fig. 9 (pocket) is a range chart in which all of the brachiopod species from the southern Sangre de Cristo area are listed. Fusulinid zones are shown on the left side of the chart. Middle and upper Desmoinesian, Missourian, and Virgilian rocks are poorly fossiliferous or not widely exposed, hence the small number of species listed for these intervals. Most of the brachiopods studied are Morrowan, Atokan, and lower Desmoinesian in age. Evaluating the evolutionary relationships of the brachiopods in this interval is the major contribution of this paper. A major change occurs in the brachiopod fauna between the Morrowan and Atokan in this area; the Atokan is more similar faunally to the overlying Desmoinesian than to the Morrowan. Ninety-four species of brachiopods have been described from the Pennsylvanian strata of the southern Sangre de Cristo area of which 29 are new. An additional 10 are probably new but inadequately represented to justify naming. Three new genera are described.

A noteworthy morphological change that has occurred in the evolution of several brachiopod genera, represented in the New Mexico faunas in the Morrowan to lower Desmoinesian stratigraphic interval, is an increase in courseness of the costation, as observed in the following 7 genera and generic pairs where we consider the second species to have evolved from the first. The arrow (-0 indicates increase in coarseness of costation.

1) *Meekella* n. sp. A, Morrowan; *Meekella* cf. *M. striatocostata* (Cox), lower Desmoinesian.
2) *Derbyia bonita* n. sp., Morrowan; ⇒ *Derbyia crassa* (Meek and Hayden), lower Desmoinesian.
3) *Neochonetes* n. sp. A, Morrowan; ⇒ *Neochonetes whitei* n. sp., Atokan; ⇒ *Mesolobus striatus* Weller and McGehee, lower Desmoinesian.
4) *Desmoinesia nambeensis* n. sp., Morrowan; ⇒ *Desmoinesia ingrata* (Girty), Atokan; ⇒ *Desmoinesia "missouriensis"* (Girty), lower Desmoinesian.
5) *Antiquatonia coloradoensis* (Girty), Morrowan and Atokan; ⇒ *Antiquatonia hermosana* (Girty), lower Desmoinesian.
6) *Hustedia gibbosa?* Lane, Morrowan; —*Hustedia "mormoni"(Marcou),* lower Desmoinesian.
7) *Spirifer goreii* Mather, Morrowan; ⇒ *Neospirifer cameratus* (Morton), Atokan and lower Desmoinesian.

A marked decrease in coarseness of the costations does not occur in any species in the Morrowan to lower Desmoinesian stratigraphic interval, although a number of genera, for example *Anthracospirifer,* do not show consistent change in coarseness of costation in this interval. The increase in coarseness noted above, however, occurring in many different orders of brachiopods, is sufficiently distinctive to give an overall cast to the difference in character of the Morrowan and lower Desmoinesian faunas in the Sangre de Cristo area.

MORROWAN

We have collected 41 different species of brachiopods from the strata of Morrowan age in the southern Sangre de Cristo region (fig. 9, pocket). Of these, 31 are restricted in this area to the Morrowan, and 7 range only into the overlying Atokan, of which 3 are uncertain. Only 3 species are common to both the Morrowan and Desmoinesian; these three are broadly interpreted "form" species: *Phricodothyris perplexa, " Orbiculoidea"* sp., and *Composita "ovata."*

We have described 15 new species from the New Mexico Morrowan; an additional 4 represent new species, but material adequate for description is not available.

The Morrowan brachiopod fauna of northern New Mexico is similar to that found in the type region of the Morrow Series in northwestern Arkansas and northeastern Oklahoma. Based on a preliminary evaluation of the brachiopod fauna in the type region, we would recognize about 38 valid species in that area, of which possibly 30 to 32 are included among the 41 which we have recorded in northern New Mexico.

The top of the Morrowan in the Sangre de Cristo area is arbitrarily placed at the highest common occurrence of typical Morrowan brachiopod species as compared with the type area. At this point occurs the most marked change in the stratigraphic evolution of the brachiopod faunas in the Sangre de Cristo area.

The study of the conodont faunas indicates that only the upper part of the Morrow Series is represented in the Sangre de Cristo area, the faunally equivalent strata in northwestern Arkansas being from the upper part of the Brentwood Limestone Member of the Bloyd Formation to the top of the Bloyd. In Arkansas, most of the brachiopod species described by Mather (1915) are from the Brentwood Limestone, with smaller numbers from the Kessler Limestone Member, in the upper part of the Bloyd Formation.

In the Sangre de Cristo area, most of the brachiopod collections have come from high-carbonate areas near Santa Fe and Nambe Falls (fig. 7). Some species have been found only in the lower or upper part of this Morrowan sequence, but a distinct overall zonation seems impossible. One horizon, however, our *Zia novamexicana (fig. 7),* is particularly noteworthy. Three different species are restricted to this single horizon: *Zia novamexicana* n. sp., *Pulchratia? pustulosa* n. sp., and *Linoproductus devargasi* n. sp. The zone is best developed in unit 61-11 where these 3 species occur with 7 other longer-ranging species. The zone is also represented in measured sections 41, 92, 90, and 36, and has been used as a datum in fig. 7.

In addition to the 3 species that characterize the *Zia novamexicana* Zone, the additional Morrowan species that are most distinct are *Neochonetes? platynotus, Tesuquea formosa, Pulchratia? picuris,* ***Buxtonia*** *grandis, Linoproductus nodosus, Schizophoria oklahomae, Plicochonetes? arkansanus,* and *Spirifer goreii.*

Rocks of Morrowan age have been recognized throughout the southern Sange de Cristo area with good faunas collected at measured section 65 (Talpa) in the north and measured section 47 (Upper Valdez) in the northeast. The southernmost extent of Morrowan strata is less certain. At measured section 93 (Lamy) , our most southerly section, the lower part is poorly fossiliferous but Morrowan strata are probably present.

At "Tigeras Cañon" east of Albuquerque, preliminary examination of the lowest fossiliferous strata suggests a tentative conclusion that Atokan strata occur at the base of the Pennsylvanian System.

ATOKAN

Rocks of Atokan age in the southern Sangre de Cristo area are not as fossiliferous as either the underlying Morrowan or the overlying Desmoinesian. The interval does provide a very interesting and significant transition in an evaluation of many elements of the brachiopod faunas of the area.

As stated earlier, the Morrowan-Atokan boundary is arbitrarily placed at the highest occurrence of typical Morrowan brachiopod species (the conodonts suggest a slightly lower horizon). The top of the Atoka is determined by good fusulinid control in measured section 36.

Overall, the Atokan brachiopods are more closely related to the overlying Desmoinesian faunas than to the underlying Morrowan faunas. We record 23 species in Atokan strata. Aside from the 3 long-ranging species, 5 are restricted to the Atokan interval; only 4 are definitely in common with the Morrowan; three add-tional species are uncertain. In contrast, 7 species definitely range into the overlying Desmoinesian with 1 additional uncertain form.

The most diagnostic Atokan species are *Neochonetes henryi, Neochonetes whitei, Desmoinesia ingrata, Sandia santafeensis,* and *Sandia brevis.* The last species may range into the overlying Desmoinesian.

LOWER DESMOINESIAN

The lower Desmoinesian can be subdivided into two fusulinid zones (II and III), but we consider it one unit in discussing brachiopod faunas. We have collected 41 brachiopod species from the entire Desmoinesian, and of these, 38 occur in the lower Desmoinesian. Eight range into the underlying Atokan, and 17 are found only in the lower Desmoinesian. As stated earlier, only 3 long-ranging "form" species range downward into the Morrowan (fig. 9, pocket). The lower Desmoinesian contains many species that do not range into the middle Desmoinesian in this area, partly because the middle and upper Desmoinesian intervals contain a higher percentage of terrigenous clastics and are less fossiliferous. Distinctive species are *Hustedia "mormoni," Neospirifer tewaensis, Anthracospirifer rockymontanus, Kozlowskia haydenensis, Desmoinesia "missouriensis,"* and *Antiquatonia hermosana.* Several of the most distinctive species occur in both the upper Atokan and lower Desmoinesian. They include *Neospirifer cameratus, Mesolobus striatus,* and *Anthracospirifer curvilateralis chavezae.*

Many of the Desmoinesian species here described occur in the equivalent strata in Colorado, but correlation with the Midcontinent is comparatively poor. Many of the species we report from the Sangre de Cristo area are unknown in the lower Desmoinesian of the Midcontinent, possibly because the lower Desmoinesian in that area is predominantly noncarbonate, poorly fossiliferous, and has not been studied extensively.

MIDDLE AND UPPER DESMOINESIAN

Only 17 species of brachiopods have been collected from the middle and upper Desmoinesian in the study area. Some represent species that range upward from the lower Desmoinesian. The single distinctive fauna in the Sangre de Cristo area that comes from this interval occurs either high in the middle Desmoinesian or possibly low in the upper Desmoinesian and includes *Desmoinesia muricatina, Mesolobus euampygus,* and *Antiquatonia portlockiana.*

MISSOURIAN

Fossiliferous Missourian strata are limited in area of exposure; specimens have been collected only from measured sections 96 and 97. The limited fauna includes forms similar to the Midcontinent species: *Echinaria cf. E. semipunctata, Linoproductus cf. L. platyumbonus,* and *Neospirifer alatus.*

VIRGILIAN

Virgilian brachiopods have been collected only near the town of Pecos and include: *Wellerella immatura, Leiorhynchoidea? rockymontana, Beecheria millipunctata,* and *Neospirifer dunbari?.*

Systematic Descriptions

INTRODUCTION

The brachiopod classification above the species level (in most cases) and the morphological terminology is from the *Treatise on Invertebrate Paleontology* (Moore, 1965). The term surface length (SL) refers to the distance from the beak to a point measured along the curve of the shell in the plane of bilateral symmetry.

Our collections are deposited at the University of Oklahoma; figured and type specimens are designated in the descriptions by the prefix OU. References are made to specimens in the following museums:

BMNH—British Museum of Natural History
MCZ—Museum of Comparative Zoology, Harvard University
USNM—U.S. National Museum
WM—Walker Museum, University of Chicago
YPM—Yale Peabody Museum

The Walker Museum specimens are now housed in the Field Museum of Natural History, Chicago but the catalogue numbers are those of the Walker Museum.

List of localities for each species are given at the end of the species description under *Material and occurrence. A* question mark in parentheses after a unit number indicates that the specimens collected from that unit are questionably assigned to that species. Thus, 60-26(?) is equivalent to *Schizophoria oklahomae?*. The symbol "cf." in parentheses following a unit number means that the specimens from that unit possess differences, but generally compare closely with the species. Thus, 41-42(cf.) is equivalent to saying *Buxtonia cf. B. grandis* n. sp.

A general estimate of the commonness of a particular species is indicated by giving the actual number of specimens collected at a specific locality or group of localities, or using the terms:

Term	Specimens per Unit
Rare	1-10
Common	11-50
Abundant	over 50

Tables of statistical data are included in Appendix 2 (on microfiche in pocket). In Appendix 3 (also on microfiche in pocket), specimen measurements are given for figured specimens only of species previously described. For newly described species, measurements of all specimens from the type unit are included. Specimen measurements from a supplemental unit or units are given only if adequate numbers of specimens do not exist from the type unit. Species that have been reestablished as a result of this study have measurements of topotypes also included in Appendix 3.

STATISTICAL PROCEDURES

Two methods of statistical analysis are used throughout this paper: Univariate analysis, for such characters as number of costellae; and bivariate analysis, for the estimation of statistical population parameters such as length-width growth lines. For many samples from fossil populations, multivariate analysis can be employed effectively to evaluate ontogenetically changing characters such as length, width, and thickness, and is preferable theoretically to bivariate analysis. However, for most paleontological samples, especially those in which a high proportion of the fossils are fragmented and /or crushed, bivariate techniques are more suitable because of the greater statistical sensitivity resulting from the increased number of existing pairs of characters in the sample, as opposed to the possible number of triplets, quadruplets, etc. of these characters.

Because the mathematical assumptions demanded by the technique of the reduced major axis (RMA) are more easily justified from a biological perspective than those for regression analysis, the bivariate reduced major axis was used for analyzing our collections of brachiopods. (For a more complete discussion, see Kermack and Haldane, 1950; Kermack, 1954; Imbrie, 1956; and Miller and Kahn, 1962.)

The descriptive statistics, and the statistics for the reduced major axes are given in tables in Appendix 2 (microfiche in pocket). These tables include the statistics that would be necessary for the comparison of other collections of similar brachiopods from other horizons and/or localities with those from our collections from north-central New Mexico. Symbols used in these tables also appear on the page for Appendix 2 at rear.

Where possible, separate statistics were computed from each sample of a fossil species from a single locality. Many individual samples were too small to be of value in statistical discrimination, however, and a number of samples were "lumped" together for the calculation of the statistics. Comparison of two "unlumped" samples is said to have statistical validity. Where "lumped" samples were compared and evaluated, however, we contend that any statistical trends thus detected in a morphological character, or set of characters, are merely suggested by the testing.

To test the statistical significance between a character in two separate collections, we relied on the Z-tests for both the univariate characters and the reduced major axes (Imbrie, 1956). Rarely have we employed Fisher's tests for the analysis of variance. The following terms are used in referring to the null hypotheses:

Term	Confidence Limit (%)
Statistically nonsignificant	90
Statistically significant difference	90 to 95
Highly significant difference	95 to 99
Very highly significant difference	99 to 100

For a pair of RMA (reduced major axes) for the same characters from collections of closely related brachiopods, statistical testing was conducted to determine whether or not a statistical difference exists in the slopes. If the results were nonsignificant, a test was performed to determine if a difference existed in the position of the RMA's (see Imbrie, 1956, p. 243); an X° was chosen for the latter evaluation at a point equal to the mean of one of the samples.

Having evaluated a pair of samples and having determined the statistical significance of the results, a decision as to whether two separate species is justifiable must still be made. Such a decision should be based on a combination of morphologic, geographic, and stratigraphic evidence (Imbrie, 1956, p. 221).

DESCRIPTIONS

Class INARTICULATA
Order LINGULIDA
Superfamily LINGULACEA
Family LINGULIDAE

GENUS *LINGULA*

***Lingula* cf. *L. carbonaria* Shumard**
Pl. 1, fig. **1**

Lingula carbonaria, Dunbar and Condra, 1932, p. 31, pl. 1, figs. 1, 2.

DISCUSSION—A small number of specimens from scattered localities agree in most aspects with the description of this species by Dunbar and Condra (1932, p. 31). The two or three that are complete have regular elliptical outlines and maximum lengths ranging from 11 to 14.2 mm and widths from 6.8 to 8.6 mm.

All specimens occur in calcareous, argillaceous, fine-grained sandstones or siltstones that contain very few other fossils except, at one place, orbiculoid brachiopods.

MATERIAL AND OCCURRENCE—The name *Lingula carbonaria* has been applied traditionally to most occurrences of the genus *Lingula* from all parts of the Pennsylvanian System in the Mississippi Valley. The 7 specimens in our New Mexico collections that we compare with this species come from the Atokan and Desmoinesian parts of the La Pasada Formation, from units 47-37, 62-26, 62-28, and locality 78. Figured specimen: OU 7529.

***Lingula* sp. A**
P1. 1, fig. 2

DESCRIPTION—The shell is of small size, and of elongated rectangular to elliptical outline. The width is slightly greater than $^{1}/_{2}$ the length. The largest shell observed is 5.8 mm long and 3.5 mm wide. The shell is compressed and the surface is marked by very fine, evenly spaced growth lines.

DISCUSSION—This small species differs from *Lingula lemniscata* Price, another minute species, in being elongate in outline and not subcircular. Its occurrence is interesting from an ecological viewpoint. It occurs in a one-foot interval of sandy calcareous shale containing irregular lenses of micrite. The only associated fossil is a pelecypod which is possibly related to *Naiadites.*

MATERIAL AND OCCURRENCE—Lingula sp. A occurs in the Morrowan part of the La Pasada Formation, unit 41-32, top one foot. It occurs commonly at this locality but most specimens are fragmentary. Our collection contains about 10 mostly incomplete specimens. Figured specimen: OU 7530.

Order ACROTRETIDA
Suborder ACROTRETIDINA
Superfamily DISCINACEA
Family DISCINIDAE

GENUS *ORBICULOIDEA*

DISCUSSION—The type species for the genus *Orbiculoidea is O. forbesi* Davidson, from the Silurian of Great Britain. The form is distinctly biconvex; Rowell (1965, p. 285) reports the range of this broadly interpreted genus to be from Ordovician to Permian.

***"Orbiculoidea" youngi* n. sp.**
Pl. 1, figs. 3-5

DESCRIPTION—The shell is subcircular in outline, being typically wider than long. The holotype is about 19 mm long and 20 mm across. The largest specimen available is 25 mm in diameter.

The pedicle valve is distinctly concave anteriorly and laterally. Posteriorly, the value is flat to gently convex immediately adjacent to the pedicle opening, which is tear-shaped and about $^{1}/_{2}$ as long as wide. On the holotype it is about 3.5 mm in length or about 1/5 the length of the shell.

The brachial valve has a height equal to about $^{1}/_{2}$ the diameter. The anterior and lateral slopes are strongly convex and in some specimens the anteriorly directed slope approaches being parallel to the commissure plane near the apex. The posterior slope is straight or concave (fig. 10; Pl. 1, figs. 3 and 4c). Internally, the

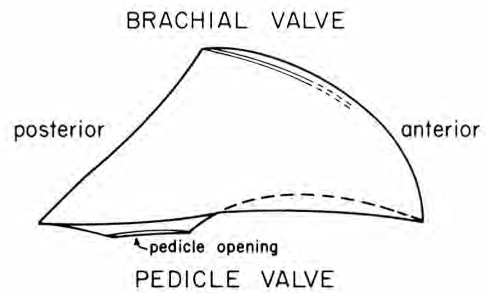


FIGURE *10 Diagrammatic cross section of* "Orbiculoidea" youngi *n. sp. Thin lines on anterior slope near apex denote two narrow tracks on the shell interior. Compare with Pl. 1, figs. 3 and 4b.*

anterior slope is characterized by the presence of two narrow tracks, each of uniform width (0.5 mm) and each bounded by a pair of fine, sharp ridges (Pl. 1, fig. 4). They diverge symmetrically at an angle of 24 to 26 degrees and have been observed to extend for 6 to 8 mm, or about 2/5 to 2/3 the distance to the anterior margin. They become faint and merge gradually into the fine, radiating striae that cover the interior of the remainder of the valve. The diverging tracks are interpreted as being vascula media.

On the shell surface are fine, concentric ridges, averaging 3 to 6 in 2 mm, being finer near the apex of the brachial valve. They are separated by broader flat areas.

DISCUSSION—This species is characterized both by a primarily concave pedicle valve and diverging paired ridges on the interior of the brachial valve. It is believed to represent a new genus differing from the type species of *Orbiculoidea* in these ways. A new generic name is not proposed at this time because the material on which the species is based is limited and we lack information on the extent to which the paired, diverging ridges on the interior of the brachial valve are developed in other orbiculoid species.

Paired, diverging ridges on the interior of the brachial valve, similar to those described here, were called "vascular sinuses (?)" by Hall and Clarke (1893, pl. IV-F, fig. 30) in describing and figuring *Orbiculoidea herzeri* from the Cuyahoga shales (Mississippian) of Ohio. That species has an almost flat pedicle valve and is considered to belong to the same new genus as that represented by *"Orbiculoidea" youngi.*

This species is named after John A. Young, Jr., the first to describe (unpublished Ph. D. dissertation, 1945, on the Pennsylvanian strata and faunas in the Taos area) the distinctive features of the species discussed here.

MATERIAL AND OCCURRENCE—There are 11 specimens in our collections from the Atokan units 67-13 and 67-23 (type localities), two closely spaced shale layers in the lower part of the Flechado Formation in Taos Canyon. Most of these specimens are strongly exfoliated. The species is doubtfully recorded from the Atokan unit 62-28(?) and the Morrowan units 41-20(?) and 61-14?), all located in the La Pasada Formation near Santa Fe. Figured specimens: holotype OU 7531; paratypes OU 7532, 7533.

"Orbiculoidea" sp.
Pl. 1, fig. 6

DISCUSSION—Poorly preserved specimens of orbiculoid brachiopods occur uncommonly in our Morrowan, Atokan, and lower Desmoinesian collections. All seem to have the pedicle valve flat or gently concave, and the convexity of the brachial valve varied from low to high. Several may belong to *"O" youngi* n. sp. but do not expose the distinctive internal features of the brachial valve.

MATERIAL AND OCCURRENCE—Orbiculoid brachiopods are rare at Morrowan units 22-41, 90-2, 90-14 to 17, common in Atokan units 62-18 and 62-28 and rare in Desmoinesian units 25-27, 29-4, 29-5, 40-3, 93-44 and locality 78. Figured specimen OU 7534.

Suborder CRANIIDINA
Superfamily CRANIACEA
Family CRANIIDAE

GENUS *CRANIA*

Crania cf. ***C. modesta*** **White and St. John**
Pl. 1, fig. 7

Crania modesta White and St. John, 1867, p. 118; Dunbar and Condra, 1932, p. 51, pl. 1, figs. 23-26.

DISCUSSION—This species is very rare in our collections, being represented by only two specimens, each consisting of a pedicle valve attached to the side of the same solitary coral. Thus, the interior of the pedicle valve can be seen. The posterior adductor scars appear as circular patches, each about 2 mm in diameter; a subcentral elevated knob may represent the posterior of the central adductors. The specimens are suboval and are longer than wide. The measurements are 6.4 x 8.3 mm and 8.2 x 9+ mm. The latter specimen (Pl. 1, fig. 7) has the posterior margin broken off. There is a thickened marginal rim. Both specimens are elongated along the length of the coral with the posterior end upward. The same relationship can be observed on several specimens figured by Girty (1915a, pl. 6, figs. 12, 14). Possibly this relationship is general for the species. If this relationship could be demonstrated with consistency on those species whose life orientation is known, then it would serve as a useful ecological guide in orienting other hosts in life position.

Rowell's (1965, p. 289) revision of the Family Craniidae leaves some doubt as to the correct generic placement of the widespread Pennsylvanian forms commonly referred to *Crania.* He gives the range of the genus as "?Carb., Cret.-Rec." but then lists no other genus in the family having a calcified pedicle valve and occurring in the Pennsylvanian.

MATERIAL AND OCCURRENCE—We have two specimens, attached to the solitary coral *Lophophyllidium*, from the lower Desmoinesian part of the La Pasada Formation at unit 93-44. Figured specimen: OU 7535.

Class ARTICULATA
Order ORTHIDA
Suborder ORTHIDINA
Superfamily ENTELETACEA
Family ENTELETIDAE
Subfamily SCHIZOPHORIINAE

GENUS *SCHIZOPHORIA*

Schizophoria oklahomae **Dunbar and Condra**
P1. 1, figs. **13-14**

Schizophoria resupinoides, Mather (not Cox), 1915, pl. 8, fig. 8 (not 6, 7).
Schizophoria oklahomae Dunbar and Condra, 1932, p. 58, pl. 29, figs. 3-5.

DESCRIPTION—(Based on New Mexico specimens.) The shell is large for the genus, suboval in outline, and wider than long. The widest part is just anterior to rounded cardinal extremities; the hinge line is about $^2/_3$ the total width. Beyond the extremities the margins curve rapidly anteriorly and anterior and lateral margins are subcircular. Most specimens in our collection are fragmentary and cannot be measured. A large specimen is 48 mm in length, 58 mm wide and 27 mm thick.

The pedicle valve varies from almost flat to very gently convex, nearly equally so in all profiles. Greatest convexity occurs at or just before the beak. A sulcus is lacking but several specimens show a slight, broad, dorsally directed flexture of the anterior margin of the commissure. The height of the ventral interarea is about 1/8 to 1/9 its total width. The value is bisected by a broad open delthyrium, equal in width to about 1/4 the length of the hinge line. Strong hinge teeth are supported on the interior of the valve by thin dental plates; these are continuous with distinct ridges that surround the bilobate muscle area. These ridges join anteriorly where they may curve slightly posteriorly to meet the medium septum that divides the muscle field. This septum is low and thin far back near the beak but, anteriorly, the septum rises and thickens, then drops abruptly to the floor of the valve at the joining of the muscle-bounding ridges. A shallow pit is developed at the base of the anterior end of the medium septum in some specimens (Pl. 1, fig. 14). The heart-shaped muscle field is impressed on the floor of the valve but is tilted upward anteriorly. In thickened adult shells the anterior margin, formed by the bounding ridge, becomes distinctly elevated above the posterior end of the muscle area. The ventral mantle canal impressions are exceptionally well developed. Arrangement is lemniscate to pinnate. Gerontic shells have much secondary shell material added to the anterior part of the interior of the pedicle valve. The anterior part of one is over 7mm thick.

The brachial valve is distinctly more convex than the pedicle valve, especially near the beak where a broad, inflated umbo is formed. This umbo protrudes posteriorly beyond the hinge line. Laterally from the umbo, a concavity causes the median part of the valve to appear quite elevated. A single internal mold shows well-developed crural plates diverging at about 90 degrees; and a narrow, low median septum originating posteriorly and extending about '/4 of the way to the anterior margin. Impressions of the mantle canals are faint but appear to be pinnate in arrangement.

The surface of the shell is marked by fine low rounded lirae with narrow groove-like striae. Every third to sixth lira is stronger than its neighbors, having risen gradually to prominence, then dropping abruptly to normal height. Well-preserved specimens show a concentric succession of nearly evenly spaced growth steps, across each of which the lirae are continuous. The enlarged lirae do not necessarily reach their crests at these steps. The shell is abundantly and finely punctate, the punctae being somewhat more numerous along the striae.

DISCUSSION—This large species, with its distinctly flat pedicle valve can scarcely be mistaken for any other. It occurs in some of our units with *S. altirostris?* which is not only much smaller in size but has more convex valves. *S. Oklahomae* differs from *S. resupinoides* (Cox), which is of similar size but has highly biconvex valves and a well-developed sulcus.

Most of the specimens in our collection consist of the broken anterior half or two-thirds of pedicle valves (Pl. 1, fig. 14). This part of the valve, as stated earlier, is thickened by secondary shelf material on the interior of the valve.

MATERIAL AND OCCURRENCE—S. *oklahomae* was first described from the Wapanucka Formation (Morrowan) in southern Oklahoma. The species also occurs in Morrowan rocks in northeastern Oklahoma; the only other known occurrence in northern New Mexico was reported by Northrop and Wood (1946, p. 1185) who found it in the basal Pennsylvanian rocks in Guadalupe Canyon, northeast of the Nacimiento Mountains.

S. oklahomae is widely distributed in the lower and middle parts of Morrowan rocks in the Sangre de Cristo area, and in the lower parts of the La Pasada and Flechado Formations. It occurs commonly in units 41-33 and 90-14 to 17 and rarely at 22-41, 41-27, 41-39, 41-42, 47-19, 60-26(?), 60-38, 90-E, 90-2, 90-7 and locality 51. Figured specimens: OU 7536, 7537.

Schizophoria altirostris? **(Mather)**
P1. 1, fig. 8

Rhipidomella altirostris Mather, 1915, p. 143, pl. 8, figs. 5-5c.
Schizophoria resupinoides, Mather (not Cox), 1915, pl. 8, figs. 6, 7 (not 8).
?Schizophoria texana Girty, 1927, p. 432, pl. 27, figs. 1-8.

DISCUSSION—Mather (1915, p. 143) based his description of *Rhipidomella altirostris* on a single pedicle valve. We have examined this specimen (WM 16135) which appears to be a gerontic individual and shows strong, abundant growth lines and an apparent thickening of the shell near the anterior margin. Mather gives a good description of this specimen except that he fails to point out that one side of the posterior part of the shell is slightly crushed. His illustration suggests a shell with a shorter hinge line than was probably the case. Easton (1962, p. 86) states that Girty's USGS collections from the Morrowan rocks of Arkansas contain hundreds of specimens of this species, some topotypes. He also states that *S. texana* Girty, described from the Marble Falls Limestone of Texas, is a junior synonym of this species. Indirect evidence from our studies supports this contention. Collections of *Schizophoria* from the Morrowan rocks of eastern Oklahoma, in the OU collections, apparently include only two species. The larger one is clearly *S. oklahomae* and the smaller species appear to be conspecific with *S. texana* as described by Girty. Before a final decision can be made, *S. altirostris* needs to be redescribed on the basis of topotype material.

Most of our New Mexico specimens are fragmentary but also appear to be included here. Most agree with Girty's (1927, p. 432) description of *S. texana* in having a cardinal area about 1/4 to 1/3 the greatest width, in being subelliptical in outline, in having a strongly convex brachial valve in which the beak is distinctly arched over the hinge line, in having a broadly sinuate pedicle valve, and in having a surface marked by 8 to 10 fine lirae in 2 mm at a surface length of 10 mm. A typical specimen is 17.8 mm in length, 20.0 mm wide, and 12.7 mm thick. Some specimens show a variation from the above description in being more quadrate, with the cardinal area being equal to about $^1/_2$ the greatest width and the dorsal beak not so strongly over-arched.

MATERIAL AND *OCCURRENCE—Schizophoria altirostris?* is a widely occurring although not well-preserved species in the lower parts of Morrowan rocks in the Sangre de Cristo area, in both the La Pasada and Flechado Formations. Our collections include about 60 specimens. The species occurs commonly at units 61-2, 90-2 and locality 99 and rarely at units 36-38, 41-26, 41-33, 47-19, 60-18, 60-26, and 92-19. Figured specimen: OU 7538.

Family RHIPIDOMELLIDAE

GENUS *RHIPIDOMELLA*

***Rhipidomella* cf. *R. carbonaria* (Swallow)**
P1. 1, fig. 9

Rhipidomella carbonaria, Dunbar and Condra, 1932, p. 52, pl. 2, figs. 1-4: Sturgeon and Hoare, 1968, p. 25, pl. 2, figs. 13, 14.

DISCUSSION—The species described here is rare in our collections; poor preservation does not make a precise identification possible. Our specimens have the following general characters: suboval outline with the width slightly greater than the length, a pedicle valve with uniform, low convexity, a brachial valve uniformly convex but much more so than in the pedicle valve, a lack of a fold or sulcus on either valve, and a surface marked by 18 to 23 lirae in 5 mm at a surface length of 5 mm, with an average of 19.75 for 8 specimens. The largest specimen is 13.4 mm in length and 13. 8 mm in width but most are 8 to 10 mm in length and crushed.

Our form appears to be related to *R. carbonaria* as described by Dunbar and Condra (1932, p. 52), but they do not give data on the range of variation in shape and in the coarseness of the surface lirae in their specimens from the Midcontinent. The specimen from Ohio illustrated by Sturgeon and Hoare (1968, p. 25, pl. 2, figs. 13, 14) has the same general suboval outline and size as our specimens but the pedicle valve illustrated has a much more highly arched umbo and a much higher ventral interarea than found in our specimens. Also, they do not record the coarseness of the surface lirae in the Ohio specimens.

The form described here differs from the Morrowan *R. trapezoida* in being more circular in outline, in lacking a dorsal sulcus, in having a more convex brachial valve, and in possibly having slightly finer lirae.

MATERIAL AND OCCURRENCE—According to Dunbar and Condra (1932, p. 54), *R. carbonaria* occurs throughout the Missourian in the Midcontinent and has been reported from the Desmoinesian in Kansas. Sturgeon and Hoare (1968, p. 25) record its rare occurrence in scattered Atokan to Missourian horizons in Ohio. All our specimens, approximately 20, come from the lower Desmoinesian portions of the La Pasada Formations, from the following units: 10-23, 29-10, and 93-44. Figured specimen: OU 7539.

***Rhipidomella trapezoida* n. sp.**
Pl. 1, figs. 10-12

Orthis Pecosii, White (not Marcou), 1877, p. 125, pl. 9, figs. 5a-e. ?
Rhipidomella pecosi, Mather (not Marcou), 1915, p. 144, pl. 8, figs. 3, 3a.
Rhipidomella carbonaria, Gehrig (not Swallow), 1958, p. 10, pl. 6, figs. 39-41.

DESCRIPTION—The shell is small, subtrapezoidal and widest anterior to midlength. The length of the hinge line is slightly less than $^1/_2$ the greatest shell width. Both valves have low, equal convexity. Margins are slightly shouldered at the cardinal extremities, straightening laterally, and becoming almost straight along an anterior line that is slightly longer than the hinge line. The length is slightly less than the width. Dimensions of the holotype are: length 9.6 mm, width 10.7 mm, thickness 4.3 mm, lenth of hinge line 4.4 mm. For 18 specimens from the type locality the average dimensions are: length 8.68 mm, width 9.33 mm, thickness 3.91 mm. The ratio of thickness to length for the same 18 specimens ranges from 0.42 to 0.51 and averages 0.45 (see Appendix 3 for shell measurements).

The pedicle valve has low convexity but the small, narrow umbo is strongly arched for the first 2 mm (SL). On most but not all specimens a faint, low mesial fold extends from the umbo to the anterior margin and gradually increases in width. At a surface length of 10 mm the fold averages about 3 mm in width. Lateral slopes are gently convex except posteriorly, where they become concave. The interarea is apsacline and quite low. The ventral muscle field is typical for the genus, being broad, with the diductor scars extending about 2/5 the distance to the anterior margin. They have scalloped margins and enclose the small, oval adductor scars that are equal in width to less than $^1/_3$ the total diameter of the muscle field.

The brachial valve is uniformly convex from beak to margin. A rounded, low sulcus starts within 1 to 2 mm of the beak, persisting, deepening, and broadening to the anterior margin. Lateral slopes are convex except posteriorly, where concavity accentuates the narrowness of the beak. The narrow interarea is orthocline. Internal features are unknown.

The shell surface is covered with fine even bifurcating lirae, three splits occurring (on the average) from beak to anterior margin; the shorter lirae on the lateral slopes split sooner. At 5 mm (SL) the number of lirae in 5 mm has an observed range from 17 to 20 and averages 19.0 for 11 specimens. The shell is finely punctate.

DISCUSSION—This species is distinguished by its subtrapezoidal shape, its low, even biconvexity, and the presence of a sulcus on the brachial valve. The dorsal sulcus and the distinctive shape are obliterated on crushed specimens, which have the misleading appearance of being oval or circular in outline. *R. carbonaria,* which occurs in the Atokan, Desmoinesian and Missourian of the Midcontinent, differs in being more circular or oval in outline, in having more strongly convex valves, in lacking a dorsal sulcus, and apparently in having slightly finer lirae.

Mather (1915, p. 144) reported the rare occurrence of a small species of *Rhipidomella* in the Morrowan strata of Arkansas but does not give a description. His figured specimen is only slightly more than 5 mm in length but could represent a young individual of *R. trapezoida.*

MATERIAL AND OCCURRENCE—R. *trapezoida* has been found only in Morrowan rocks in the Sangre de Cristo area. We have not found specimens of the genus *Rhipidomella* in Atokan rocks in our area, but Gehrig (1958, p. 10, pl. 6, figs. 39-41) describes and figures what appear to be examples of this species from the lower part of the Derry Series in southern New Mexico.

There are about 50 specimens in our collections. The species is common in unit 41-33 (type locality) and rare in units 36-68, 61-6A, 92-23 to 27 and locality 68. Figured specimens: holotype OU 7540; paratypes OU 7541, 7542.

Order (uncertain)
Family ISOGRAMMIDAE

GENUS *ISOGRAMMA*

DISCUSSION—Isogramma is unusual and rare. Some species are among the largest of all known brachiopods. *I. renfrarum* Cooper reaches a diameter in excess of 180 mm. The shell is exceptionally thin and fragile for the large size; complete specimens of the larger species are unknown. Details of the hinge structures and some of the internal features are not well described or understood. The pedicle valve is characterized by the presence of an umbonal plate, the shell surface by distinct concentric ornamentation of closely spaced elevated fila, and the wall by a cellular structure that apparently represents exceptionally large and closely packed punctae. The origins of this genus are unknown and its classification is uncertain.

***Isogramma* sp.**
P1. 1, fig. 15

DESCRIPTION—The one specimen in our collection consists of the partly exposed, eroded interior of the pedicle valve, partly concealed by about half of the eroded brachial valve that is compressed onto the pedicle valve. The posterior margins of both valves are missing. The shell is exceptionally large with a restored width greater than 140 mm and a length greater than 65 mm. The valves are almost flat, possibly distorted by compaction. A slight curvature of both valves in the posterior region suggests a gently concavo-convex shape. The valves are exceptionally thin and fragile for the large size. The surface is covered by fine, regular, concentric fila separated by somewhat wider, flat depressions; these fila curve inward slightly along the posterior margin. At 10 mm from the broken beak area are 11 concentric bands in a distance of 5 mm. By 18 mm from the beak area this number has dropped to 7 and remains at 6 or 7 out to the margins.

The outline of the prominent triangular platform located in the umbonal region of the pedicle interior is well shown and is at least 25 mm long, at which length its width is 18 mm. The surface of this raised platform has a fine granular texture, and presumably marks the location of the adductor muscle attachment. The axial part of this platform is obscured by a fragment of the overlying brachial valve containing the cardinal process and medium septum. The cardinal process is a short, stout shaft 2.3 mm in diameter; details are not visible. It is joined to a long narrow median septum that, together with the process, has 37 mm of length preserved, extending $^{2}/_{3}$ the length of the brachial valve.

The eroded surface of the brachial valve shows well the cellular wall structure, which is presumed to represent a modified form of punctae. The punctae are closely crowded and vary greatly in size and shape with an observed range between 0.1 and 0.4 mm in diameter. The walls separating the punctae are thin.

DISCUSSION—Isogramma sp. resembles *I. renfrarum* (Cooper, 1952, p. 114) from Upper Pennsylvanian (Virgilian) rocks in north Texas, in the large size, shape and general character of the concentric ornamentation. *Isogramma* sp. differs in having slightly coarser surface ornamentation, the fila numbering about 7 instead of 9 in a space of 5 mm, and in having a more diverging shape to the triangular platform in the pedicle valve. However, the range of variability is unknown in both forms.

Isogramma sp. occurs in a very fine-grained, calcareous, platy sandstone, in which the only other fossils observed are small pelecypods including a pecten.

MATERIAL AND OCCURRENCE—The single specimen of *Isogramma* sp. is earliest Desmoinesian in age, from unit 36-97. Figured specimen: OU 7543.

Order STROPHOMENIDA
Suborder STROPHOMENIDINA
Superfamily DAVIDSONIACEA
Family MEEKELLIDAE

GENUS *MEEKELLA*

DISCUSSION—Dunbar and Condra (1932, p. 66) give an excellent discussion of *Meekella* and related genera. They state (p. 135): "So far as known, *Meekella* succeeds *Schellwienella* about the beginning of Pennsylvanian time, no representative of the latter genus occurring in the Upper Carboniferous faunas." They give the range of *Meekella* as Pennsylvanian to Permian. This appears to be true in North America with *Meekella* n. sp. A, described in this paper from the Morrowan rocks of New Mexico, being the earliest substantiated species of *Meekella* recorded. The same form occurs in Morrowan rocks in eastern Oklahoma and Arkansas. Elias (1957, p. 493) referred a fragment of an external mold from Upper Mississippian rocks in southern Oklahoma to *M. striatocostata* but the specimen is almost certainly a spiriferid fragment. However, Sokolskaya (1954, p. 28) gives the lowest occurrence of *Meekella* to be in the Visean Stage (C_1 Zone) on the Russian Platform. Most of the Mississippian species of *Meekella* which Sokolskaya illustrates have very faint plications but *Meekella eximia* (Eichinald), from the C_2 and C_3 Zones (Upper Mississippian) has plicae typical of the genus.

***Meekella* n. sp. A**
Pl. 1, figs. 16-17

Meekella striatocostata, Mather (not Cox), 1915, pl. 10, fig. 10.

DESCRIPTION—The shell is medium in size but variable in shape. The valves are about equally convex except for the elevated beak of the pedicle valve. The hinge line is equal to about $^{3}/_{4}$ the greatest width. The figured specimen has restored, estimated dimensions of: length 36 mm, SL 39 mm, width 40 mm, thickness 19 mm, hinge line 31 mm. A smaller specimen has the following dimensions: length 27 mm, SL 28 mm, width 22 mm, thickness 16 mm, hinge line 19 mm. A fold or sulcus is lacking.

The pedicle valve has a high, apsacline interarea. In the figured specimen the valve is $^{1}/_{2}$ as high as wide but in another the height is equal to $^{2}/_{3}$ the width. The pseudodeltidium has an apical angle of about 15 degrees. The brachial valve has low to moderate convexity. Internal features are unknown.

The surface is covered with angular plications that do not begin until a surface length of 12 to 14 mm from the beak. They number 6 or 7 in 20 mm at a surface length of 25 mm. The figured specimen has possibly 16 to 18 on each valve but a smaller specimen has only 12 per valve. Radial lirae number about 4 per mm and are mostly parallel to the plications, showing only a slight tendency to converge towards the plication crests.

DISCUSSION—The specimens of *Meekella,* from Morrowan strata almost certainly represent a new species but the material available is inadequate for description and comparison. This species differs from the highly variable *Meekella striatocostata* (Cox), from the Middle and Upper Pennsylvanian of the Midcontinent, in having less coarse plications that do not originate near the beak, in having a wider hinge line for the width of the shell, and in having lirae that show less convergence on the plication crests.

MATERIAL AND OCCURRENCE—Nine specimens were collected from the following Morrowan units, all in the lower part of the La Pasada Formation near Santa Fe and at Nambe Falls: 41-33, 41-39, 41-42, and 90-7. The species also occurs in the Morrow Group of northwestern Arkansas and northeastern Oklahoma. Figured specimens: OU 7544, 7545.

Meekella cf. *M. striatocostata* (Cox)

Pl. 1, fig. 18

Meekella striatocostata, Dunbar and Condra, 1932, p. 125, p1. 16, figs. 1-10.

DISCUSSION—A single brachial valve from the lower Desmoinesian rocks of the Pecos valley appears to fall within the wide range of variability described for this species by Dunbar and Condra (1932, p. 125). The specimen is large for the species and is strongly convex with an inflated umbo and about 12 or 13 large rounded plicae; at a surface length of 25 mm, are 5 plicae in 20 mm. Two or three of the plicae tend to split. The plicae originate at or near the beak. A shallow sulcus is present.

The specimen described here differs from *Meekella* n. sp. A, from the Morrowan, in being more convex and in having coarser plicae which originate near the beak.

MATERIAL AND OCCURRENCE—One specimen was collected from the lower Desmoinesian part of the La Pasada Formation: 29-3. Figured specimen: OU 7546.

Family ORTHOTETIDAE
Subfamily ORTHOTETINAE

GENUS *ORTHOTETES*

Orthotetes sp.

Pl. 2, figs. 1-3

DISCUSSION—The specimens included here are mostly crushed or incomplete and do not form an adequate basis for specific identification. They come from our lower Desmoinesian rocks but do not differ in any discernible way from Weller's (1914, p. 77) description of *O. kaskaskiensis* from the Upper Mississippian of Illinois. Weller does not illustrate interiors but he describes the presence in the pedicle valve of "a shallow, triangular chamber in the apex of the valve" formed by the joining of the dental plates to the posterior part of the median septum. A similar spondylium can be seen in the single specimen in our collection showing the interior of the pedicle valve (P1. 2, fig. 2).

One of our larger shells has the following dimensions: length of pedicle valve 32.5 mm, width 39 mm, length of hinge line 32 mm. The radiating costae number about 10 in 5 mm at a surface length of 10 mm and 8 to 9 in 5 mm at surface length of 20 mm.

MATERIAL AND OCCURRENCE—There are 15 mostly crushed specimens from the lower Desmoinesian strata near Lamy, unit 93-44. Figured specimens: OU 7547, 7548, 7549.

Subfamily DERBYIINAE

GENUS *DERBYIA*

Derbyia bonita n. sp.

Pl. 2, figs. 4-7

DESCRIPTION—The shell is subrectangular in outline and small in size for the genus with a large specimen having a length of about 17 mm, a width of 20 mm and a thickness of 5.5 mm (see Appendix 3). The shell is comparatively thin with a low convexo-plane profile. The ratio of thickness to length is 0.40 for 13 specimens measured. The hinge line is a little shorter than the greatest width, which is at midlength. The anterior margin is nearly straight. The cardinal extremities are slightly obtuse.

The pedicle valve is almost flat in longitudinal profile and only slightly convex transversely. The low interarea is apsacline and equal in height to 1/5 to 1/6 its greatest width. It is broken by a distinctly convex pseudodeltidium, which is as high as wide and marked by well-developed transverse growth lines. A single pedicle valve interior, which possibly belongs to this species, from the Atokan unit 62-28, shows (Pl. 2, fig. 7) a median septum extending less than $^{1}/_{3}$ the distance to the anterior margin. The dental plates are strong but exceptionally short and are not connected with the valve floor or septum. Muscle impressions are weak. The valve floor reflects the external lirae.

The brachial valve is uniformly and gently convex mesially, with a slight anterior flattening. The transverse profile is gently convex with lateral and mesial flattening at midlength. A few specimens show the development of a very faint, broad, shallow sulcus extending forward from about midlength. A single brachial valve interior (Atokan unit 62-28) possibly belonging to this species, shows (Pl. 2, fig. 6) a very low, rounded, short median ridge. The cardinal process is bilobed posteriorly, each lobe marked with two radial grooves. Crural plates are strong but relatively short. The muscle area is large but faint and longitudinally striated.

Both valves are marked by extremely fine, sharp, radiating lirae, averaging 29.1 (range 22-36) in 10 mm at a surface length of 10 mm for 14 specimens counted. Intercalation is common_

DISCUSSION—D. *bonita* differs from *D. crassa,* from the Desmoinesian and higher strata in the Midcontinent, in being smaller in size, subquadrate in shape, relatively thinner, and with finer lirae. Our specimens show remarkably little variation in character or distortion in growth form, compared with descriptions by Dunbar and Condra (1932) for most species of this genus.

MATERIAL AND OCCURRENCE—This is a rare species in Morrowan strata; possibly the same species occurs even more rarely in Atokan strata. There are 27 specimens in our Morrowan collections of which 15 are from the type units, 90-14 to 17; the remaining are from the following units: 36-38(?), 36-68(?) 41-33, 60-18, 61-2, and 61-6A. There are 7 questionable specimens from the following Atokan units: 62-17 and 18(?), 62-28(?), and 67-13(?). Figured specimens: holotype OU 7550; paratype OU 7551; other figured specimens OU 7552, 7553.

Derbyia crassa **(Meek and Hayden)**

P1. 2, figs. 8-12

Derbya crassa, Dunbar and Condra, 1932, p. 79, pl. 3, figs. 1-12.
Derbyia crassa, Sturgeon and Hoare, 1968, p. 26, pl. 3, figs. 1-4.

DISCUSSION—Dunbar and Condra (1932, p. 79) describe *D. crassa* as being highly variable in character. The New Mexico specimens we include in this species fall within the broad range that Dunbar and Condra indicate for size and shape but appear to have somewhat finer surface lirae. Dunbar and Condra do not describe the range of variation in coarseness of the lirae, but their figures (1932, pl. 3) seem to show from about 15 to 23 lirae in 10 mm at a distance of 10 mm from the beak. Sturgeon and Hoare (1968, p. 26) record 16 to 18 in 10 mm at distance of 10 mm from the beak, based on specimens from Ohio. The New Mexico specimens have somewhat finer lirae with 20 to 32 in 10 mm (average 24) at a surface length of 10 mm for 15 specimens counted and 20 to 30 in 10 mm (average 23) at 20 mm (SL) for 7 specimens counted. Our specimens have the following characteristics: length and width are subequal; thickness to length ratio for 36 specimens measured is 0.57. The hinge line is slightly shorter than the greatest width, but extremities may be pointed as a result of a constriction in the posterolateral margin. Both valves are gently and subequally convex. The ventral interarea is orthocline in some specimens and apsacline in others and is moderately high. The pseudodeltidium is strongly convex. Several eroded pedicle valves show a long and prominent median septum. No one specimen has all of these "typical" features. Often the ventral beak is twisted, distorted, and/or flattened. Many specimens have become gibbous with the addition of numerous thick growth lamellae at the anterior margin. The contortion of some of the shells appears to have resulted from growth against other nearby objects.

Our specimens referred to *D. crassa,* all from the lower Desmoinesian, differ from *D. bonita,* from the Morrowan, in being larger in size, comparatively thicker, in having a higher interarea and slightly coarser lirae, and in showing much greater variation in growth form.

MATERIAL AND OCCURRENCE—D. *crassa* ranges in age from Desmoinesian to Virgilian in the Midcontinent. All specimens which we refer to this species are from the lower Desmoinesian part of the La Pasada Formation. There are 41 specimens from locality 105, 14 from units 36-133 and 2 from unit 29-5(?). Figured specimens: OU 7554-7558.

Derbyia **cf.** ***D. haesitans*** **Dunbar and Condra**

Pl. 2, fig. 13

Derbya haesitans Dunbar and Condra, 1932, p. 110, pl. 13, figs. 3-5.

DISCUSSION—We have one well-preserved and three poorly preserved specimens that are included here. We have compared them with Dunbar and Condra's co-types. Our figured specimen has a similar pedicle valve but the brachial valve shows lower convexity, and the lirae on our specimens are finer, numbering 23 to 24 in 10 mm at a surface length of 20 mm.

MATERIAL AND OCCURRENCE-This species occurs in the Missourian of the Midcontinent. Our four specimens come from the upper part of the Alamitos Formation, from the Missourian unit 97-54 and the Virgilian unit 97-74. Figured specimen: OU 7559.

Order STROPHOMENIDA
Suborder CHONETIDINA
Superfamily CHONETACEA
Family CHONETIDAE

DISCUSSION—The division of this family into the subfamilies proposed by Muir-Wood (1962) is not followed here. Her grouping is not explained and appears illogical, for example, she places the genera *Neochonetes* and *Mesolobus* in separate subfamilies. We consider these genera to be very closely related, and some species of *Neochonetes* to have given rise to some species of *Mesolobus* during the Atokan Epoch (see discussion under these genera). Rowell (1967) discusses various ways of grouping chonetid brachiopod genera using numerical taxonomic techniques.

GENUS *PLICOCHONETES*

DISCUSSION—The internal features of the type species for this genus, *Chonetes buchianus* de Koninck, are not well known and for this reason we refer *Plicochonetes? arkansanus* (Mather) from the Morrowan of Oklahoma and New Mexico to *Plicochonetes* with uncertainty. Muir-Wood (1962, p. 82) gives the range for the genus as being Devonian to Lower Carboniferous, but according to Moore (1965, p. 430), the range also includes the Upper Carboniferous. In the latter work, the range of the type species is given as Lower or Upper Carboniferous of northern England. The type species has a highly convex pedicle valve with extraordinarily coarse costae that number about 3 per 5 mm (Muir-Wood, 1962, pl. 15, fig. 1).

Plicochonetes dotus Sturgeon and Hoare (1968, p. 33) from the lower Desmoinesian of Ohio is the only Pennsylvanian chonetid from North America to have been previously referred to this genus.

Plicochonetes? arkansanus (Mather)

Pl. 3, figs. 1-9

Chonetes arkansanus Mather, 1915, p. 149, pl. 8, fig. 4.

DESCRIPTION--(Based on specimens from unit 41-33 and locality 68.) One of the largest specimens in our collection has an incomplete length of 8.2 mm, width 12 mm, and a restored height greater than 3 mm. Mean dimensions for our entire collection are: length 6.4 mm and width 9.0 mm. (For descriptive statistics of all chonetid species described, see Appendix 2, tables 1 and 2.) The maximum width is at the hinge line. The shape is subelliptical except for the hinge line, which is extended laterally and possesses distinct alae. The posterior margin diverges from the plane of symmetry at approximately 80 degrees.

The pedicle valve is strongly convex in lateral profile, especially near the beak, which overhangs the hinge slightly. The umbo is inflated and its lateral slopes are steep; the alae are flat and thin. Anteriorly, the umbo flares rapidly. There is no sulcus, although a slight flattening of the anterior slope is present on a few specimens. Generally, the transverse profile at or near the anterior margin is strongly and uniformly convex. The interarea is crushed on most specimens but can be seen on uncrushed specimens to be approximately orthocline, narrow, and slightly concave. A narrow, small pseudodeltidium has been observed on one specimen. The hinge line has a maximum of 7 spines on each side of the beak. The spines increase in diameter away from the beak, and the angle at which they diverge from the hinge line also appears to become greater with increased distance from the beak. This angle has been observed to be as high as 60 degrees.

The brachial valve is gently concave. It is crushed into the pedicle valve on almost all articulated specimens, giving the incorrect appearance of marked concavity. Estimating the volume of the visceral cavity is difficult but it would appear to be great for the size of the shell.

The surfaces of both valves are ornamented with strong, subangular costellae that bifurcate every 2 to 3 mm anteriorly. On the pedicle valve, they average 23.6 and range in number from 19 to 27, measured in 5 mm at a surface length of 5 mm. One or two prominent growth lines may be present near the anterior margin.

Four pedicle interiors in our collection have considerable variation in character due, in part, to ontogenetic differences. Thicker, larger shells show thicker and larger internal ridges and some features not observed on thinner shells. The median septum varies in height and extent. In one specimen, it is elevated under the delthyrium for a distance of no more than 1 mm and is virtually lacking anteriorly. Other specimens have a low septum extending up to 1/4 or 1/5 the distance to the anterior margin. The thinnest shell does not have lateral ridges. Three thicker ones have thickened, low ridges closely set to the median septum. These lateral septa begin at the anterior margin of the small, oval, and slightly elevated adductor scars and extend anteriorly for distances of from 1 to 3 mm. In one specimen, the ridges stop abruptly at midlength. In the other two, they extend to $^2/_3$ the valve length. The lateral ridges may or may not be greater in elevation than the median septum. The diductor scars are distinctly inset posteriorly and laterally with sharp margins. They fan out anteriorly and extend approximately $^1/_2$ the distance to the anterior margin. The anterior and lateral slopes are covered with rows of medium-sized papillae that become finer near the anterior margin.

The brachial interior (we have 6 well-preserved specimens) is highly distinctive in character. The strength of the features also varies with the thickness and size of the valve, presumably also representing differences in development with age. The median septum is separated from the cardinal process by a shallow alveolus. It begins low, rises gradually to form a slightly elevated ridge, and stops abruptly at or immediately posteriorly to midlength. Lateral septa diverge from the alveolus at angles of approximately 25 degrees from the median septum. They are about the same length or slightly shorter than the median septum and about the same thickness, giving the shell interior a distinctive trilobed division. The lateral septa separate two sets of adductor scars that are clearly delineated only on the thickest valve (Pl. 3, fig. 5). On this specimen, they form distinctive tear-shaped depressions about $^2/_3$ as long as the lateral septa. Socket ridges diverge from the hinge line at about 20 degrees and enclose thin, elongated, and narrow socket grooves up to 1 mm in length but only about 0.3 or 0.4 mm in width (Pl. 3, fig. 6). The cardinal process is short, small, and blunt. The specimen that best reveals the process (Pl. 3, fig. 6) has a trilobed process both internally and externally, with a groove extending down the posterior face of each lobe. Brachial ridges are not developed. Large, blunt papillae cover the anterior valve floor except at the margin where small pustules are arranged in radial rows along the summits of the internal costellae.

DISCUSSION—We have examined Mather's (1915, p. 149, pl. 8, fig. 4) cotypes of *Chonetes arkansanus* from the Morrow Series of northeastern Oklahoma. They number 9 specimens (WM 16084) of which 4 are complete shells. All are minute specimens, the single figured one being the largest: length 3.3 mm, width 4.6 mm. At the anterior margin, the costellae number 5 per mm. However, Mather's collection also contains two non-type specimens from another locality in the Morrow Formation of northeastern Oklahoma. These are larger; one has a length of 4.6 mm and at hinge, a width of 7.5 mm. The costellae number 5 per mm at the anterior margin. Our own collections from the Morrowan of northeastern Oklahoma contain specimens as large as the average-sized specimens in our New Mexico collections. We observe no differences between the shells from northeastern Oklahoma and New Mexico, including Mather's types, except that the largest New Mexico shells are slightly larger than any in our collections from northeastern Oklahoma.

P. ? arkansanus is characterized by the small size, marked convexity of the pedicle valve, inflated umbo, lack of a sulcus, extended hinge line, and relatively coarse costellae for the small size of the shell. It is strikingly different from other lower Pennsylvanian chonetid brachiopods.

Plicochonetes dotus Sturgeon and Hoare (1968, p. 33, pl. 4, figs. 6-15), from the lower Mercer Shale (lower Desmoinesian) of Ohio, is similar to *P.? arkansanus* and may prove to be a junior synonym of it. They state that *P. ? arkansanus* differs from *P. dotus* "in being consistently larger, in having the greatest convexity posterior to midlength, and in having finer costae and costellae." Specimens of *P.? arkansanus* from northeastern Oklahoma in the OU collection as well as Mather's type specimens, have an average size no greater than their listed mean measurements for *P. dotus.* The convexity of most, if not all, chonetid brachiopods is greatest posterior to midlength. Our specimens from northeastern Oklahoma average about 5 costellae per mm at the anterior margin compared to their 5 to 6 per mm. The difference in stratigraphic range of the two species appears to be the only factor of significance.

MATERIAL AND OCCURRENCE—P.? *arkansanus* was first described by Mather from the Morrowan of northeastern Oklahoma. It is widely distributed in that area, as well as in Arkansas, and locally occurs in abundance. The species also occurs rarely in the Wapanucka Formation (Morrowan) of southern Oklahoma.

P.? arkansanus is widely distributed in Morrowan strata in northern New Mexico. It occurs commonly only at units 41-33, 41-56, and locality 68. It occurs rarely at units 36-38, 36-63, 41-42, 41-47, 41-56, 61-2, 61-6A, 65-63, 90-14 to 17, and 92-23 to 27. There are 79 specimens in our collection, including 4 pedicle and 6 brachial interiors. Figured specimens: OU 7577-7585.

GENUS *NEOCHONETES*

DISCUSSION—The shell is most typically quadrate to trapezoidal in shape, capillate or partly smooth, with a low concavo-convex profile. A sulcus may be present on the pedicle valve. Internally, the pedicle valve is characterized by a short median septum, flanked by longer, parallel, lateral ridges that typically are prominent and may extend well past midlength. The brachial interior has a long median septum, elevated anteriorly, short lateral septa, and thick inner socket ridges.

Neochonetes is most closely related to *Mesolobus.* Externally, *Mesolobus* differs only in the consistent presence of a well-developed mesial lobe on the pedicle valve. Internally, the two genera are essentially the same except for the differences in the shape of the internal surfaces resulting from the development of the sharper sulcus and distinct mesial lobe in *Mesolobus.* Our collections would suggest that at least some species of *Mesolobus* evolved from *Neochonetes* during the Atokan Epoch.

Muir-Wood (1965, p. 432) gives the range of *Neochonetes* as Pennsylvanian to Permian. The type species, *N. dominus* (King), is from the upper Marble Falls Limestone (Atokan) of central Texas. Species have not previously been reported from rocks older than Atokan. Our species *Neochonetes* n. sp. A, from the lower part of our New Mexican Morrowan sequence is apparently the earliest recorded species of this genus. *Neochonetes? platynotus* (White), from our highest Morrowan rocks, has the internal characteristics of *Neochonetes* but externally has some similarities to *Eolissochonetes. N. whitei* n. sp. and *N. henryi* n. sp., which occur in Atokan strata, are transitional forms between *Neochonetes* and *Mesolobus.* Some individuals in both species develop a faint mesial lobe. *M. striatus* Weller and McGehee, a typical species of *Mesolobus,* also occurs in Atokan strata but extends upward into the Desmoinesian rocks where other typical mesolobids such as *M. euampygus* (Girty) and *M. profundus* n. sp. also occur.

Neochonetes? platynotus (White)

Pl. 2, figs. 14-26; Pl. 3, figs. 10-14

Chonetes platynota White, 1874, p. 19; 1877, p. 121, pl. 9, figs. 6a-e.

ORIGINAL DESCRIPTION—Shell rather under average size, transversely suboval or indistinctly four-sided; hinge-line usually about equal to the greatest width of the shell, often slightly exceeding it, and occasionally shorter.

Ventral valve moderately convex, flattened a little toward the hinge-extremities, without a proper mesial sinus, but, in place of it, there is a mesial flattening or slight bending-upward, at the front only, which straightens the front border a little; beak not prominent; area of moderate width wider than that of the dorsal valve, bearing on its posterior margin five or six rather small oblique tube-spines upon each side of the beak.

Dorsal valve almost flat, oftener a little convex than concave, especially from side to side; mesial fold represented only in adult shells, and in them merely by a very slight elevation of the front, causing its margin to follow that of the ventral valve in a gentle sinuosity; surface of both valves marked by numerous fine, obscure, radiating striae and occasional imbricating lines of growth.

This species is readily distinguished from others by its flat or slightly convex dorsal valve.

Length, nine millimeters; width, twelve millimeters.

REMARKS ON TYPE SPECIMENS—We have examined White's syntypes of *Chonetes platynotus.* There are 4 loose specimens, 3 complete and 1 broken, free pedicle valve, all similar in character. In the same tray is a piece of rock that is lithically different from the four loose specimens, and bearing the extra number 2850. The 2 specimens on this block are too poorly preserved for positive identification, but have a much lower convexity, and probably do not represent the same species as the 4 loose specimens. Probably this block has been subsequently added to White's syntypes, and we exclude the specimens on it from the syntypes.

White's descriptions are generally accurate, but we would describe none of the specimens as having a suggestion of convexity of the brachial valve. Two of the four loose specimens are clearly those illustrated by White (1877, pl. 9, figs. 6a-e). One of these is a complete specimen and one is a loose pedicle valve. We are here reillustrating these specimens and designate the former (White's figs. 6a, b, d, e) as the lectotype. His drawing of this specimen is good in depicting the outline and the peculiarities of the spines on the hinge, but is incorrect in the illustration of a narrow mesolobid fold in a broad sulcus. This specimen, in fact, shows a flattening of the anterior margin that has only the faintest suggestion of a mesial fold (Pl. 2, fig. 14e). White's description is accurate on this point; he mentions only the presence of mesial flattening. Also, possible capillae are less clearly seen on the specimen than are shown in White's drawing. The other 2 specimens, which White did not figure, resemble the figured specimen closely. Although both have a flattening of the anterior slope, neither shows any suggestion of a mesial lobe (Pl. 2, figs. 18b, 19b). All of the type specimens are decorticated. Whether they are capillate cannot be determined with certainty, although possible capillae or pseudo-capillae are faintly suggested locally on the anterior slopes of the pedicle valves of the lectotype and one other specimen. These capillae number 7 or 8 per mm; none can be seen on the brachial valve.

DESCRIPTION—(Based on specimens from unit 41-49.) The shells are small and distinctly subrectangular. The maximum width is at midlength or at the hinge line. The alae are quite small and are not distinctly set off from the rest of the shell. The lateral margins are almost straight, and the anterior margin is gently curved. The posterior margin is slightly curved so that the beak is faintly extended. Our largest specimen has a length of 9.5 mm and a width of 13.1 mm. The mean dimensions for 35 specimens are: length 7.79 mm and width 11.18 mm. The mean height for 26 specimens is 2.20 mm. The reduced major axes (RMA) for length and width and for length and height are plotted on figures 11A and 11B. Additional RMA statistics, which can be used for comparison with our collection of *N.? platynotus*, are given in Appendix 2, tables 3 and 4.

The pedicle valve is gently and uniformly convex. A slight mesial flattening generally is present anteriorly; a few specimens have a broad and very shallow sulcus that develops approximately at midlength and extends to the anterior margin. Five to eight small hinge spines are present on each side of the beak. The spines apparently were directed laterally at approximately 35 to 45 degrees. The apsacline interarea is flat and has a height approximately 1/10 the width, and is striated horizontally. The pseudodeltidium is convex and fills no more than about the posterior $^{1}/_{3}$ of the delthyrium. Most specimens are decorticated but the pedicle valve of some has what may be faint capillae, apparently confined to the anterior slope, which number 7 or 8 per mm. Some specimens appear to be smooth. When eroded, the smooth surface shows abundant pits of pseudopunctae arranged along radiating striae. Prominent growth lamellae are developed anteriorly.

The brachial valve is flat and smooth except that an occasional very well preserved specimen shows what may be faint capillae on the anterior parts of the valve; anterior growth lamellae are present on the larger shells. A slight, broad fold is found on those specimens which have a sulcus on the pedicle valve. The interarea is very narrow, and is about $^{1}/_{2}$ the width of the interarea of the pedicle valve. Its attitude is hypercline and it lies in the same plane as the apsacline interarea of the pedicle valve.

The pedicle interior has a median septum that extends typically about $^{1}/_{2}$ the distance to the anterior margin. The median septum is abruptly swollen just before the delthyrium, then drops to moderate height with a rounded top; at valve midlength it drops to a very low ridge that may become continuous with a row of low papillae. In adult stages the median septum is flanked by parallel, closely spaced, rounded lateral ridges in the median part of the shell. These originate at the anterior edge of the small, oval adductor scars. The lateral ridges extend farther anteriorly than the elevated

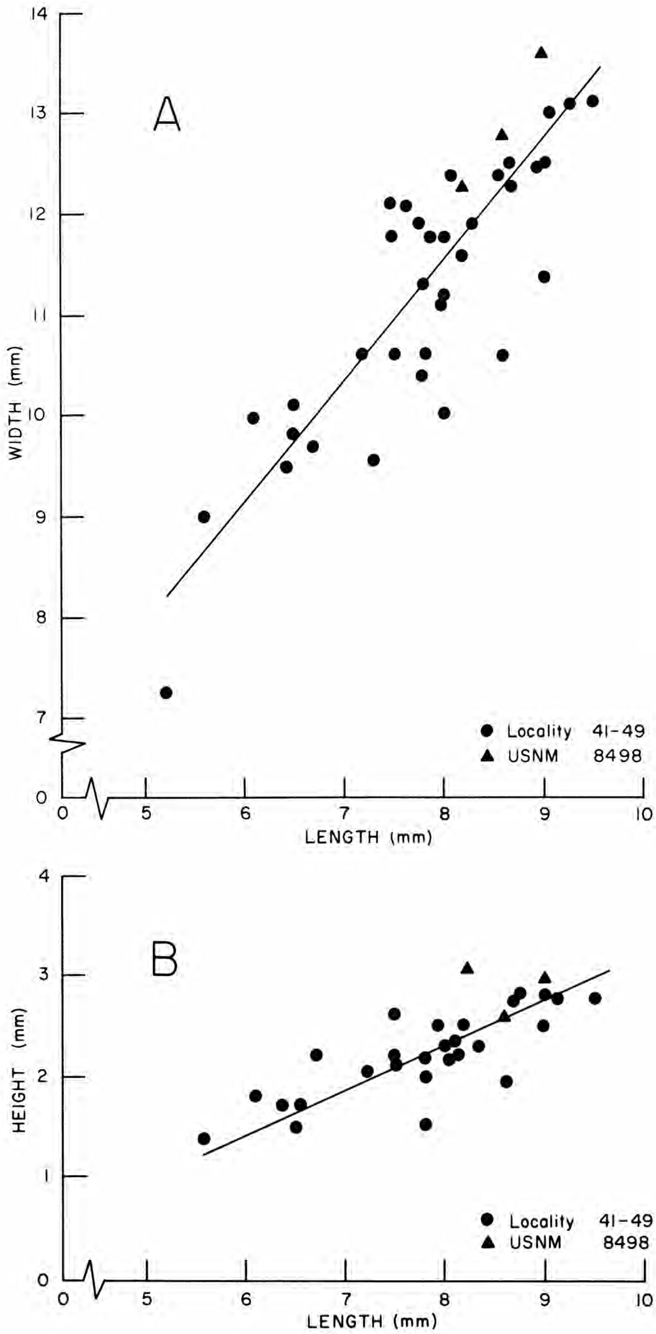


FIGURE 11—**A.** *Plot of width vs length for mature specimens of* Neochonetes? platynotus *from unit 41-49, shown as dots. White's (1877) syntypes (USNM 8498) are plotted as triangles. The line is the RMA (reduced major axis), based on the specimens from unit 41-49, and is calculated to be W = 1.31 + 1.27 L for 35 specimens. The coefficient of correlation of 0.86 reveals a relatively high degree of linear correlation between length and width; the dispersion around the RMA (0.88) is relatively low.*

B. *Plot of height and length for 26 specimens from unit 41-49. The RMA is H = -1.20 + 0.44 L; the correlation coefficient (0.81) is also relatively high. The dispersion around the RMA (0.66) is low.*

part of the median septum. They become thickened in adult specimens; in some cases these lateral ridges form, with the median septum, a rather irregular elevated platform in the median part of the valve (Pl. 2, fig. 21). The lateral ridges are represented in a young specimen only by low rows of papillae (Pl. 2, fig. 23). The diductor scars are broad and flaring, and the anterior and lateral parts of the shell interior are covered with regular, radiating rows of papillae.

The brachial interior, seen on 9 specimens in our collection, shows marked variation in character due, in part, to the addition of secondary shell material to the internal features of what are presumed to be older specimens (compare Pl. 3, figs. 10, 11, 12). A specimen of average thickness (Pl. 3, fig. 11) shows a median septum that is low posteriorly and becomes elevated anteriorly. At about 3/5 of the distance to the anterior margin the median septum abruptly terminates. It is separated from the cardinal process by an alveolus. The cardinal process is stout and its distal surface is parallel with the interarea, and is sculptured with 3 narrow diverging channels marking 4 sectors; the outer 2 of these are narrow and rounded, the middle 2 are broad and shallowly furrowed; fine, sharp, horizontal striae further sculpture the sectors. Anteriorly, the process may overhang the alveolus. The socket ridges are stout and diverge from the hinge line at about 20 degrees. Low broad, rounded lateral septa diverge from the median septum at an angle of about 30 degrees and become progressively indistinct. Brachial ridges are low but distinct. The lateral and anterior parts of the valve interior are finely papillose. Specimens that are interpreted as older individuals show the filling of the alveolus and the marked thickening of the lateral septa (Pl. 3, fig. 10). In immature specimens (Pl. 3, fig. 12) the brachial ridges are obscure, the median septum is thin and low, and the lateral septa are thin, short and more distinct than in later growth stages.

DISCUSSION—No other known *Neochonetes* possesses the distinctive features of *N. ? platynotus.* It is characterized by the small size, rectangular shape, the faintness or absence of capillae on both valves, lack of a sulcus on many shells, and the presence of strongly developed internal features as described above. The faintness of the capillae and poor development of a sulcus suggests *Eolissochonetes*, but the internal features are those of *Neochonetes.* In particular, our specimens differ from *Eolissochonetes* in that two parallel ridges bound the median septum in the pedicle valve interior and well-developed lateral septa are present in the dorsal interior.

We have found only two species of *Neochonetes* in Morrowan rocks in our area, and these appear to be separated stratigraphically. We have found *N. ? platynotus* only in the higher Morrowan rocks at Nambe Falls whereas *N.* n. sp. A appears to be confined to the lower part of the Morrowan strata and is distributed more widely. It differs from *N. ? platynotus* in being more transverse in shape with an extended hinge line and better-developed capillae.

N.? platynotus differs from *N. dominus,* from the upper Marble Falls Limestone (Atokan) in central Texas, in being much smaller in size, in lacking a sulcus, and in lacking well-developed capillae. Internally, the two species are similar in character.

We have found *N. ? platynotus* to occur uncommonly in the upper part of the Morrow Group in northeastern Oklahoma. *"Chonetes" choteauensis* Mather, which occurs in that sequence, differs in being much smaller in size, more sulcate and more transverse in shape. *N. ? platynotus* is similar in size and shape to *Chonetes chesterensis* Weller, from the Chester of Illinois, a species which Muir-Wood (1962, p. 65) places in the genus *Rugosochonetes.* However, Weller (1914, p. 84) states that the internal characters of that species are unknown. He describes that species as having fine capillae which number 5 to 6 per mm on the anterior slope of the pedicle valve, while in *N. ? platynotus* what are possibly very faint capillae number 7 to 8 per mm.

MATERIAL AND OCCURRENCE—The 4 syntypes of *Neochonetes? platynotus* (USNM 8498), labelled as being from Carboniferous strata from "near Santa Fe, New Mexico" were collected by a member of an 1873 survey party under the direction of Wheeler (1875). We have found the species only at Nambe Falls in the upper part of the Morrowan sequence (La Pasada Formation), in unit 41-49. We designate this unit as the type locality (see discussion on "Early surveys in the Santa Fe area"). Our collection from unit 41-49 includes about 50 specimens in addition to 3 free pedicle and 9 free brachial valves. The species also occurs in the upper part of the Morrow Group in northeastern Oklahoma. Figured specimens: lectotype and paralectotypes USNM 8498a-d; topotypes OU 7560-7571.

Neochonetes n. sp. A

Pl. 3, figs. 15-1 9

DESCRIPTION—The shell is much wider than long, the greatest width is along the hinge, the cardinal extremities are quite pointed and the lateral slopes converge. The largest specimens are about 7.8 mm long and up to 14 mm wide. The pedicle valve has low convexity and some specimens are very gently sinuate anteriorly. Valve surfaces are not well preserved but clearly low capillae cover the entire valve surface and number about 7 per mm on the anterior slope. The brachial valve is flat and capillate, as on the pedicle valve. The internal features of both valves, seen only on a few specimens, appear to agree closely with those found in *N. ? platynotus.*

DISCUSSION—Specimens referred to *Neochonetes* n. sp. A are not common in our collections and generally are found in a distorted condition, as the shell is quite fragile. The species has been found only in the lower part of our Morrowan strata. It differs distinctly from *N. ? platynotus,* which we have found only near the top of Morrowan strata, in having an extended hinge line, giving, in some specimens, a subtriangular outline instead of the distinctive rectangular outline of *N.? platynotus.* This new species also has better-developed capillae clearly present over the surfaces of both valves.

MATERIAL AND *OCCURRENCE—Neochonetes* n. sp. A does not occur commonly at any of our localities; all available specimens are poorly preserved. The collection, including about 40 specimens in addition to 4 pedicle interiors and 3 brachial interiors, has been collected only from the lower parts of our Morrowan sequences. In the lower part of the La Pasada Formation, the species occurs in units 36-38(?), 36-41, 61-2 (10 specimens), 61-6A, 90-2 (11 specimens) and 92-23 to 27. In the lower part of the Flechado Formation the species occurs rarely in unit 65-56(?). Figured specimens: OU 7572-7576.

Neochonetes henryi n. sp.

Pl. 3, figs. 20-34

DESCRIPTION-The shell is small. Our largest specimen has the following dimensions: length 8.4 mm, width 12.8 mm, height 3.2 mm, and surface length 10 mm; the smallest is 3.6 mm long and 6.3 mm wide. For 112 specimens the mean dimensions are: length 6.26 mm and width 9.86 mm. The mean height for 91 specimens is 2.42 mm. Figures 12A and 12B are scatter diagrams on which width is plotted against length, and height against length. The calculated reduced major axes are also plotted on each. For additional statistics see Appendix 2, tables 3 and 4. The largest shells are generally subrectangular with subparallel lateral margins having minute alae.

The pedical valve is moderately and uniformly convex in longitudinal profile. The beak is small and low, and the umbo is not prominent. A sulcus arises about 1 to 1.5 mm anteriorly from the beak and continues to the anterior margin, broadening and deepening slightly. The bottom of the sulcus is either slightly concave or flat. Rare individuals show an obscure mesial lobe developed near the anterior margin. The valve surface is marked by fine capillae (fig. 13A) that average 27.30 in a space of 5 mm on the venter at 5 mm surface length for 46 specimens measured. Each side of the posterior margin has oblique hinge spines numbering 6 or 7 per side on specimens longer than 7.0 mm. Specimens with lengths less than 4.0 mm generally have only 4 spines per side.

The brachial valve is crushed on most specimens. It is almost flat to concave except for the mesially flattened fold. Surface ornamentation is similar to that on the pedical valve.

The 13 pedicle interiors in our collection exhibit marked variation in character, which possibly represents, in part, ontogenetic variation. The median septum tends to be high and blade-like posteriorly and in most specimens extends forward as a low ridge 1/3 to $^{1}/_{2}$ the shell length (Pl. 3, figs. 28, 29). In a few specimens, the median septum is confined to the posterior elevated ridge under the delthyrium. The adductor scars are circular and may be raised on small platforms in larger specimens. Anteriorly to these scars, parallel lateral ridges may be represented by low ridges having several large pustules on their crests, or they may be represented by a row of large pustules (Pl. 3, fig. 27) . The diductor scars are large, elongated, and extend approximately to midlength. The remainder of the interior, with the exception of the lateral and anterior margins, is covered with large pustules that are arranged radially. The flat marginal areas are more finely pustulose.

The interior of the brachial valve is slightly convex, except for an abrupt marginal flattening. The cardinal

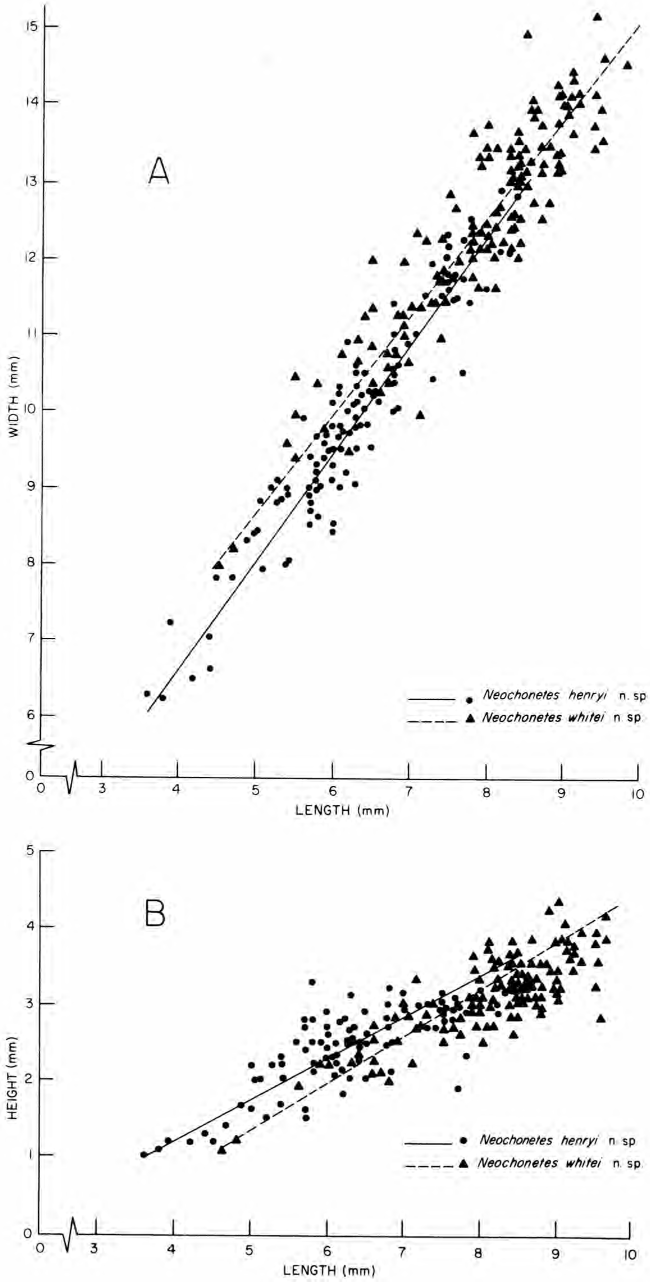


FIGURE 12- **A.** *Scatter diagram of width vs length for type specimens of* Neochonetes henryi *n. sp. from unit 62-28 (shown by dots) and* N. whitei *n. sp. from unit 62-17 and 18 (triangles). The reduced major axes for the two species are plotted as solid and dashed lines, respectively. The RMA (reduced major axis) for* N. henryi *is W = 0.88 + 1.43 L; that for* N. whitei *is W = 2. 01 + 1.31 L. The coefficient of linear correlation for both species is very high (0.95 and 0.93, respectively), and the coefficient of dispersion around the RMA (0.56 and 0.70, respectively) is very low. For additional comparisons, see discussion of* N. whitei.

B. *Plot of height vs length for same specimens as above. The RMA 's for* N. henryi *and* N. whitei *for length and height are H = -0.99 + 0.54 L and H = -1.51 + 0.5 7 L. The linear correlation coefficients (0.78 and 0.86) are not as high as those for length and width. The coefficients of dispersion (0.79 and 0.65, respectively), are relatively low. For a statistical comparison of the two RMA 's, see discussion of* N. whitei.

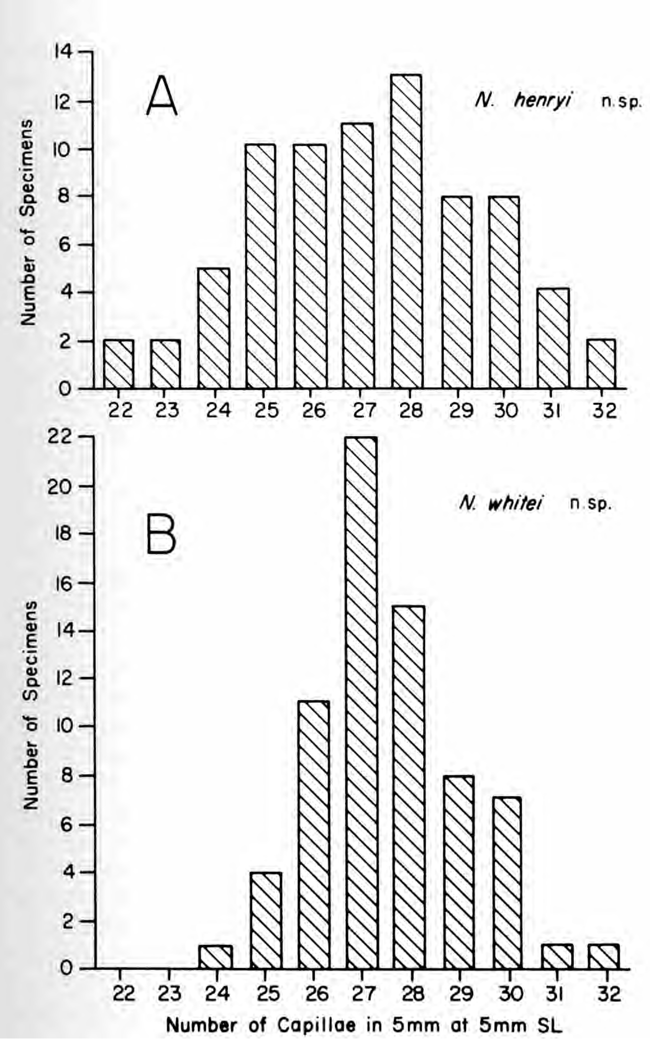


FIGURE 13—**A.** *Frequency histogram of the number of specimens and the number of capillae measured in 5 mm on the venter at a surface length (SL) of 5 mm for type specimens of* Neochonetes henryi *n. sp. from unit 62-28.*

B. *Same type of histogram for type specimens of* Neochonetes whitei *n. sp. from unit 62-17 and 18. Note the greater variability in the number of capillae of* N. henryi *compared with that of* N. whitei. *For statistical comparisons, see discussion of* N. whitei.

process is short and blunt and is internally bilobed. The posterior part of the process is quadrilobed. The cardinal process is separated from the median septum by an alveolus, which is as broad as the process itself. Strength of the median septum is variable. It arises anteriorly to the alveolus as a broad low ridge and extends anteriorly, becoming a moderately high, thin blade by midlength. Commonly 2 to 3 mm in length, it ends abruptly at about $^{2}/_{3}$ the shell length. The two pairs of adductor scars are separated by lateral septa that are generally strong and fan out broadly from the musculature. They are ornamented with pustules. The socket plates are stout. The brachial platform is ornamented with strong pustules on the larger specimens and set off by a distinct brachial ridge. The entire platform is tilted posteriorly at about 10 degrees to the plane of commissure. Less mature specimens have smaller pustules on the brachial platform, and the platform itself is less distinct on the smaller specimens. The flattened anterior and lateral margin is ornamented with densely spaced, small pustules.

DISCUSSION—The species is closely related to *Neochonetes whitei* n. sp. (see discussion for that species).

Neochonetes henryi appears to have close affinities to the genus *Mesolobus* because of the transversely quadrate shape, radial coalescing of the pustules of the interiors, pronounced brachial ridge on the larger interiors, and the high median septum of the brachial valve. This relationship is also suggested by the deep ventral sulcus that occasionally has an indistinct mesial lobe. However, we have placed this species in the genus *Neochonetes* and not *Mesolobus,* because of the inconsistent development of a mesial lobe; but emphasize its transitional nature between the two genera.

MATERIAL AND OCCURRENCE—We have a total of over 300 complete specimens on which the brachial valve is almost invariably crushed except when the brachial valve has been disarticulated. There are also a total of 13 pedicle interiors and 72 brachial interiors. All of these specimens come from the Atokan unit 62-28 in the lower part of the La Pasada Formation. Figured specimens: holotype OU 7586, figured paratypes OU 7587-7600.

Neochonetes whitei n. sp.

P1. 4, figs. 1-13

DESCRIPTION—The shell is moderate in size. One of the largest specimens has the following dimensions: length 9.5 mm, width 15.2 mm, height 3.8 mm, and surface length 12 mm. The smallest specimen is 4.6 mm long, 8.0 mm wide, 1.1 mm high, 0.8 mm thick, and has a surface length of 5 mm. The mean dimensions of over 130 specimens are: length 7.97 mm, width 12.45 mm, and height 3.04 mm. Figures 12A and 12B are scatter diagrams on which width is plotted against length, and height against length; on each is also plotted the calculated RMA. The shell varies in outline from subtrapezoidal to subrectangular, and most specimens have small alae.

The pedicle valve is moderately convex, the beak is small, and the umbo is neither inflated nor prominent. About 3 to 4 mm anterior to the beak, a broad, shallow sulcus arises and deepens slightly anteriorly. The anterior margin on the larger specimens may be broadly sulcate or obscurely mesolobate. About 2 out of 5 specimens longer than 7.5 mm have an obscure mesial fold in the sulcus. The ventral interarea is apsacline, concave, and about 12 times wider than high on larger specimens. The pseudodeltidium is a narrow, thin ridge arched above the level of the interarea and covers only about 1/3 to 1/4 of the posterior and lateral parts of the delthyrium. Seven to nine spines are present on the posterior margin of the hinge line on each side of the beak of the larger specimens. The surface of the pedicle valve is marked by fine capillae (fig. 13B), which average 27.6 in a space of 5 mm at a surface length of 5 mm, for 70 specimens measured; and which average 28.1 in a space of 5 mm at 10 mm (SL) for 41 specimens measured. The crests of the capillae are marked by abundant pits that appear to open anteriorly, and possibly mark the position of minute surface spines.

Mature specimens commonly have several strong growth lamellae near the anterior margin.

The brachial valve is gently concave except for a broad, very low mesial fold present on the anterior half of most specimens. Commonly this fold is flattened or even bears 2 low symmetrical ridges in those specimens obscurely mesolobate on the pedicle valve. Surface markings are similar to those on the pedicle valve. The interarea of the brachial valve is hypercline and about $^{2}/_{3}$ as wide as the interarea of the pedicle valve. In well-preserved specimens, a strongly convex and triangularly-shaped chilidium can be seen to cover the proximal part of the cardinal process. The chilidium is partially worn off on most specimens, giving the false impression of narrow chilidial plates.

The median septum in the interior of the pedicle valve rises abruptly near the beak, forming a spike-like ridge no greater than about 1 mm long, anterior to which the septum is reduced to a low ridge that extends to about midlength or slightly beyond. Small oval adductor scars straddle the median septum in the posterior part of the shell. Extending forward from their anterior margins are rounded, parallel lateral ridges wider and higher than the median septum in the middle part of the shell. They extend to the end of the median septum or slightly beyond (Pl. 4, fig. 11). The diductor scars are large and longitudinally striated. Coarse pustules are arranged in roughly radial rows on the valve floor away from muscle field. Along the anterior and anterolateral margins, a distinctly flattened rim interrupts the concavity of the valve and is marked by fine radial striae.

The features of the interior of the brachial valve have been seen on only 2 specimens but appear typical for the genus. The median septum arises approximately 1 to 1.5 mm anterior to a shallow alveolus. It rises to maximum height at about $^{1}/_{2}$ the valve length and disappears anteriorly at about $^{2}/_{3}$ the valve length. Low, broad lateral septa diverge from the median septum at about 30 degrees.

DISCUSSION—Neochonetes whitei is closely related to *N. henryi,* which occurs abundantly 50 ft higher stratigraphically in measured section 62 in the Atokan strata of the Santa Fe Quarries. Both differ from *N. dominus,* the type species for the genus, from the Atokan of central Texas, in being much smaller in size, in having a well-developed sulcus, and in developing an obscure mesial lobe in the sulcus of the more mature specimens. In referring to *N. dominus* King (1938, p. 259) states that "most individuals are almost imperceptibly sinuate but some specimens have a distinctive sinus on the anterior third of the shell."

N. henryi differs from *N. whitei* in being consistently smaller in size, in having greater convexity, in having a deeper sulcus, and in developing an obscure mesial fold in only a few of the larger specimens. In contrast, *N. whitei* has an obscure mesial lobe present in approximately 40 percent of the specimens over 7.5 mm in length. Also, *N. henryi* differs internally by the more swollen brachial ridge and the coarser pustules.

Since *N. whitei* and *N. henryi* are very similar in many respects, statistical analyses were conducted to determine if there are statistically significant differences in the RMA's between the two species for width and length, and for height and length (figs. 12 and 13). Although the slopes of the length-width RMA's are highly significantly different (z = 2.02), a test of the length-height RMA's produced no statistically significant differences (z =0.58). However, when the position of the length-height RMA's is tested at a point, X_o, equal to the mean length of *N. henryi*, a very highly significant difference (z=5.18) is obtained.

A statistical comparison was also conducted for the coarseness of the capillae in the two species. *N. henryi* has a mean of 27.3 capillae in 5 mm across the venter measured at 5 mm (SL) (mode=28, s=2.34, n=46) (fig. 13A); *N. whitei* has a mean of 27.6 (mode =27, s =1.55, n =70) for the same feature (fig. l3B). The z-test reveals no statistically significant differences in means (z =1.93) at 95 percent confidence limits; however, at 90 percent confidence limits, the null hypothesis that both samples are from the same population would be rejected. The F-test for differences in variances reveals a very highly significant difference in variances at 99 percent confidence limits (F =1.92).

Rugosochonetes delicatus Sturgeon and Hoare (1968, p. 28), from rocks of Atokan and early Desmoinesian age in Ohio, appears to be more closely related to *Neochonetes* than to *Rugosochonetes*, particularly in its internal character. It is similar to *Neochonetes* in having a short median septum in the pedicle valve interior and in having " vascular trunks of enlarged endospines, in some cases fused, present in many specimens." *Neochonetes whitei* differs from their specimens primarily in having a consistently better-developed sulcus, in having a mesial lobe developed on the sulcus of many specimens, and in having finer capillae.

N. whitei differs from *N. ? platynotus,* which occurs slightly lower stratigraphically, in the higher Morrowan strata, in having a much better-developed sulcus and well-developed capillae over the surface of both valves.

MATERIAL AND OCCURRENCE—We have found *chonetes whitei* only in units 62-17 and 18 in the Santa Fe Quarries, where it occurs in abundance. These layers are Atokan and occur in the lower part of the La Pasada Formation. We have over 300 specimens, including 8 pedicle interiors and 2 brachial interiors. Figured specimens: holotype OU 7601, figured paratypes OU 7602-7613.

GENUS *MESOLOBUS*

DISCUSSION—One of the most characteristic and widespread of Middle Pennsylvanian brachiopod genera is *Mesolobus.* All species included in the genus have a number of features in common, summarized as follows.

The average adult width varies from about 5 to 18 mm. The growth takes place in two stages. In the first stage the shell is relatively wide, as much as twice as wide as it is long; prominent growth lamellae are not present, although very fine concentric wrinkles may be abundant. In the second stage, lateral growth proceeds slowly and the shell mainly lengthens; the area of the second stage is marked by numerous prominent growth lamellae that generally converge towards the posterolateral margins. The cardinal extremities may or may not be produced into fragile, mucronate extensions. Except for such extensions, the lateral and posterior margins generally intersect nearly squarely, with the sides continuing forward nearly straight and rounding abruptly into a straight or slightly sinuate anterior margin. The appearance is thus subrectangular, a distinguishing characteristic of the genus.

The pedicle valve is rather strongly convex for a chonetid, resembling *Chonetinella;* but in contrast to that genus, the convexity persists laterally in *Mesolobus* with concavity, if at all present, limited to a small region near the ears. The depth and width of the mesial sulcus are variable; within the sulcus is a rounded fold, or lobe, which may be sharply set off and as high as the lateral lobes, or lower and less distinct.

Besides the concentric sculpture, the earlier species of *Mesolobus* are radially capillate. A smooth area is present near the beak and along the posterior margin, and the radial capillae, which all point towards the beak, arise at the edges of the smooth area. The capillae are generally subangular; they increase by bifurcation so that their transverse linear density is nearly constant on any particular specimen. Capillae disappear gradually in succeeding species by enlargement of the smooth area. Even the smooth species of *Mesolobus* occasionally show faint capillae commonly near the anterior margins.

Species of *Mesolobus* are notable for their tendency to show pseudo-striation. Erosion of the surface reveals rows of internal radially elongate pits that appear to resemble the true capillae of earlier species. If the shell is translucent, then the pits may show through and give the appearance of capillae, but the true nature of the surface is revealed by viewing in direct reflected light. In some specimens, pits are visible on well-preserved surfaces; if the surface is truly capillate, then these pits are restricted to crests of capillae. Slight erosion of the non-capillate species can result in a very shaggy appearance to the marginal areas crowded with prominent growth lamellae.

The posterior margin of the pedicle valve has a single row of many spines, near the beak small and close together; laterally they become stout and more widely spaced.

The interarea may be low or high and a convex pseudodeltidium acts as a hood covering part of the inserted cardinal process.

Specimens with especially good beak preservation commonly have a very tiny, axially elongate depression at the beak of the pedicle valve. This depression is matched by a corresponding pustule at the brachial valve beak. Perhaps the animals were cemented during early stages of development, but the form of the elongate depression at the ventral beak is too uniform to make attachment a reasonable explanation.

The brachial valve exteriorly reflects the features of the pedicle valve. The brachial valve is generally rather shallow in concavity leaving a thicker internal cavity than in some other chonetid genera.

While the pedicle valve was usually strongly constructed, the brachial valve material is in part thin. As a result, the brachial valve commonly collapsed into the pedicle valve during sediment compaction, while the latter remained undistorted. The most common effect of compaction on a pedicle valve was to crack it along a mesial line, particularly at the beak, and in some cases it was punctured along this line by the median septum on the interior of the brachial valve.

The valve interiors are quite characteristic. The pedicle valve has a stout but short apical septum extending forward as a low ridge; by midlength, more or less, the ridge disappears into a narrow mesial trough deepest at about midlength and becoming shallower anteriorly. The adductor scars are small, nearly round, and lie close to the base of the stout septum. The diductor scars are large and somewhat tear shaped; they enclose the adductor scars on all but their anterior tips. Posterolaterally the diductor scars are impressed into the shell. Just under the hinge line is a row of openings that formed communication to the spines. All the valve surface, except that of the scars and of a flattened marginal rim, is covered by small pustules whose arrangement is more or less in radial rows. At the margins, the narrow flattened rim, if present, has finer pustules arranged in radial rows under the external striations, if such are present. These finer pustules are the source of the radially arranged pits visible when the external surface is eroded. Internally, the animal covered these with secondary shell material and created secondary pustulosity not correlated with the primary. Immature shells show only the primary internal surface and thus present a considerably different appearance from the corresponding part of the interior of a mature shell.

The brachial valve interior can be viewed as a nearly flat plain with three prominent features arising from it. Mesially there is a long septum which begins low, at the margin of a small alveolus, near the cardinal process, and rises to a blade-like crest at, or in front of, midlength, then drops to obscurity near the margin. On its descending crest, the septum is sometimes pustulose. The other two prominent features are large symmetrically paired brachial platforms that are fan shaped with apex near the point of septum origin. Each flat-topped platform is separated from the septum by a deep trough; distally the platforms truncate abruptly along a curved arc that parallels the margins anteriorly, curving inward posteriorly where the platform is level with the valve floor.

The cardinal process is formed of 3 fused lobes diverging from the beak. Each lobe has one mesial, longitudinal groove on its posterior face. In front of the central lobe is the small, circular alveolus. Supporting the lateral lobes are socket ridges diverging nearly parallel to the hinge line and enclosing, on their posterior sides, the dental sockets. From in front of the alveolus there diverge 2 short lateral septa at angles of up to 45 degrees from the median septum. The inner pair of adductor scars lie between the short lateral septa and the mesial septum; the scars are elongate oval and small. The outer adductor scars lie between the short lateral septa and the socket ridges; the scars are larger and triangular with acute apex pointing towards the beak. The flatter marginal valve floor has primary pustules radially arranged in the same way as in the pedicle valve. The lateral platforms are developed to a varying extent within the genus by a deposit of secondary shell material with larger pustules, again in radial rows, many fused together to form pustulose ridges.

The species of *Mesolobus* are distinguished from one another mainly by the following features: 1) Size and shape of shell, 2) Degree of pedicle valve convexity, 3) Depth of sulcus and nature of mesial lobe, and 4) Nature of capillae, if present.

Mesolobus striatus Weller and McGehee
Pl. 4, figs. 14-24

Chonetes mesolobus, Girty, 1915 a, pl. 7, figs 10, 11.
Mesolobus mesolobus, Dunbar and Condra, 1932, p. 161, pl. 20, figs. 2a, b (not fig. 1).
Mesolobus striatus Weller and McGehee, 1933, p. 110; Hoare, 1960, p. 222, pl. 31, figs. 9-11; Hoare, 1961b, p. 46, pl. 3, figs. 9-14; Sturgeon and Hoare, 1968, p. 32, pl. 4, figs. 1-5, pl. 7, figs. 20-37.

DESCRIPTION—(Based on specimens from unit 93-44.) The shell is moderate in size. One of the largest has the following dimensions: length 8.7 mm, width 14.6 mm, height 2.7 mm and SL 10 mm; the smallest is 5.0 mm long, 7.8 mm wide, 1.9 mm high, 1.3 mm thick, and has a surface length of 6 mm. The mean dimensions for over 58 specimens are: length 6.9 mm, width 11.5 mm, height 2.5 mm. Figures 14A and 14B are scatter diagrams on which length is plotted against width, and length against height, respectively. On each is also plotted the calculated RMA.

The pedicle valve is moderately and decreasingly convex with increasing length. The beak and umbonal region are bounded by lateral slopes that are slightly concave posteriorly but become convex anteriorly. The cardinal extremities are generally only slightly extended, but several specimens (Pl. 4, fig. 20) possess alae that project as far as 2 mm laterally beyond the lateral margins. The maximum width for most specimens is at the hinge line, but many specimens are widest at a point slightly anterior to the hinge line (Pl. 4, fig. 16). Most specimens are subtrapezoidal, but many are subrectangular in outline. The sulci and mesial lobe begin within 3 to 4 mm of the beak, and the degree of development of these features is highly variable. On most specimens, these features are moderately developed with the sulci depressed no more than 1.5 mm below the surface of the mesial lobe, which, in turn, extends no higher than the lateral surfaces of the valve. The fold and sulci are rounded. On a few specimens, the sulci are only slightly depressed, about 0.5 mm below the lateral surfaces and the gentle fold; such shells consequently have a transverse profile at midlength in which the sulci and mesial lobe make only a minor interruption in the convexity of the valve. On the larger shells, the mesial portion, with the sulci and lobe, attains a maximum width at the anterior margin of approximately 4 to 5 mm. The largest specimens have 8 hinge spines on each side of the beak. The smaller specimens generally have 6 or 7 spines, with a few specimens of intermediate lengths having only 5 spines on each side. As in most chonetids, the hinge spines are smallest and most closely spaced near the beak and become progressively larger and farther apart laterally. (Specimens from locality 10-11, Pl. 4, fig. 16, reveal that the laterally directed spines intersect the hinge line at 40 to 45 degrees.) The interarea of the pedicle valve is apsacline to orthocline. An arched pseudodeltidium covers the posterior $^1/_3$ of the delthyrium.

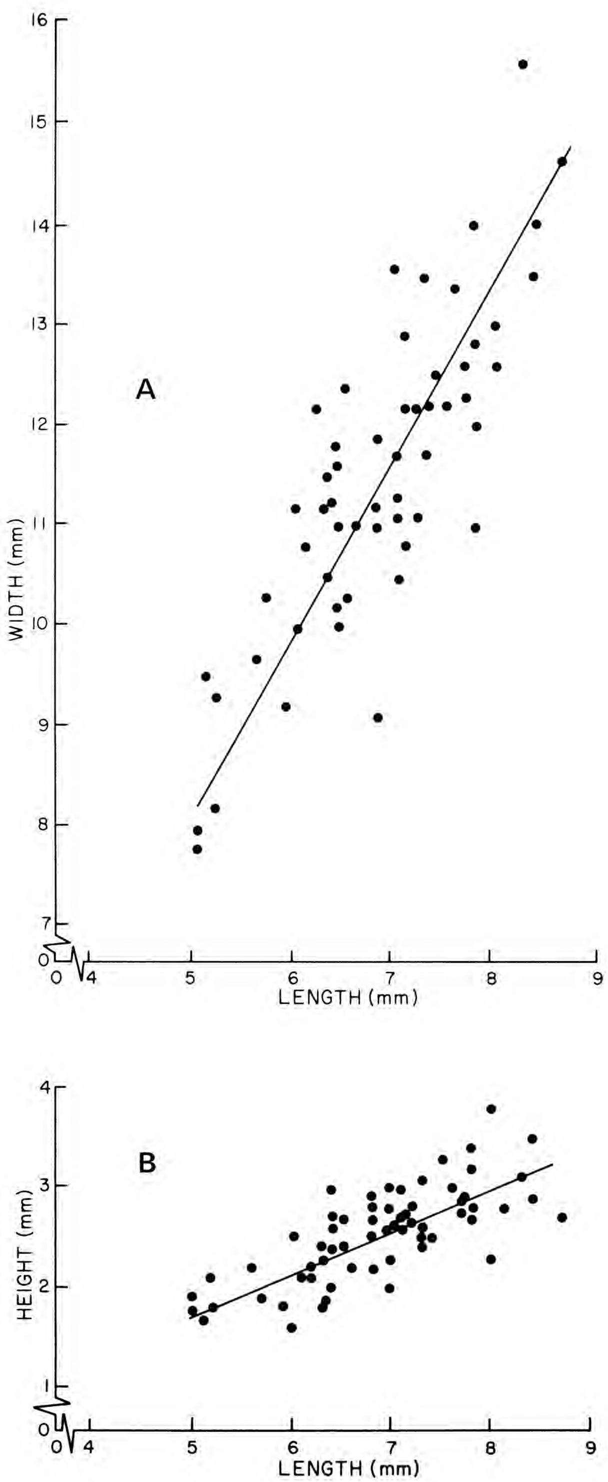


FIGURE 14—**A.** *Scatter diagram for width vs length for specimens of* Mesolobus striatus *from unit 93-44. The RMA (reduced major axis), shown as a solid line, is calculated to be W = -0.70 + 1.78 L for 58 specimens. The coefficient of correlation (r = 0.83) indicates a moderately high degree of linear correlation between length and width; the dispersion around the RMA (S_d = 1.07) is relatively high.*

B. *Height plotted against length for 63 specimens of* M. striatus *from the same locality as above. The RMA is H = -1.17 + 0.54 L with a low coefficient of linear correlation (r = 0.75). The dispersion around the RMA is relatively low (S_d = 0.70).*

The brachial valve is moderately concave with the 2 folds, which correspond to the sulci of the pedicle valve, constituting the most marked feature of the valve. Lateral and anterior margins are commonly flattened. The uncrushed, better-preserved specimens show a chilidium fused to the posterior part of the cardinal process, which is, in turn, quadrilobate.

The surfaces of both valves are covered with faint but distinct capillae most prominent near the anterior and anterolateral margins. The capillae average 24.4 in a space of 5 mm at a surface length of 5 mm (fig. 15), for 40 specimens measured. The capillae generally bifurcate and maintain the same lateral spacing anteriorly. A few of the capillae, however, apparently arise by intercalation. The capillae are low and rounded. Growth lamellae are present but inconspicuous even on the larger specimens.

There are 6 pedicle interiors typical for the genus in our collection. The median septum is high posteriorly and is either absent anteriorly or extends forward as a low, obscure ridge to midlength. Lateral ridges are well developed at midlength, beginning at the anterior edge of the adductor scars, and are ornamented along the crests with pustules. Lateral ridges and pustules are obscure in the smaller valves.

The brachial interiors, of which we have 14, are also typical for the genus. A very prominent, blade-like median septum originates immediately anteriorly to the alveolus. It increases progressively in height to midlength, projecting a maximum of 1.3 mm above the surface of the valve. It then progressively decreases in height and disappears at a point typically 3/4 to 4/5 the distance to the anterior margin. The cardinal process is short, broad, and separated from the median septum by a deep, circular alveolus. Two lateral septa diverge from the short socket ridges at approximately 30 degrees. The lateral septa are narrow and 1 to 2 mm long. A raised area of coarse pustules continues anterolaterally for an additional 2 to 3 mm. A distinct brachial ridge is present, and is most distinct anteriorly where radial rows of fused papillae and very coarse pustules are elevated well above the floor of the valve on a few specimens. Anteriorly and laterally, the radial rows of pustules are much finer, and the posterolateral portions of the interior are unornamented.

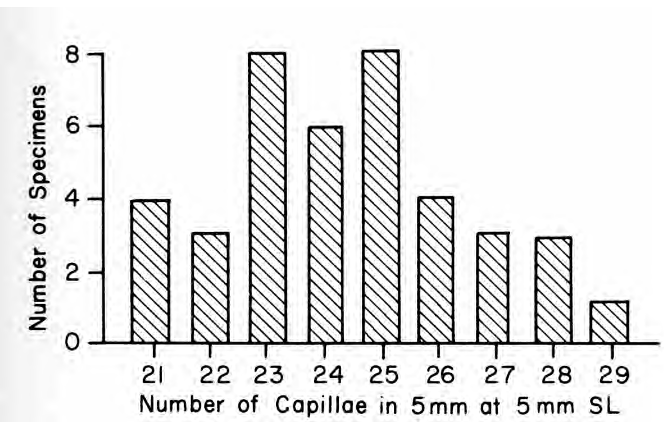


FIGURE 15—*Frequency histogram with the number of specimens of* Mesolobus striatus *from unit 93-44 plotted against the number of capillae measured in the venter in 5 mm at a surface length (SL) of 5 mm.*

DISCUSSION—The controversy over the rightful authorship of the species name *Mesolobus striatus* has been discussed adequately by King (1965, p. 293), and the details are not repeated here. King accepts Hoare's (1961b, pl. 3, figs. 9-14) figured specimens, from the lower Desmoinesian of Missouri, as the types for the species.

Hoare's description (1961b, p. 47) states that the number of capillae at the anterior margin number 8 to 11 per mm, a figure clearly not supported by his figured specimens. However, Sturgeon and Hoare (1968, p. 33) published a correction, stating that the type specimens from Missouri have capillae that number 4 to 6 per mm. Our specimens from New Mexico agree with this revised number and do not differ in other discernible ways from the specimens from the Atokan and early Desmoinesian rocks of Missouri as described by Hoare (1961b) and from Ohio as described by Sturgeon and Hoare (1968, p. 32). The species is highly variable both in their collections and in ours.

Some specimens of *M. striatus* from unit 93-44, and others from locality 105 and unit 10-11 (all early Desmoinesian) are much narrower than typical, one specimen with a length of 7 mm having a width of only 9 mm. These specimens intergrade with more typical specimens. Specimens from units 36-128 and 36-133 are larger than normal, some attaining a maximum length of 10. 3 mm and a maximum width of 15.3 mm.

Mesolobus profundus n. sp., from possibly higher in the lower Desmoinesian and from the middle Desmoinesian, differs from *M. striatus* in having a larger size, a more shapely developed mesial lobe, even in early growth stages, and in being more highly arched. However, some specimens of *M. striatus,* particularly those from units 36-128 and 36-133, are larger than typical, have a better-developed mesial lobe, and approach *M. profundus* in character except not being so highly arched.

Our Atokan specimens of *M. striatus,* from units 67-13 and 67-23, differ from the lower Desmoinesian forms in having a smaller size and a more poorly developed mesial lobe. This species is probably ancestral to *M. profundus* and constitutes a transition from the genus *Neochonetes* and more particularly from the species *N. henryi. N. henryi,* which occurs in Atokan strata in unit 62-28, differs from the Atokan specimens of *M. striatus,* from units 67-13 and 67-23, in having only a faintly developed mesial lobe on the anterior portion of some specimens, in having a more distinct sulcus, fainter capillae, and in being more highly arched. Internally, the two species are closely similar.

MATERIAL AND OCCURRENCE—Mesolobus *striatus* is a widely occurring species in the Midcontinent in rocks ranging in age from Atokan to early Desmoinesian. The species has the same approximate stratigraphic range in northern New Mexico. Our collection contains over 200 specimens. It occurs abundantly in the lower Desmoinesian unit 93-44 from which we have 67 complete specimens, 14 brachial interiors, and 6 pedicle interiors. It occurs rarely or commonly at the following lower Desmoinesian units from the lower part of the La Pasada Formation: 10-11, 10-23, 29-4, 29-5, 29-10, 36-122, 36-128, 36-133, 40-3, 42-20, 47-28, and localities 43 and 105. Typical specimens also occur in Atokan units 67-13 and 67-23, in the lower part of the Flechado Formation. Figured specimens: OU 7614-7624.

Mesolobus profundus n. sp.

Pl. 4, figs. 25-32; Pl. 5, figs. 1, 2

DESCRIPTION—The shell is large for the genus. One of the largest specimens has the following dimensions: length 9.7 mm, width greater than 17 mm, height 4.2 mm, and surface length 13 mm. The smallest specimen is 4.5 mm long, 8.5 mm wide, 1.9 mm high, and has a surface length of 6 mm. The mean dimensions for our collection are: length 7.82 mm, width 12.79 mm, and height 3.41 mm. Figures 16A and 16B are scatter diagrams on which length is plotted against width, and length against height. The calculated reduced major axes (RMA) are also plotted on each of the diagrams. The shell is subrectangular to trapezoidal in outline, with moderately to well-developed alae commonly broken off.

The pedicle valve is strongly convex, giving an exceptionally high relative height for the genus. Deep, narrow sulci and a distinct mesial lobe appear within approximately 2 to 3 mm (SL) from the beak. The sulci and mesial lobe broaden very slightly and continue to the anterior margin. The mesial lobe is distinctly rounded and the lateral margins are sharply bounded by the sulci, which also sharply delineate the two gibbous lateral surfaces. These, in turn, are no higher than the fold. Up to 8 small and laterally directed spines have been observed on each side of the beak on the posterior margin.

The brachial valve is moderately concave with 2 sharp folds bounding a mesial sulcus. The posterolateral margins are flat to gently convex. On the larger valves, the anterior and lateral margins are generally flattened.

The surfaces of both valves are ornamented with fine, faint capillae that bifurcate anteriorly and range in number from 27 to 33 in 5 mm on the mesial portion of the pedicle valve at a surface length of 10 mm. The brachial valve has less distinct capillae than the pedicle valve, and some appear to be almost smooth. Small spinule bases are present on the crests of the capillae. Slightly weathered specimens reveal rows of coarse punctae. Closely spaced concentric growth lines become rather prominent at surface lengths ranging from 7 mm to 10 mm.

There are 5 pedicle interiors in our collection, all molds. We have made latex rubber casts of 2 (Pl. 4, figs. 31, 32); these reveal a median septum, elevated posteriorly and extended forward as a low ridge to $^{2}/_{3}$ the total length. The adductor scars are small, oval, and slightly elevated. The diductor scars are large, tear shaped, and radially striated depressions. The internal expression of the sulcus is sharp. All of the interior is ornamented with fine, closely spaced pustules or endospines that increase in diameter slightly toward the margins. The visceral area is set off by a flattened platform at the margins of the shell.

Two latex casts of the large brachial interiors (Pl. 5, figs. 1, 2) have features typical for the genus. A broad median septum, beginning at an alveolus, extends at least $^{3}/_{4}$ the distance to the anterior margin. Short lateral septa diverge from the alveolus at approximately 40

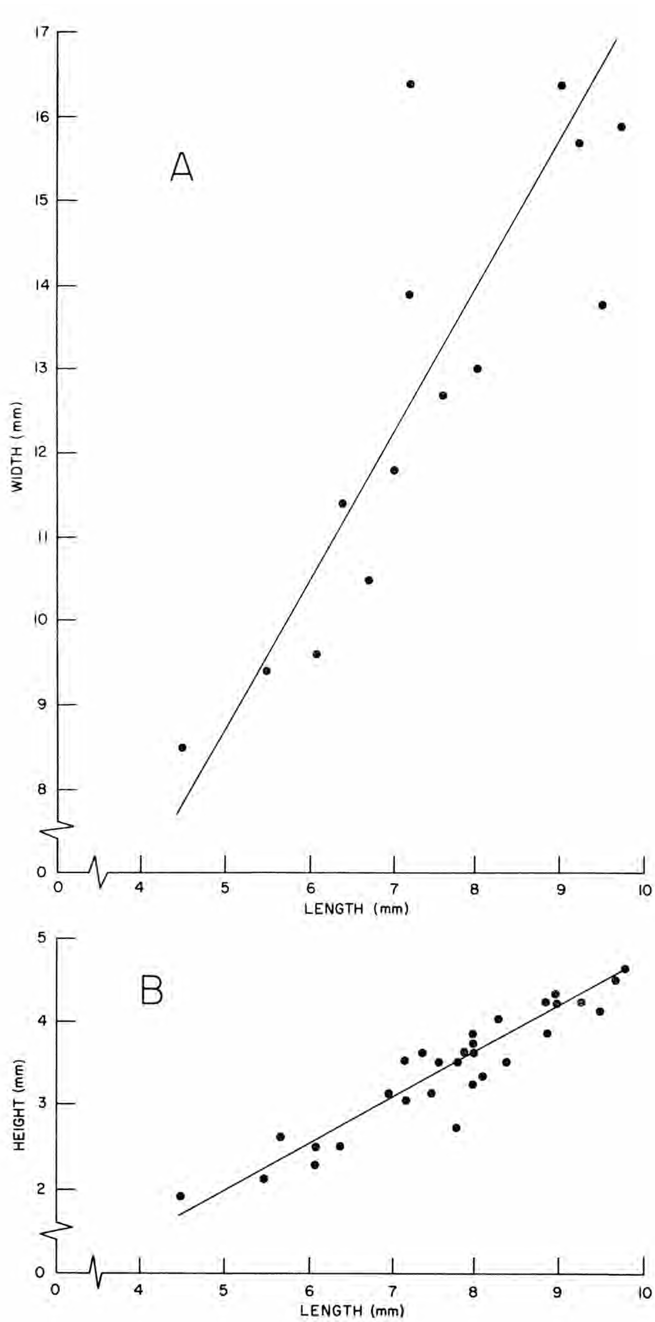


FIGURE 16—**A.** *Scatter diagram for length plotted against width for 14 type specimens of* Mesolobus profundus *n. sp. from locality 78. The RMA (reduced major axis) for length and width is W = -0.08 + 1.74 L; the correlation coefficient is 0.84; and the dispersion around the RMA is high (1.75).*

B. *Plot of length vs height for* M. profundus *for 30 specimens from the same locality. The RMA is H = -0.90 + 0.56 L. Note the very high coefficient of linear correlation (r = 0.94) and the low coefficient of dispersion (0.53).*

degrees from the median septum. The brachial surfaces are flat and distinctly elevated and covered with coarse pustules.

DISCUSSION—This species, with its strong external features, is highly distinctive. *Mesolobus profundus* is distinctly larger, more strongly lobed, and more convex and gibbous than *M. striatus*, from which it is separated stratigraphically. It is relatively less broad and has slightly fainter capillae. The range of variation includes occasional smaller shells with a fainter mesial lobe, resembling *M. striatus.* Probably *M. profundus* evolved from that species. (For additional comparisons, see discussion of *M. striatus.*)

MATERIAL AND OCCURRENCE—Mesolobus *profundus* occurs in the upper part of the lower and in the middle Desmoinesian part of the La Pasada and Alamitos Formations. It occurs commonly at locality 18, rarely in unit 40-45, and abundantly at type locality 78, where we collected 54 complete specimens plus 5 natural molds of the pedicle interior and 2 of the brachial interior. Figured specimens: holotype OU 7626; paratypes OU 7627-7635.

Mesolobus euampygus (Girty)

Pl. 5, figs. 3-5

Chonetes mesolohus var. *euampygus* Girty, 1911, p. 129; 1915a, p. 64, pl. 7, figs. 8, 9.
Mesolobus mesolobus var. *euampygus,* Dunbar and Condra, 1932, p. 167, pl. 20, figs. 23-29.

DESCRIPTION—(Based on specimens from units 10-56, 10-57, and 10-58.) The shell is exceptionally small for the genus. One of our largest specimens has the following dimensions: length 5.7 mm, width 9.2 mm, height 2.6 mm, and SL 7 mm. The mean dimensions for our collections are length 4.29 mm, width 6.61 mm, and height 1.92 mm. Figures 17A and 17B are scatter diagrams on which length is plotted against width, and length against height. The shells are subrectangular in outline with the maximum width generally at the hinge line. Minute alae may be slightly extended.

The pedicle valve is highly convex. A rounded mesial lobe, bounded by well-defined, narrow sulci, is present on even the smallest specimens and originates at surface lengths ranging from 2 to 3 mm. The lateral surfaces are strongly inflated near the sulci and are slightly higher than the mesial lobe. The lateral shell margins are decreasingly convex.

The brachial valve is moderately concave, and 2 distinct folds, corresponding to the pedicle sulci, bound the mesial sulcus. The lateral and anterior margins are flattened.

The surfaces of the shells lack capillae and are smooth, although some show 1 or 2 growth ridges on the anterior slopes. The translucence of the shells reveals radial rows of punctae, resulting in the erroneous impression of capillae not present on the surface. Slightly weathered specimens are most deceptive in this regard. Internal features are unknown.

DISCUSSION—Mesolobus *euampygus* is a highly distinctive species not closely similar to any other. Our New Mexico shells agree in all respects with Girty's (1911, 1915a) original descriptions, based on specimens from Oklahoma. The species is characterized by the very small size, marked convexity, smooth surface, and distinctly delineated mesial lobe.

MATERIAL AND OCCURRENCE—Mesolobus *euampygus* was first described by Girty from the Wewoka Formation of Oklahoma, which is late Desmoinesian (Marma-

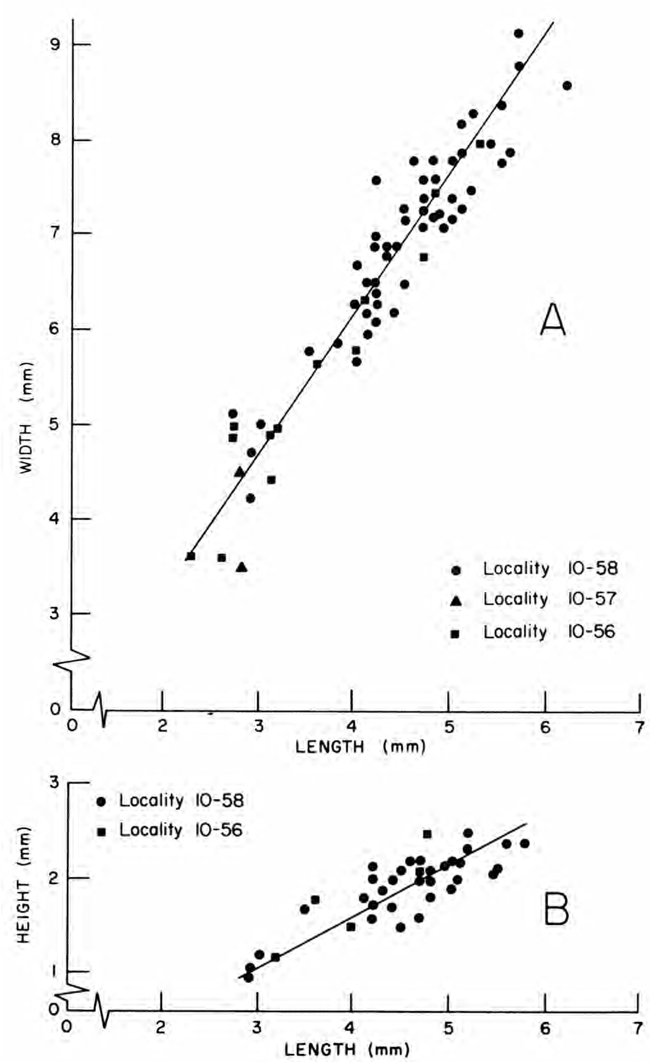


FIGURE 17—**A.** *Plot of width vs length for specimens of* Mesolobus euampygus *from units 10-56, 10-5 7, and 10-58, representing a stratigraphic interval of 42 feet. RMA (reduced major axis) is W = 0.32 + 1.47 L; the correlation coefficient (r = 0.95) is very high, indicating a close linear relationship, and the coefficient of dispersion (S_d = 0.50) is low.*

B. *Scatter diagram of length vs height for same collection of* M. euampygus. *The RMA is H = -0.52 + 0. 54 L with a coefficient of linear correlation equaling 0. 84. The dispersion around the RMA is low (S_d = 0.46).*

ton). Dunbar and Condra (1932, p. 168) report its occurrence in various upper Desmoinesian localities in the Midcontinent, particularly from the Fort Scott and Pawnee Limestones, but also report its occurrence in the Cherokee Shale in Missouri, indicating a longer range.

In northern New Mexico, the species has been collected from the lower part of the Alamitos Formation, from horizons appearing to be high in the middle Desmoinesian but could be low in the upper Desmoinesian. The species occurs abundantly in the 42-foot stratigraphic interval represented by units 10-56, 10-57, and 10-58. It occurs rarely at locality 18 and in unit 60-232(?). Figured specimens: OU 7636 to 7638.

GENUS *CHONETINELLA*

Chonetinella jeffordsi Stevens
Pl. 5, figs. 6-13

Chonetinella jeffordsi Stevens, 1962, p. 627, pl. 93, figs. 18, 19.

DESCRIPTION—(Based on specimens from locality 78.) The shell is moderately large and thick for the genus. Dimensions of our largest specimen are: length 11.7 mm, width greater than 16 mm, height 4.8 mm, thickness 3.5 mm, and surface length 16 mm. Our smallest specimen is 6.6 mm long and 10.0 mm wide. For our collection, the mean dimensions are: length 9.16 mm, width 12.66 mm, and height 3.81. The width dimension is misleading in that the alae are broken off on most shells. A fragmentary shell, not as large as the largest specimen listed above, but with the total length unknown, has a reconstructed width along the hinge of 19 mm. Statistics are given in Appendix 2, tables 1 to 4.

The umbo of the pedicle valve is high and varies from moderately narrow to broad. The lateral slopes are moderately and decreasingly concave, accentuating the height of the umbo and mesial region. The sulcus is narrow and well defined, but shallow. The floor of the sulcus varies from broadly U-shaped to V-shaped, although the later condition is exceedingly rare. The sulcus begins near the beak and deepens and broadens slightly anteriorly. There are 7 to 8 spines preserved on each side of the beak on the posterior margin of several larger specimens but with the alae commonly broken, an accurate count is impossible to obtain. One specimen (Pl. 5, fig. 11) has 1 incomplete lateral hinge spine 5.0 mm long. These spines diverge laterally from the hinge line at approximately 20 to 30 degrees and then curve, approaching a position parallel to the hinge line. The interarea of the pedicle valve is strongly curved at the beak and is approximately orthocline. An arched pseudodeltidium covers the posterior $^{1}/_{3}$ of the delthyrium.

The brachial valve is moderately concave in longitudinal section but becomes flatter in the posterolateral regions. A distinct mesial fold is low. The dorsal interarea is $^{1}/_{2}$ the width of the pedicle interarea and is hypercline. Worn plates on some specimens represent either chilidial plates or a chilidium.

Ornamentation of both valves consists of fine radiating costellae that increase in number anteriorly by bifurcation. There are 17 to 25 costellae in 5 mm on the venter measured at a surface length of 10 mm. For 25 specimens the mean number of costellae is 20.5. The costellae are equally spaced except near a point of bifurcation and are generally equally prominent. A few specimens, however, are distinctly fasciculate (P1. 5, fig. 9b). Faint growth lines are present. Spinule bases are scattered on the top of the costellae. Slightly worn specimens reveal numerous tiny pits arranged compactly in rows between the costellae.

There are only 2 interiors of the pedicle valve in our collection, 1 of which is an internal mold. They are characterized by a low median septum that disappears past midlength. Mesial oval adductor scars are depressed and surrounded by a low ridge. Large, tear-shaped diductor scars have points that are directed posteriorly and diverge from the median septum at approximately 45 degrees. They extend anteriorly for about $^{1}/_{3}$ the length of the shell. The remainder of the interior is ornamented with large, strong pustules that are arranged in radial rows and increase in diameter anteriorly and laterally. At the extreme margin, the pustules abruptly become smaller and more densely spaced.

We have only 1 brachial interior, an internal mold (Pl. 5, fig. 13b). It is characterized by a low median septum that extends to midlength where it becomes rhopaloid and elevated. The cardinal process is small, internally bilobed, and separated from the median septum by an alveolus. Large and broad socket ridges are present. Lateral septa diverge from the median septum at approximately 30 degrees but are not attached to it. The adductor scars are narrow, oval-shaped depressions bounded by low ridges. A distinct brachial ridge is ornamented with strong pustules.

DISCUSSION—The specimens that we have assigned to *Chonetinella jeffordsi* appear to differ from those of Stevens (1962, p. 627) only in being slightly smaller in size. Our largest specimen is 11.7 mm in length and the 5 specimens for which he gives dimensions range from 12 to 15 mm in length. He states that "about three striae occur in 1 mm" but does not indicate where these are measured on the valve.

We have compared our specimens with the Dunbar and Condra (1932, p. 157, pl. 19, figs. 37-40) syntypes of *Chonetinella crassiradiata,* the most closely related species to *C. jeffordsi.* Our specimens differ in being slightly larger in size and more elongate, in having a more shallow sulcus, and in having slightly coarser costellae.

MATERIAL AND OCCURRENCE—Stevens (1962, p. 627) based the species *Chonetinella jeffordsi* on specimens from a locality in the Minturn Formation in northwestern Colorado. His specimens come from an interval within the lower Desmoinesian which also contains *Fusulina distenta, F. rockymontana,* and *Wedekindellina.*

C. jeffordsi is widely occurring in the La Pasada Formation, in the southern Sangre de Cristo area, in rocks ranging from early to middle Desmoinesian. The collection contains 138 specimens, of which over 90 are from the upper lower Desmoinesian locality 78. The species occurs rarely in the lower Desmoinesian units 10-11, 10-23, 22-89, 29-3, 29-8, 36-133, 40-3?, 42-15, 93-44? and locality 105, and rarely at the upper middle Desmoinesian locality 18, and units 10-56 and 10-58. Figured specimens: OU 7639 to 7646.

Suborder PRODUCTIDINA
Superfamily STROPHALOSIACEA
Family STROPHALOSIIDAE

GENUS *LEPTALOSIA*

***Leptalosia* sp.**
Pl. 5, figs. 14, 15

DISCUSSION—Only 2 specimens in our collections can be referred to *Leptalosia;* possibly these do not represent the same species. Both are Morrowan, and both are extremely small and represent the pedicle valve only, attached by almost the entire external surface. The larger specimen (P1. 5, fig. 14) is attached to the slope of the umbo of *Linoproductus nodosus* (Newberry). It is 1.4 mm long, 1.8 mm wide, and oval in outline. It is fringed with 8 irregularly oriented adnate spines about equally distributed around the valve. The hinge line and interior surfaces are partly decorticated and do not show a median septum.

The second specimen is more transverse in shape, having a length of 1.1 mm and a width of 1.7 mm. It is attached to the anterior slope of *Pulchratia? pustulosa* n. sp. The spines are not well preserved but appear to number 7 or 8. The interarea is narrow and the delthyrium broadly triangular and open. A median septum is not present. A distinct but low ridge is present on the anterior margin.

Most Pennsylvanian specimens of this genus have been referred to *Leptalosia ovalis,* but Dunbar and Condra (1932, p. 263) describe that species as having a median septum in the pedicle valve and "commonly attaining a length of 4 mm and a width of 4.5 mm."

MATERIAL AND OCCURRENCE—Leptalosia is SO small as to be commonly overlooked. Our collections contain 1 attached pedicle valve each from the Morrowan units 61-11 and 90-2, both in the lower part of the La Pasada Formation in the Santa Fe area. Figured specimens: OU 7647 to 7648.

Superfamily PRODUCTACEA
Family OVERTONIIDAE
Subfamily OVERTONIINAE

GENUS *KROTO VIA*

Krotovia globosa (Mather)
Pl. 5, fig. 16

Pustula globosa Mather, 1915, p. 167, pl. 10, figs. 7-9; Murphy, 1954, p. 27, pl. 2, figs. 3a-e.
?Krotovia maccoyensis Stevens, 1962, p. 628, pl. 94, figs. 1-2.

DISCUSSION—We have only 3 specimens that we refer to this species. Our figured specimen has the following dimensions: length 8.9 mm, width 9.0 mm, and height 5.0 mm. This species is characterized by globular shape, rather strong convexity, and nearly circular outline. The cardinal extremities are slightly extended with the development of small ears. On the pedicle valve, the coarse, erect spine bases average about 1.0 mm apart; on the brachial valve they are of smaller diameter and are a little more crowded. The pedicle valve has rather coarse concentric laminae but is not costate. The brachial valve is pitted and marginally laminated.

We have examined Mather's 2 type specimens of *Pustula globosa* (WM 16130) and cannot detect differences from our specimens except that the holotype is slightly longer than wide (length 9.0 mm, width 8.1 mm).

Krotovia maccoyensis, described by Stevens from Atokan rocks in Colorado, does not appear to differ externally (the internal characters for both forms are unknown) from *K. globosa* except that his specimens are slightly larger in size, being typically about 10 mm long and 11 mm wide.

MATERIAL AND OCCURRENCE—Krotovia *globosa* was originally described by Mather (1915, p. 167) from the Morrowan of northeastern Oklahoma. Murphy (1954, p. 27) has recorded this species from the Morrowan part of the Oquirrh Formation in central Utah.

This species is extremely rare in New Mexico. We have 3 specimens from units 90-2 and 99, in the lower part of the Morrowan sequence, in the La Pasada Formation from near Santa Fe. Figured specimen: OU 7649.

Family MARGINIFERIDAE
Subfamily MARGINIFERINAE

GENUS *KOZLOWSKIA*

Kozlowskia montgomeryi n. sp.
Pl. 5, figs. 19-25

DESCRIPTION—(Based on specimens from units 62-17 and 18). The shell is small and globular, with the greatest width at the hinge line. A larger specimen has the following dimensions: length 11.7 mm, width 12.0 mm, height 7.3 mm, surface length 18 mm. Specimen measurements are given in Appendix 3.

The pedicle valve is strongly convex. Some shells ar almost evenly rounded but most show a faint to moderat geniculation at about 7 mm surface length, suggesting tw distinct growth stages. In youth, the pedicle valve was quit gently convex, although its beak curved sharply over the hing line. Past the geniculation, the valve is broadly inflate laterally and the anterior slope is evenly curved. Most shell are flat on the venter and lack a sulcus, but a few have a fai suggestion of a broad sulcus. Ears are small but sharply s off. This species has the 6 symmetrically placed steepl inclined spines characteristic of the genus: 2 are along th venter in the plane of symmetry; 2 occur laterally on th anterior slope; and 1 occurs on each flank near the cardin extremities. In addition, small spine bases, generally 3 i number, flank each side of the beak and extend diagonall along the base of the broad umbonal flank. Faint costellae a present over most of the valve surface but are most obscure i the umbonal region. On the anterior slope, at a surface lengt of 10 mm, they average 13.5 in 5 mm (fig. 18).

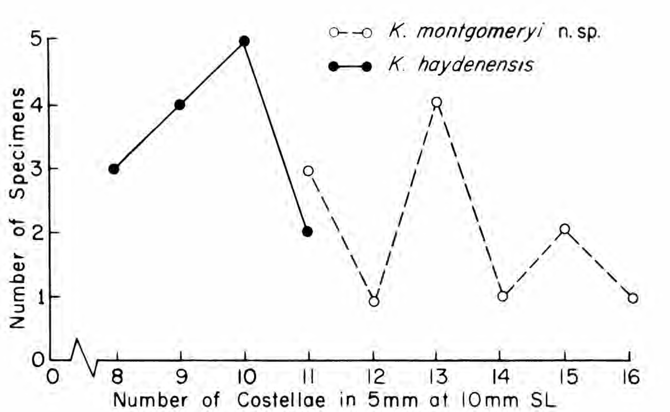


FIGURE *18—Frequency plots with a number of specimens plotted against number of costellae in 5 mm measured at a surface length (SL) from beak of 10 mm for specimens of* Kozlowskia montgomeryi *n. sp., Atokan (specimens from type unit 62-17 and 18); and* K. haydenensis, *lower Desmoinesian (specimen from units 29-10 and 43).*

Irregular transverse rugae are present along the anterior margins of the larger shells.

The brachial valve is slightly and uniformly concave during the first stage of growth. During the second growth stage, after the pedicle valve changes growth direction, the brachial valve does not increase in length to any large extent but rather builds up an anterior marginal thickening layer by layer to close the gap between it and the lengthening pedicle valve (fig. 19).

FIGURE 19—*Drawing of thin section along plane of symmetry of* Kozlowskia montgomeryi *n. sp., x4. Atokan; unit 62-17 and 18.*

Externally, this thickening appears as an irregular band of lamellae that is 1 or 2 mm thick, marking successive positions of a short trail. The brachial valve has either very faint costellae or may be almost smooth away from the anterior margin.

Our collection includes 2 fragments of the pedicle valve interiors (Pl. 5, fig. 25) and 6 well-preserved natural molds. A well-developed and sharply elevated adductor muscle platform extends forward for 3 to 4 mm on a shell with a maximum width of 14 mm. A separate median septum is not present. Diductor scars are fan shaped and extend 1 or 2 mm beyond the adductor platform, bear dendritic grooves, but are only faintly incised. Anteriorly and laterally to the muscle areas, the shell interior is coarsely pustulose. Three large, erect, internal spines are present, which do not coincide in position with the 3 large erect spines on the exterior anterior slope. The internal molds show the presence of a distinct marginal ridge or low flange, which extends around the valve to the hinge line on each side, sharply separating the alae from the main cavity. This ridge rested within the groove formed by the paired ridges on the extremities of the brachial interior.

Five well-preserved brachial interiors each have a median septum present only on the central part of the flat visceral surface. The septum commonly terminates anteriorly in an oblique spine. The cardinal process is small, sessile, trilobed and heart-shaped on the myophore face, with the lateral flaps dorsally free. Lateral ridges are low and obscure near the hinge line and where they cross the ears. At this point they pass obscurely into a strong, thick, rounded marginal ridge that curves around the anterior edge of the visceral disc. On each ear, outside the lateral ridge, is an additional low ridge. The resulting paired ridges apparently form a " socket" into which fits the internal ridge of the pedicle valve. On one specimen (Pl. 5, fig. 21) the lateral ridges do not pass into the marginal ridge but into the more lateral ridges on the ears. Posteriorly elevated, elon gated adductor platforms parallel the median septum, flanked laterally by a second pair of small oval adductor scars. Distally placed, isolated brachial ridges are sharply looped. A pair of oblique endospines may lie between the brachial loops and are adjacent to the anterior end of the median septum.

DISCUSSION—Kozlowskia *montgomeryi* differs from *K. haydenensis* (Girty) in being much smaller in size and less sulcate, and in having finer costellae. *K. montgomeryi* is typically developed in Atokan strata; our interpretation is that this species gave rise to *K. haydenensis* in the early Desmoinesian by an increase in size, development of a sulcus, and increase in coarseness of the costellae. Both species are highly variable and some collections include gradational specimens between the two species. Well up in the lower Desmoinesian sequence, some collections of typical *K. haydenensis* include smaller, nonsulcate specimens but these most commonly have the coarser costellae typical of *K. haydenensis.* In measured section 29, in the lower Desmoinesian, the gradual shift from *K. montgomeryi* to typical *K. haydenensis* can be documented through a stratigraphic interval of approximately 90 ft. Units 29-3 and 29-4 contain typical *K. montgomeryi.* Units 29-5 and 29-8 contain transitional collections spanning the range of variation between the two species, and 29-10 is dominated by typical specimens of *K. haydenensis,* but still include a few variants reminiscent of *K. montgomeryi.*

We have observed a similar stratigraphic relationship in southern Oklahoma, where the Bostwick Formation (Atokan) contains typical specimens of *K. montgomeryi* and the Pumpkin Creek Formation (lower Desmoinesian) contains typical specimens of *K. haydenensis.*

MATERIAL AND OCCURRENCE—K. *montgomeryi n.* sp. has as its type locality Atokan units 62-17 and 18 in the lower part of the La Pasada Formation in the Santa Fe Quarries. We have approximately 100 specimens from this locality and about the same number from the following lower Desmoinesian units in the lower part of the La Pasada and Flechado Formations: 10-4, 29-3, 29-4, 29-5(cf.), 40-3, 40-4 to 6, 42-20, 60-124, 93-44. Figured specimens: OU 7650 to 7656.

Kozlowskia haydenensis (Girty)
P1. 5, figs. 17, 18

Marginifera haydenensis Girty, 1903, p. 380, pl. 5, figs. 9-11a.
Kozlowskia haydenensis, Sturgeon and Hoare, 1968, p. 39, pl. 12, figs. 1-5.

DISCUSSION—The specimens that we include in *K. haydenensis* appear to be similar in all respects to those figured by Girty (1903). For a drawing of a thin section of a typical specimen see fig. 20. The exact stratigraphic horizon for Girty's type specimens from the Pennsylvanian of central Colorado is not clear, but he does report its occurrence with *Desmoinesia muricatina,* which, if correct, would indicate a Desmoinesian age. In the Sangre de Cristo area, the species is apparently restricted to the lower Desmoinesian. (For a comparison with *K. montgomeryi,* see the discussion under that species.)

FIGURE *20 Drawing of thin section along plane of symmetry of* Kozlowskia haydenensis, *x4. Lower Desmoinesian, unit 29-10.*

MATERIAL AND OCCURRENCE—Kozlowskia *haydenensis* was first described by Girty (1903) from the Pennsylvanian of central Colorado. Sturgeon and Hoare (1968, p. 40) report its occurrence in lower Desmoinesian strata in Ohio. The specimens included here from New Mexico are also early Desmoinesian in age. We have approximately 200 specimens, all in the La Pasada Formation from units 10-19, 29-8(cf.), 29-10, 36-109(cf.), 36-122, 36-133, and localities 43, 78 and 105. Figured specimens: OU 7657, 7658.

Subfamily COSTISPINIFERINAE

GENUS DESMOINESIA

DISCUSSION—Muir-Wood and Cooper (1960, p. 230) give the stratigraphic range for the genus *Desmoinesia* as Desmoinesian. In this paper we record, in addition, species from both the Morrowan and Atokan. Generally, in our New Mexico collections, the Morrowan and Atokan forms are more finely costate than those in the Desmoinesian. However, in the lower Desmoinesian there is an overlap in the ranges of the more finely costate species *D. " missouriensis"* and primitive variants of the coarsely costate *D. muricatina. D. muricatina* reaches its maximum size and develops the coarsest costae in the middle and upper Desmoinesian.

Desmoinesia nambeensis n. sp.

P1. 6, figs. 12-15

Productus nanus, Mather (not Meek and Worthen), 1915, p. 156, pl. 8, figs. 12, 12a, 12b.

DESCRIPTION—The shell is small in size, a large specimen having the following dimensions: length 17.8 mm, width at hinge 16.2 mm, height 10.2 mm, and surface length 31 mm. In contrast, a specimen 11 mm in length has a maximum width of 13 mm, showing that in earlier growth stages the shell increased in width at a more rapid relative rate than in length. The trail in larger specimens is extended after the maximum width has been achieved. Specimens with the trail broken appear incorrectly to be wider than long. For all described species of *Desmoinesia,* specimen measurements are given in Appendix 3 and descriptive statistics for number of costellae and for the surface length to the end of reticulation are given in Appendix 2, table 5.

The pedicle valve is strongly convex posteriorly with the umbo inflated. On the anterior slope of the umbo, the venter is flattened or slightly depressed into a nonpersistent, shallow sulcus on some but not all specimens. The sulcus is absent on the trail. Ears are slightly extended with the greatest shell width being at the hinge. Ears are moderately to strongly set off from the shell body. The surface is marked posteriorly by irregular, concentric rugae, which reticulate with the costellae only on the crest of the umbo. The surface length to the end of reticulation (fig. 21A) ranges from 8 to 13 mm and averages 10.7, for 66 specimens measured. Beyond the reticulation, concentric markings consist of very fine undulations except near the anterior

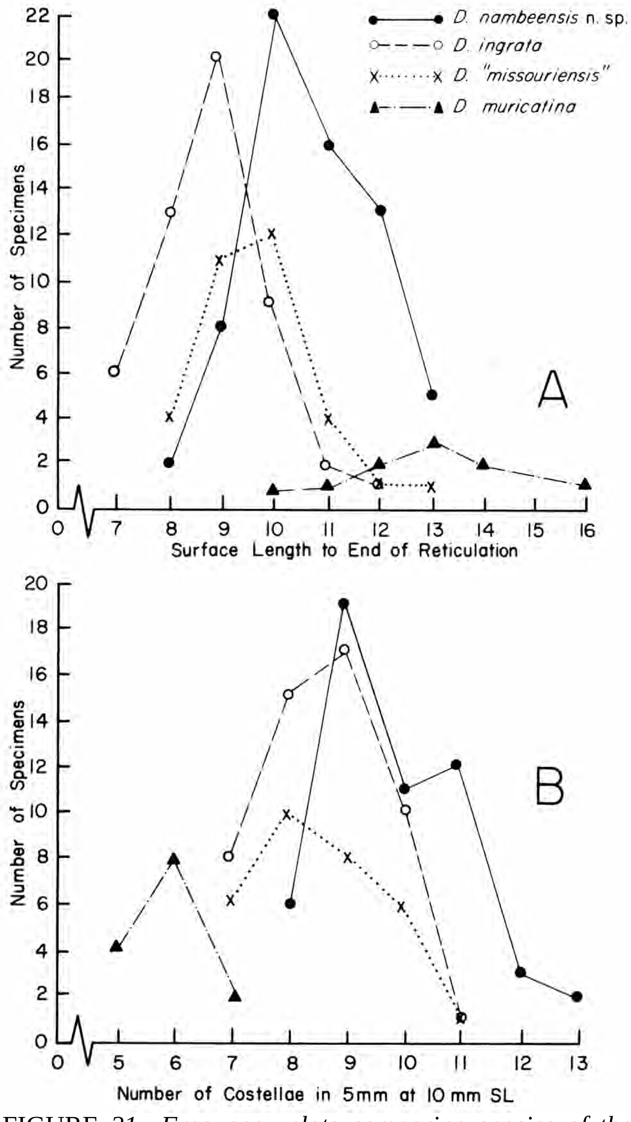


FIGURE *21—Frequency plots comparing species of the genus* Desmoinesia, *as follows:* D. nambeensis, *n. sp. Morrowan (specimens from unit 41-49);* D. ingrata, *Atokan (units 62-17 and 18);* D. "missouriensis," *lower Desmoinesian (locality 78); and* D. muricatina, *upper middle Desmoinesian (unit 10-58).*

A. *Number of individuals is plotted against surface length to end of reticulation.*

B. *Number of individuals is plotted against the number of costellae per 5 mm measured at a surface length from beak of 10 mm. See text for discussion, and Appendix 2, table 5 for descriptive statistics.*

margin where the largest shells display considerable irregular lamination. Costellae are obsolete on the beak and ears, but overlap with the transverse wrinkles on the umbo. They are very low and rounded on the shell body, also being somewhat irregular and occasionally bifurcating. The number of costellae per 5 mm counted at a surface length of 10 mm (fig. 2 l B) ranges from 8 to 13 and averages 9.9, for 53 specimens. Numerous tiny, erect spines are present over the beak and umbo; becoming fewer and coarser over the remainder of the valve. An irregular row of larger erect, more widely spaced spines may lie along the lower flank of the umbo. Each ear has one fairly large lateral spine, and a few finer ones are distributed irregularly in the general area of the ear and hinge line. A consistent row of spines is lacking along the hinge line.

The exterior of the brachial valve is not well shown on our specimens. It appears to be uniformly and moderately concave, except for the ears, which are distinctly set off from the remainder of the valve. Spines appear to be absent.

Our collection of pedicle valves includes 2 internal molds and fragments of 3 pedicle interiors. Adductor scars are elevated anteriorly on a low, elongated platform that is up to 2 mm in diameter and that extends forward about $^1/_3$ the valve length. The diductor scars are elongated, flaring, marked by elongated ridges, and extend about $^1/_2$ the valve length. Anteriorly, the surface is finely papillose. Near the extreme anterior and lateral margins, the shell thins and abruptly forms a ledge that fits over the lateral ridge of the brachial valve.

Based on about 20 beautifully preserved brachial interiors, the adductor scars are observed to be in two distinct sets (Pl. 6, figs. 14a-c). The mesial scars are elongate-oval, slightly raised, and longitudinally ridged. The lateral adductor scars are subtriangular in shape, lying slightly above the bottom of the depressions immediately beside the mesial pair. Low, broad ridges extend from the base of the cardinal process to the mesial adductor scars. The median septum originates in the channel between these scars and rises sharply anteriorly to form a thin, high blade just beyond the middle of the visceral disc, then ends abruptly. The cardinal process is short, sessile, but broad for the size of the shell. In posterior view, the process is distinctly trilobed, with the lobes surrounding two deep, elongated pits. The middle lobe is thicker than the others and grooved. Broad lateral ridges diverge from the hinge line by about 30 degrees. They set off a flat, marginal area adjacent to the hinge line, which passes laterally into the ears. The lateral ridges broaden laterally and may subdivide or become indistinct adjacent to the ears. Just laterally from this point, a low sharp ridge arises and passes around the far anterior of the visceral disc. This ridge is strongly but finely striated radially. Exceptionally strong brachial ridges arise beside the lateral edge of the lateral adductor scars and form elevated loops on the anterolateral parts of the interior. A straight row of 6 or 7 strong, anteriorly inclined, short, blunt spines lies between the anterior extremities of the brachial impressions. Between this row and the anterior ridge is an abundance of oblique, anteriorly directed pustules.

DISCUSSION—Desmoinesia nambeensis is characterized by low or faint, rounded costellae, averaging about 9.9 in 5 mm, extended cardinal extremities, scarcity of spines along the hinge line, and apparent absence of spines on the brachial valve.

D. nambeensis differs from *D. ingrata,* which occurs in the Atokan, in that the average surface length to end of reticulation is 10.7, compared with 8.8 mm (fig. 21A), and the mean number of costellae per 5 mm measured at 10 mm (SL) is 9.9 compared with 8.6 for *D. ingrata (fig.* 21B). In both cases, the differences are highly significant statistically (z =8.56; z =5.48). *D. ingrata* also tends to be more quadrate in shape.

MATERIAL AND *OCCURRENCE—Desmoinesia nambeensis* occurs in the lower parts of the La Pasada and Flechado Formations and is restricted to the Morrowan part of the sequence. It is an uncommon species in most areas but occurs in extraordinary abundance in unit 41-49, in the upper Morrowan, where a limestone layer half a foot thick is a coquina formed of shells of this species, almost to the exclusion of other species except for comparatively few specimens of *Neochonetes? platynotus* (White). Our collection contains over 300 specimens from unit 41-49 and over 100 specimens from units 22-41(cf.), 36-63, 41-42(cf.) , 47-21(cf.), 65-56(?), and locality 68(cf.).

D. nambeensis has been identified from the Morrowan of northeastern Oklahoma; and smaller specimens probably belonging to this species were described by Mather (1915, p. 156) as *Productus nanus.* Figured specimens: holotype, OU 7670; paratypes, OU 7671 to 7674

Desmoinesia sp. A

Pl. 6, fig. 16

DISCUSSION—In the lower part of the Morrowan sequence in unit 90-7, specimens of *Desmoinesia* are similar to *D. nambeensis* except for the presence of 3 or even 4 rows of erect spines, instead of 1 row, on the flanks of the umbo and lateral slopes. The costellae may be slightly coarser than in *D. nambeensis,* averaging 9.1 compared with 9.9 for the latter species.

MATERIAL AND OCCURRENCE—There are 18 specimens from unit 90-7, in the lower Morrowan part of the La Pasada Formation. Figured specimen: OU 7672.

Desmoinesia ingrata (Girty)

Pl. 7, figs. 1-6

Productus longispinus, White (not Sowerby), 1877, p. 118, pl. 8, figs. 5c, 5d (not 5a, 5b).
Marginifera ingrata Girty, 1903, p. 379, pl. 5, fig. 12, 12a, 13, 13a.

DESCRIPTION—(Based on specimens from unit 62-17 and 18.) The shell is below average size for the genus. A large specimen has the following dimensions: length 13 mm, hinge width 14.5 mm, and surface length 19 mm.

The pedicle valve is strongly convex with the beak slightly incurved. The greatest width is at the hinge line, the extremities being distinctly extended with ears that are large for the size of the shell. Mesially, the valve is flattened transversely and a few specimens are slightly sinuate. Lateral slopes are steep, the ears being distinctly set off. The surface is marked by rather low posterior wrinkles, forming a reticulation with the costellae that ends at an average surface length of 8.8 mm for 51 specimens measured (fig. 21A). The costellae are strong, but irregular in individual thickness and height. They average 8.6 per 5 mm, counted on the venter at a surface length of 10 mm (fig. 21B). Laterally and near the beak, the costellae are indistinct or lacking. Spines are prominent and abundant.

The brachial valve is strongly concave except on the flattened ears. Costellae are lower than on the other valve. Spines are as abundant, anteriorly as on the pedicle valve, but are extremely short and fine. Spines. have not been observed on the posterior part of the valve.

The interior of the pedicle valve is known from 3 well-preserved specimens. The muscle field is at the same elevation as the floor of the valve. The adductor scars are small, oval shaped, and separated by a slight groove. A median septum is absent. The diductor scars are large, gently striated, and tear shaped. In reflection of the external markings, the interior is costate anterior to the muscle scars, and anteriorly directed spines are abundant, scattered, and sharp. A nearly smooth marginal flange is strongly developed.

There are 4 poorly preserved brachial interiors in our collection, typical for the genus as described by Muir-Wood and Cooper (1960, p. 229).

DISCUSSION—Girty's (1903, p. 379) original description of *Marginifera ingrata* follows: "It is small, transverse, subrectangular. A transverse diameter of 15 mm and a longitudinal of 11 mm is somewhat above the average. The curvature is strong, the ears distinct, large, quadrate, and somewhat upturned. The surface is marked by strong, moderately fine striae, about 7 in the space of 5 mm, and by fine, regular concentric wrinkles over the posterior half of the shell. The spines are small and rather numerous. Mesial sinus absent. Submarginal ridges persistently well developed." In a later paper, Girty (1915b, p. 350) states: " Although in my description of the latter species it is stated to be without a median sinus, both of the typical specimens show this feature in a slight degree though possibly as a result of compression." Girty (1903, pl. 5, figs. 12, 12a) figures a second uncrushed and unexfoliated specimen (from a locality near that of the type specimens) that does show a faint sulcus. The range of variation of the species in its type area has not been established.

The specimens assigned to this species from northern New Mexico appear to differ from Girty's Colorado specimens only in having possibly finer costellae. All are distinctly quadrate and are either flattened on the venter or have a faint sinus.

The specimens that we assign to this species come only from the Atokan interval. For comparisons with *D. nambeensis* (Morrowan) and *D. "missouriensis"* (lower Desmoinesian), see the discussions of those species.

MATERIAL AND OCCURRENCE—Girty's (1903, p. 380) original specimens of *Marginifera ingrata* came from what he termed the "base of the Weber formation" in the Leadville district of Colorado. More recently, Brill (1942, 1952) described the dark shales at the base of the Weber Formation in Colorado as the Belden Formation. He (1958, p. 103) states: "It is probable that the typical Belden of the Maroon basin is Atokan." He also records a personal communication from Walter Sadlick who states that *Profusulinella* or a primitive *Fusulinella* occurs in the basal 20 ft of the Belden in the Leadville-Ruedi area. This evidence indicates that Girty's original specimens are probably Atokan.

The specimens from northern New Mexico occur commonly in units 62-17 and 18 in the Atokan part of the La Pasada Formation. There are about 130 specimens in our collection. Figured specimens: OU 7675 to 7680.

***Desmoinesia "missouriensis"* (Girty)**

Pl. 7, figs. 7-12

Marginifera muricata var. *missouriensis* Girty, 1915b, p. 350. pl. 30. figs. 2-5.

Marginifera missouriensis, Dunbar and Condra, 1932, p. 224, pl. 35, figs. 11-16.

DESCRIPTION—(Based on specimens from locality 78.) The shell is medium in size for the genus. A large specimen has the following dimensions: length 14.5 mm, width 16.3 mm, hinge width 14.0 mm, height 8.2 mm. The maximum width slightly exceeds the length on most specimens, and the hinge width is slightly shorter than the greatest width.

The pedicle valve is strongly convex but not geniculate. A transverse profile at midlength is semicircular, with the mesial part being slightly flattened but only rarely sinuate. Posteriorly, the lateral slopes are steep; the ears are small for the size of the shell but distinctly set off. The cardinal angle is obtuse. The surface is marked by low, rounded costae of irregular size increasing by bifurcation, especially laterally, but are obsolete on the ears and at the beak. Commonly 1 or 2 of the mesial costae disappear or coalesce near the margin. On the venter, the number of costellae in 5 mm at a surface length of 10 mm ranges from 7 to 11 and averages 8.5 (fig. 21B). Concentric wrinkles, strongest on the ears, cover the posterior half of the shell, forming a reticulation ending at an average surface length of 9.7 mm (fig. 21A). Near the margin of mature shells are usually several strong, concentric lamellae. Crests of the costae and wrinkles bear many erect spines, slightly more abundant posteriorly. Typically, a costella will have 2 spines over its length.

The brachial valve is strongly and rather uniformly concave except for the small ears, which are flat and set off by a strong deflection line. The ears are slightly deflected ventrally below the commissure plane. Valve sculpture is similar to that of the pedicle valve. Spines are finer, but as numerous as on the pedicle valve.

The interior of the pedicle valve is imperfectly known, but clearly possesses the strong ridge around the anterior margin, characteristic of the genus.

The brachial interior is typical for the genus except that the median septum is short and low, and the lateral adductor scars are relatively small.

DISCUSSION—Girty's (1915b, p. 350) original description of *Marginifera muricata* var. *missouriensis* follows: " It is small and in shape subquadrate, marked by fine, regular costae which are crossed over the visceral region by fine, more or less strong and irregular transverse wrinkles. Numerous small spines spring from the costae and from the ears. From typical *M. muricata* this shell is distinguished by its small size and less transverse shape. The costae are finer and more regular and there is no trace of a sinus, a character sometimes faintly developed in other species."

Girty's original specimens were from the lower Desmoinesian of Missouri. The species has not been redescribed and information is not available as to the range of variation found in the species in its type region. Dunbar and Condra (1932, p. 224) point out that the species may be a junior synonym of *Productus nanus* Meek and Worthen. Its authors (Meek and Worthen, 1866, p. 321) characterized that species as having a "peculiar sudden bifurcation of its costae on a somewhat raised band around the free border of its valve." The species description apparently was based on a single specimen from an unrecorded location in Jefferson County, Iowa. We agree with Dunbar and Condra (1932, p. 225) that the exact specific character of *P. nanus* is in doubt, and we reject the use of the name. Apparently the same procedure was followed by Muir-Wood and Cooper (1960, p. 230) who do not mention *Productus nanus* but list *Marginifera muricata* var. *missouriensis* Girty as an example of the genus *Rudinia* (a junior synonym of *Desmoinesia).* On the other hand, Hoare (l961 b, p. 63) lists the latter species as a junior synonym of *Desmoinesia nana.*

The New Mexico specimens (lower Desmoinesian) we have included in this species, vary considerably in size and character. Most of the ones from locality 78, described above, agree with Girty's description in lacking a sinus. They are also characterized by having a hinge width less than the maximum width with correspondingly small ears. In some collections, there is a mixture and a gradation between typical, nonsulcate specimens of *D. " missouriensis"* and proportionally broader specimens, some of which have a sulcus. Such variants more nearly resemble *D. ingrata,* from the underlying Atokan. We are faced with the familiar problem of applying typologically defined species names to large collections that show wider variation in morphological character. Both *D. "missouriensis"* and *D. ingrata* need to be redescribed based on large collections from their type regions. Possibly a consistent distinction cannot be found for the two species. Based on specimens from the Sangre de Cristo area, most of the lower Desmoinesian specimens of *D. "missouriensis"* differ from the Atokan specimens assigned to *D. ingrata* in being proportionally less broad and in having fewer specimens developing a sulcus. Coarseness of the costellae is only slightly different, with *D. "missouriensis"* being slightly coarser (fig. 21B).

D. "missouriensis" is distinctly smaller in size than *D. muricatina;* the costellae are much less coarse, averaging 8. 5 as contrasted to 5.9 per mm at 10 mm (SL) for specimens of *D. muricatina* from the middle Desmoinesian.

MATERIAL AND OCCURRENCE-Girty's type specimens were from the Cherokee Shale (lower Desmoinesian) in Missouri. Dunbar and Condra (1932, p. 225) state that this species appears to be confined to the lower part of the Desmoines Series in the Midcontinent. In the southern Sangre de Cristo region, the specimens we include here are limited to the lower Desmoinesian, and included in Fusulinid Zones II and III. This species occurs commonly at many localities, but most specimens are not well preserved. There are over 500 specimens in our collections. The best preserved are from locality 78. They also occur in units 29-5, 29-10, 36-l05(?), 36-109, 36-128, 36-133, 40-3, 42-13, 47-48(?), 60-124, and 93-44(cf.). Figured specimens: OU 7681 to 7686.

Desmoinesia muricatina **(Dunbar and Condra)**

Pl. *7* , fig. 13

Productus muricatus Norwood and Pratten (not Phillips), 1855, p. 14, pl. 1, figs. 8a-e.
Marginifera muricatina Dunbar and Condra, 1932, p. 222, pl. 35, figs. 1-10.
Desmoinesia muricatina, Hoare, 1960, p. 226, pl. 33, figs. 8-13; 196 lb, p. 61, pl. 4, figs. 17-22.
Rudinia muricatina, Muir-Wood and Cooper, 1960, p. 64, figs. 11-25.

DISCUSSION-The species is the largest known for the genus, has the coarsest costellae (fig. 21B), and extends the highest stratigraphically. The species as used by most authors is based on the diagnosis given by Dunbar and Condra (1932, p. 222), which is in turn based mostly on specimens from localities other than the type locality or region (see below).

Dunbar and Condra (1932, p. 223) state that the species ranges throughout the Desmoines Series and that it is common both in the Cherokee Shale (lower Desmoinesian) and in the Fort Scott Limestone (upper Desmoinesian). Our study of specimens we assigned to this species from various formations in southern Oklahoma suggests progressive increase in average size for the species upward throughout the Desmoinesian, and an increase in the coarseness of the costellae. For example, specimens from the Boggy Shale (lower Desmoinesian) have costellae averaging 7.7 in 5 mm at 10 mm surface length (s=0.79, n =30) and those from the Wetumka Formation (middle Desmoinesian) average 6.5 in 5 mm at 10 mm surface length (s=0.78, n=30). This difference can be seen in specimens from the Boggy and Wetumka Formations illustrated by Dunbar and Condra (1932, pl. 35, compare figs. 1-3).

The New Mexico specimens we include in this species are mostly crushed but appear to be typical for the species. They are possibly somewhat coarser than the Oklahoma specimens for the same stratigraphic horizons but sufficient samples have not been examined to establish this point with certainty. New Mexico specimens in the lower Desmoinesian units 10-11 and 10-23 are smaller and the costellae average 6.5 in 5 mm at a surface length of 10 mm. In the upper middle Desmoinesian units 10-56 to 10-58, the shells are larger and the costellae average 5.9 in 5 mm at a surface length of 10 mm (fig. 21B).

In their original description of *Productus muricatus* Norwood and Pratten (1855, p. 14, pl. 1, figs. 8a-e) figured one complete specimen and two interiors which must be either from "Fish-hook creek, Pike county, Illinois" or from "six miles northwest of Richmond, Missouri." The figured specimens are listed as being part of the Illinois State Collection. The type locality needs to be re-established and the stratigraphic horizon determined. Norwood and Pratten' s figure measures about 13 mm in length and 17 mm in width. The costellae number about 6 in 5 mm at about midlength on the venter.

MATERIAL AND OCCURRENCE—Norwood and Pratten's original specimens of *Productus muricatus* came from an unrecorded horizon in either Illinois or Missouri. Dunbar and Condra (1932) record the range of the species in the Midcontinent region as being throughout the Desmoinesian.

In northern New Mexico, *D. muricatina* is not a commonly occurring species except in the lower part of the Alamitos Formation in units 10-56, 10-57, and 10-58. Specimens in these units are of the large, coarsely costate variety characteristic of the upper Desmoinesian Wewoka Formation in Oklahoma. The precise age of the upper part of measured section 10 is uncertain. Fusulinids are lacking but the composition of the brachiopod fauna and the stratigraphic position indicate a later middle or possibly a late Desmoinesian correlation. The coarsely costate variety occurs also at locality 18(?) and in unit 60-232. The less coarsely costate variants occur in the lower Desmoinesian units 10-11(cf.) and 10-23(cf.) Figured specimen: OU 7687.

GENUS *SANDIA* Sutherland and Harlow, n. gen.

DESCRIPTION—The shell is small to medium size and the pedicle valve is strongly inflated and may have a sulcus. The surface is marked by regular radiating costellae except on the anterior slope where they tend to become faint. In some species the costellae coalesce to form radiating ridges on the anterior slope. The umbo has concentric rugae, and the anterior margin may be coarsely lamellar. Erect spines are scattered over the valve surface; on the ears, however, the spines are oriented in one or more irregular rows that diverge slightly from the hinge.

The brachial valve is strongly concave and is somewhat geniculate. The surface is costellate and rugose. Small, erect spines are scattered over most of the valve surface. Along the posterior margin, some of these may be arranged in an irregular row that diverges slightly from the hinge. On the anterior slope of mature specimens are a few irregularly distributed prostrate spines directed anteriorly. In some species these spines are curved toward the pedicle valve and interrupt the growth of one or both of the valves. These prostrate spines are associated with the radiating ridges on the pedicle valve.

The interior of the pedicle valve has a strongly raised mesial adductor platform, which is located far anteriorly. A row of pustulose hinge teeth is present along the hinge, these being associated with the row of spines along the pedicle hinge line and corresponding pits along the brachial hinge line.

The brachial valve interior has a small, distinctly elevated adductor muscle platform separated by a median groove, in which originates a median septum that extends anteriorly to midlength. Brachial ridges are well developed. The valve is abundantly pustulose or spinose anteriorly and laterally from the brachial ridges. The marginiferid cardinal process is sessile, small and posteriorly trilobed. Laterally the process is supported by narrow ridges that diverge slightly from the hinge line.

TYPE SPECIES—Sandia *brevis* n. sp., Atokan, La Pasada Formation, New Mexico.

OCCURRENCE—Lower Pennsylvanian (Morrowan and Atokan), New Mexico, Oklahoma, Arkansas.

SPECIES OTHER THAN TYPE SPECIES ASSIGNED TO GENUS—*Sandia santafeensis* n. sp., Atokan, La Pasada Formation, New Mexico. *Productus welleri* Mather, Morrowan, northeastern Oklahoma and northwestern Arkansas, northern New Mexico.

DISCUSSION—The most distinctive feature of the genus *Sandia* is the presence of large, anteriorly directed, prostrate spines near the anterior margin of the brachial valve of mature shells. This feature distinguishes *Sandia* from the genus *Desmoinesia.* Also, *Sandia* has a much thicker development and greater elevation of the muscle-supporting platforms in both valves, and in the development of coarse spines near the hinge of the pedicle valve. *Sandia* also resembles the Mississippian genus *Inflatia* but that genus lacks spines on the brachial valve.

Muir-Wood and Cooper (1960, p. 265) questionably placed the species *Productus welleri* Mather in the genus *Protoniella.* We have included that form in the genus *Sandia.* The internal features of the type species of the genus *Protoniella* are not well known but Muir-Wood and Cooper consider that genus "to be probably a small buxtoniid" which is not the case with either *Sandia* or *Productus welleri.*

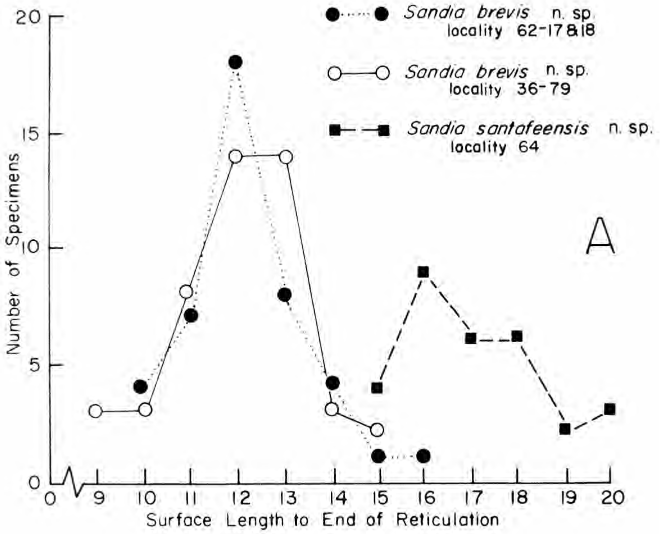
***Sandia brevis* n. sp.**

Pl. 7, figs. 14-23; Pl. 8, figs. 1-3

?Productus gallatinensis, Girty, 1903, p. 361, pl. 3, figs. 4-8 (not Girty, 1899).

DESCRIPTION—The shell is small and compact with the maximum length and width subequal. A large specimen has the following dimensions: length 20.9 mm, width 20.5 mm, hinge width 20.0 mm, height 12.9 mm, and surface length 40 mm. Descriptive statistics and specimen measurements are given in Appendix 2, table 6 and Appendix 3.

The pedicle valve is strongly convex posteriorly and the beak extends 1 to 2 mm past the hinge line. Lateral slopes are steep posteriorly. The ears, which are strongly set off, have slightly pointed extremities, but the hinge width is approximately equal to the maximum width at midlength. Most shells are slightly flattened anteriorly and some possess a faint mesial sinus, starting on the umbo or on the trail. The umbo is marked with 12 to 14 strong concentric rugae. The surface length to the end of reticulation averages 12.2 mm for 43 specimens from units 62-17 and 18 (fig. 22A). In the umbonal area, the costellae are obscure but beyond they are strong and even and average 7.6 in 5 mm at 20 mm surface length, for 38 specimens from units 62-17 and 18 (fig. 22B). Toward the anterior margin, they become irregular in thickness and height and are locally interrupted by stout radiating ridges or irregular bulges. These reflect the location of the larger spines that originate on the exterior of the brachial valve, curve ventrally, and interrupt the growth of the pedicle valve. Spines occur over the entire shell surface but are smaller and more closely spaced on the umbo. A row of stout spines



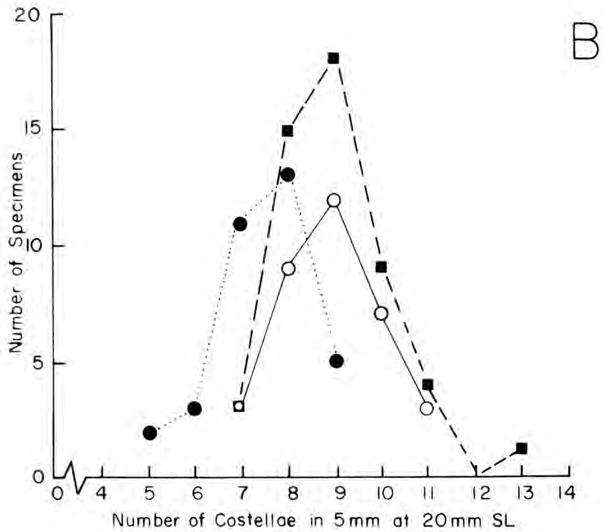


FIGURE 22—**A.** *Frequency plots with number of specimens plotted against surface length to end of reticulation for specimens of* Sandia santafeensis *n. sp. from locality 64, and for specimens of* S. brevis *n. sp. from the type units, 62-17 and 18, and from unit 36- 79.*

B. *Frequency plots for the number of costellae measured in 5 mm in the venter at 20 mm surface length. For descriptive statistics see Appendix 2, table 6.*

diverges slightly away from the posterior margin and numbers about 6 on each side of the beak.

The brachial valve is strongly concave, slightly geniculate, and its visceral disc has concentric rugae. Costellae are developed anteriorly and laterally. They are crested with scattered, small, erect spines that may appear to be lacking on slightly exfoliated shells. Corresponding to the enlarged anterior ridges on the pedicle valve are rather irregularly distributed shallow grooves. Each bears a stout spine (Pl. 7, fig. 14e), which is at first nearly erect but immediately deflects forward, then curves ventrally and interrupts the growth of the brachial valve at that point. These ventrally hooked spines also interrupt the growth of the pedicle valve. The longest observed of these spines is about 3 mm.

The interior of the pedicle valve, known from 8 fragmentary shells and internal molds is characterized by a raised adductor muscle platform dendritically sculptured and about $^{1}/_{4}$ as wide as the shell interior. Diductor scars are deeply depressed and longitudinally grooved. They are bounded laterally by thick ridges that diverge at about 45 degrees from the hinge line and in turn set off deep lateral elongate pits. The surface, anterior to the muscle field, is marked by numerous fine pustules.

The brachial valve interior, known from 7 specimens, is geniculate and has a small sessile, posteriorly trilobed, marginiferid cardinal process. The process is thick at its base but is not continuous posteriorly with the median septum, which begins in a groove between the elevated muscle platforms and rises to a sharp ridge at midlength. Stout lateral ridges diverge from the base of the cardinal process at an angle of about 10 degrees from the hinge margin and curve around, inside the small ears, as broad elevated ridges. These ridges do not extend onto the posterolateral margin. Adductor scars lie close to the median groove. The posterior adductors are dendritic and the anterior adductors oval and have a granular surface. Brachial ridges extend $^{2}/_{3}$ the length of the visceral disc to a point opposite the end of the median septum. Laterally and posteriorly from the brachial ridges, the surface has numerous endospines.

DISCUSSION—The description is based primarily on specimens from units 62-17 and 18 (Atokan, near Santa Fe) . We also have a large number of specimens from unit 36-79 (Atokan, Pecos valley). Comparing the degree of similarity of these two collections is important for stratigraphic reasons. The two collections differ in the coarseness of the costellae (fig. 22B) but are similar in other respects. We have included specimens from unit 36-79 in *S. brevis* and consider that geographic variation may explain the difference observed or that unit 36-79 may be slightly higher stratigraphically than units 62-17 and 18. The latter assumption is based on the fact that specimens from unit 36-79 approach *Sandia santafeensis* in coarseness of costellae (fig. 22B). This species, from locality 64, lies stratigraphically higher in Atokan strata of the Santa Fe Quarries than units 62-17 and 18. Statistical tests were used to establish the significance of the range of variation. For specimens from units 62-17 and 18, the mean number of costellae measured in 5 mm on the venter at 20 mm surface length for the type specimens is 7.6, with a range of from 5 to 9 costellae, for 38 specimens. Specimens from unit 36-79 have a mean of 8.9 with a range of from 7 to 11 costellae, for 34 specimens. The difference ($z = 5.06$) between the mean number of costellae for the two samples is highly significant. The surface length to the end of reticulation was also compared between the two collections (fig. 22A); at 90 percent confidence limits, the difference ($z=0.43$) between the two is not significant. Specimens from units 62-17 and 18 have a range from 10 to 16 mm surface length to end of reticulation, with a mean calculated to be 12.2 mm for 43 specimens. The specimens of this species from unit 36-79 have a mean of 12.1 mm surface length to end of reticulation, for 47 specimens, with a range of from 9 to 15 mm. When length is plotted against surface length (fig. 23A), the specimens from units 62-17 and 18 and those from unit 36-79 cluster closely about an approximate mean growth curve. When width is plotted against surface length (fig. 23B), the cluster of points is not as close to the mean. Qualitatively, the points from both localities are interdispersed enough to preclude differentiation for these features. Both curves suggest that length to surface length, and width to surface length are logarithmic growth forms, although not enough small specimens (that is, smaller than 20 mm) are present in our collections to permit mathematical analysis.

Sandia brevis n. sp. differs from *S. santafeensis* n. sp. in being smaller in size (fig. 23) and more narrow at the umbo, in having a shorter surface length to the end of reticulation, and in being less tightly coiled. When the mean surface length to end of reticulation (fig. 22A) is compared for specimens of *S. brevis* from units 62-17 and 18 with those of *S. santafeensis* from locality 64, a very highly significant difference (z =14.4) is obtained.

S. brevis, which we have found only in Atokan or lower Desmoinesian strata, differs from *S. welleri*, which occurs in Morrowan rocks, in being smaller in size, in having less tendency to develop a sulcus, and most strikingly, in developing hooked prostrate spines on the anterior margin of the brachial valve.

MATERIAL AND OCCURRENCE—Sandia *brevis* n. sp. is common in the Atokan interval in the lower part of the La Pasada and Flechado Formations. Inadequately preserved specimens from lower Desmoinesian strata may belong to this species. There are more than 250 specimens in our collections from the following Atokan units: 36-71, 36-79, 62-17 and 18 (type locality), 62-28, 67-13, 67-23, 67-30, and 93-25. Small numbers of questionable specimens come from the following lower Desmoinesian units: 29-5(?), 36-l28(?), 40-3(?), 47-37(?), and 93-44(?). Figured specimens: holotype, OU 7688; paratypes, OU 7689 to 7694; other figured specimens, OU 7695 to 7700.

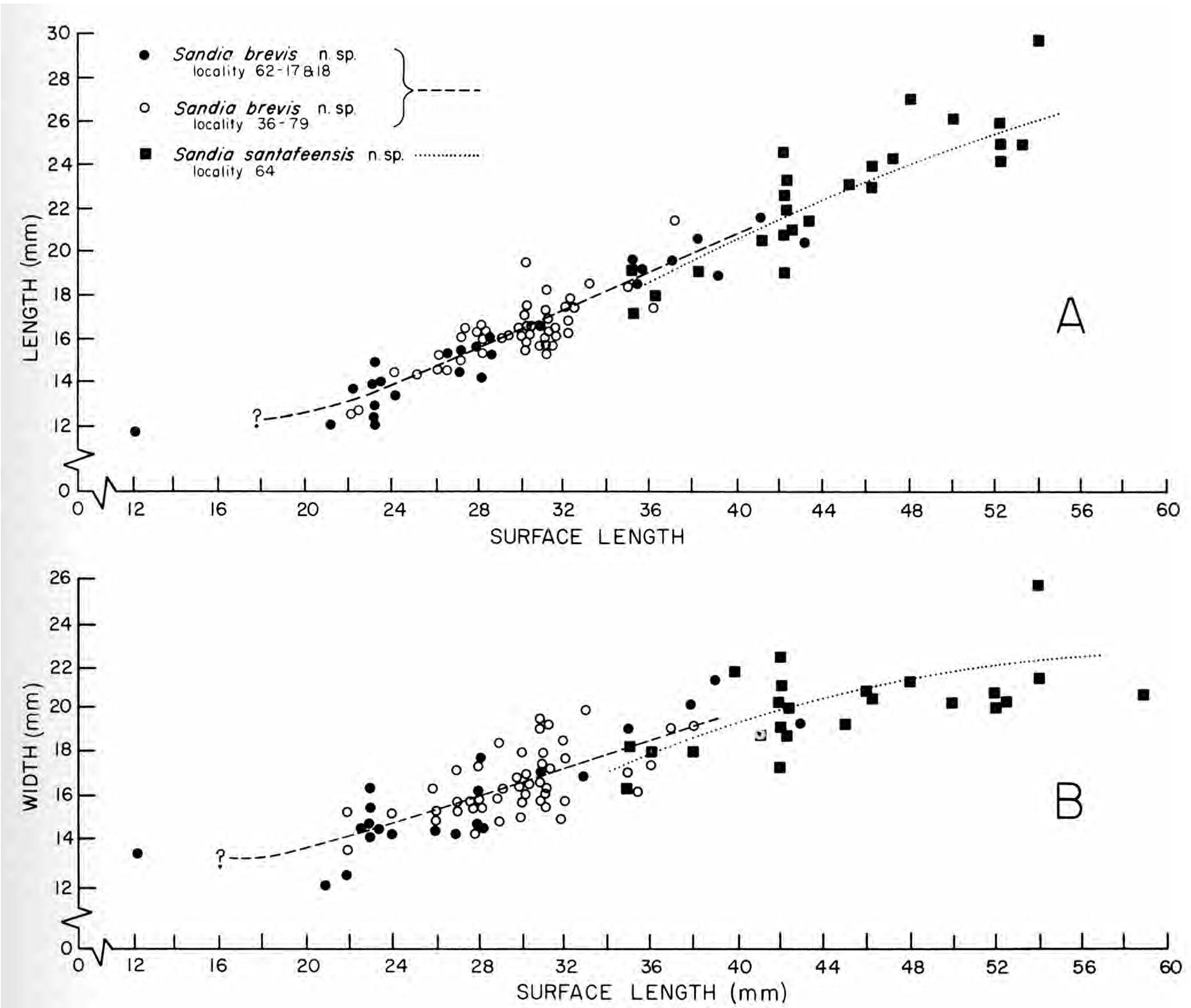


FIGURE 23—*Scatter diagrams for* Sandia brevis *n. sp. from the type units 62-17 and 18 and from unit 36-79 and for* S. santafeensis *n. sp. from the type locality 64. The approximate growth curves for* S. brevis *are shown as dashed lines; those for* S. santafeensis *are depicted as dotted lines.*

A. Length plotted against surface length.

B. Width plotted against surface length.

Sandia santafeensis n. sp.

P1. 8, figs. 4-12

?*Marginifera* cf. *M. haydenensis,* Gehrig (not Girty, 1903), 1958, p. 21, pl. 3, figs. 4-6.

DESCRIPTION—The shell of a complete adult specimen is long and relatively narrow for a productid brachiopod. A larger specimen has the following dimensions: length 27.5 mm, width 21.1 mm, height 18.5 mm, and surface length 59 mm. Descriptive statistics and specimen measurements are given in Appendix 2, table 6 and Appendix 3.

The pedicle valve is extremely convex posteriorly, producing a greatly inflated umbo, which overhangs the posterior margin. Medially, the valve surface may either be flattened or depressed into a very shallow and broad sulcus. A few specimens have a relatively narrow sulcus, which attains a maximum depth of 1.5 to 2 mm (Pl. 8, fig. 4). The ears are strongly set off from the umbo and the extremities are square or slightly produced. On the umbo, the surface is marked by strong concentric rugae that extend anteriorly an average of 17.7 mm surface length, for 30 specimens (fig. 22A). The surface is also ornamented with costellae, which are rounded and evenly spaced. An average of 9.8 costellae is present in 5 mm in the venter at a surface length of 10 mm (range 8-12, n=43). Although the costellae commonly bifurcate, at a surface length of 20 mm the average number decreases to 9.0 (range 7-13; n =50; see fig. 22B), and at 30 mm surface length, the average has decreased further to 8.0 (range 7-10, n =31). On the trail at an average distance of 28.9 mm surface length (range 23-35, n =38), one or more stout, radiating ridges develop and are commonly quite angular (Pl. 8, fig. 4b). As many as 7 ridges may thus be produced, which are variable in thickness and height; these ridges generally continue to the anterior margin. They reflect the location of large hooked spines that originate on the surface of the brachial valve and affect the growth of the pedicle valve. The smaller costellae tend to become obscure and die out on the anterior slope, partly because of the development of irregular growth lamellae resulting from possible injury to the trail and subsequent repair. Abundant, small, erect spines are present in the reticulate area, but on the anterior part of the shell, the erect spines are larger and more widely scattered. Along each cardinal margin is a row of about 7 spines that diverges slightly from the margin. On some specimens, the spines form an irregular double row.

The brachial valve is deeply concave and distinctly geniculate in larger specimens. A few specimens have a broad and very low fold corresponding to the sulcus of the pedicle valve. The ears are flat and distinctly set off from the rest of the valve. The rugae are coarse posteriorly, and become subdued anteriorly where fine growth lines or lamellae become the only concentric ornamentation. The costellae are generally quite low over the entire surface of the valve, but are not found on the ears. Suberect small spines are scattered over the valve surface. Several of these spines may form an irregular row near the posterior margin. Along the anterior margin, however, a number of long, stout, prostrate spines grow anteriorly. Some are curved ventrally and interrupt the growth of the brachial valve margin. Some extend ventrally past the brachial valve causing the pedicle valve margin to have grown around their ends, resulting in the irregular digitations and ridges found on the trail of the pedicle valve.

The interior of the pedicle valve, known from 10 fragmentary specimens, is greatly thickened in the umbo. The adductor scars are raised on large, broad, elongate, dendritically sculptured platforms (Pl. 8, figs. 11, 12). The deeply depressed and longitudinally striated diductor scars extend laterally and slightly anteriorly. The remainder of the valve is strongly concave except for two narrow ridges that diverge at approximately 45 degrees from the posterior margins and sharply set off deep grooves up to 5 mm in length and triangular-shaped posterolateral areas. Along the hinge 6 or 8 large pustules occur on each side of the beak, apparently serving as rudimentary teeth, thus articulating with the brachial valve.

The brachial valve interior is known from 20 specimens. It has a stout, trilobed, sessile cardinal process. The lateral lobes extend far laterally before curving dorsally (Pl. 8, fig. 7). The internal features are strongly developed. The adductor scars are raised on strong, rounded platforms, separated by a shallow mesial groove. The median septum begins in the groove, becomes elevated anteriorly and is truncated at midlength. The brachial ridges are also very strongly elevated. The anterior and lateral pustules and endospines are numerous and strong, particularly along the anterior geniculation (Pl. 8 figs. 8, 9). The hinge line usually has a row of pits into which the ventral pustules are articulated. The posterolateral areas are flat except in large thickened specimens that develop a raised ridge along the margin of the geniculation.

DISCUSSION—Sandia *santafeensis* differs from *S. brevis* in being distinctly larger in size, more tightly coiled, and in having a greater surface length to the end of the reticulation. Internally the two species are similar except that the internal features of *S. santafeensis* are more thickened and more distinctly developed. It is similar to the Morrowan species *S. welleri* (from which it probably evolved) in size and coarseness of the costellae. It differs from *S. welleri* in being proportionally more elongated and more sharply coiled, and in the more common hooking, ventrally, of the prostrate spines on the anterior margin of the brachial valve, interrupting the growth of the valves.

MATERIAL AND OCCURRENCE—We have found *Sandia santafeensis* only at locality 64 in the Santa Fe Quarries in Atokan strata in a horizon higher than either units 62-17 and 18 or 62-28. These rocks are in the lower part of the La Pasada Formation. At locality 64, the species occurs as a brachiopod coquina composed mostly of this species and *Anthracospirifer newberryi.* Our collection contains more than 150 specimens. Figured specimens: holotype, OU 7702; paratypes, OU 7701, 7703 to 7709.

Sandia welleri (Mather)

P1. 8, figs. 13-17

Productus welleri Mather, 1915, p. 155, pl. 9, figs. 10-11.

DESCRIPTION—(Based on New Mexico specimens from all localities.) The shell is medium sized with a larger specimen having the following dimensions: length 25 mm, width 25 mm, height 15 mm, and surface length 48 mm.

The pedicle valve is strongly convex, the lateral slopes are steep, and a mesial sulcus is developed on some specimens. The surface is marked posteriorly by fairly strong concentric wrinkles originating on the ears and are strong over the umbo. The surface length to the end of reticulation averages 19.0 (range 14-22, n =13). The number of costellae in 5 mm at 20 mm surface length averages 8.8 (range 7-10, n =11). They tend to become faint and to broaden irregularly on the anterior slope.
On some shells a few scattered costellae are elevated forming ridges near the anterior margin. Other shells are almost smooth in this region except for growth lamellae and scattered large erect spine bases. Spines are scattered over the entire shell surface and are more closely spaced, smaller, and erect on the umbo. The ears are sharply set off from the body of the shell and the hinge width is equal to the greatest width of the shell. Along the hinge line, a single or double row of spines diverges slightly from the margin.

The brachial valve is concave and distinctly geniculate. Small, erect spines are scattered sparsely over the surface. Along the hinge is a row of small, erect spines. Along the anterior margins of the trail, a few irregularly distributed prostrate spines are directed anteriorly. On most specimens, these spines are parallel to the valve surface, but on others, a few spines are curved toward the pedicle valve and interrupt the growth of the valve margin.

The pedicle valve interior, known from 5 fragmentary specimens from unit 41-47 has a long, narrow, elevated adductor muscle platform and broad, longitudinally striated diductor scars. Each of the latter are bounded laterally by a low ridge, which sets off a flat triangular-shaped posterolateral area.

The brachial valve interior, known from 13 specimens from unit 41-47, has a small, short, trilobed cardinal process. The process is supported laterally by nearly straight ridges. These ridges diverge by a very small angle from the hinge line, thickening and becoming low and pustulose at the lateral extremities. The adductor muscle platforms are comparatively small but distinctly elevated, the longest side lying along a deep mesial channel that separates the platforms. From within the channel arises a sharp, low, median septum, truncated abruptly at midlength. Anteriorly and laterally, the surface is covered by fine low pustules and endospines. Along the hinge line, a row of pits is well developed, presumably aiding articulation.

DISCUSSION—Mather (1915, p. 155, pl. 9, figs. 9, 10) based his description of *Productus welleri* on two specimens from the Morrow Group of northwestern Arkansas. We have examined these two figured specimens, both labeled as being from the Hale Formation, East Mountain, Fayetteville (WM 16095). The holotype is partly exfoliated and the costellae, particularly on the anterior slope, appear fainter than typical. The allotype is a mostly exfoliated brachial interior. Neither specimen shows the brachial valve exterior. The types appear to be conspecific with the New Mexico specimens (on which the above description is based) but whether the brachial valves of the type specimens contain exterior prostrate spines on the anterior slope cannot be determined. Mather (1915, p. 156) states that the species is characterized by a "remarkably consistent linear arrangement" of a single row of prominent erect spine bases across each ear. However, specimens of this species in the OU collection from the Morrowan strata in northeastern Oklahoma have a wide variation in the number and arrangement of spines on the ear, with some specimens having a double row.

The specimens from New Mexico clearly possess long prostrate spines on the anterior slope of the brachial valve. In most specimens, these spines are parallel to the valve surface; only in rare cases do they curve toward the pedicle valve, interrupting the growth of one or both of the valves. Thus, only a few specimens have linear ridges on the anterior slope of the pedicle valve, a feature characteristic of the two Atokan species, *S. brevis* and *S. santafeensis. S. welleri* also differs from *S. brevis* in being larger, and in having a greater ratio of width to length. *S. welleri* is more closely related to *S. santafeensis*, comparing in size and coarseness of costellae. *S. sanafeensis* differs in being more tightly coiled, and in the hooking, ventrally, of the prostrate spines on the margin of the brachial valve. (For a comparison with *Sandia welleri* var. A, see discussion of that variant.)

Muir-Wood and Cooper (1960, p. 265) place *Productus welleri* Mather questionably in the genus *Protoniella*, but the internal character of the type species of that genus is not well known. They consider *Protoniella* to be buxtonid, certainly not of the case for *Productus welleri.*

MATERIAL AND OCCURRENCE—Sandia *welleri* is a commonly occurring species in the Morrowan strata of northeastern Oklahoma and northwestern Arkansas; the range of variation has not been established in that area. *S. welleri* is rarely found in the Wapanucka Formation in central Oklahoma. In northern New Mexico, the species occurs throughout the Morrowan sequence, but is less common in the lower strata where *S. welleri* var. A. is more common. Our collections include about 125 specimens of which 40 come from unit 41-47. Others are from units 36-38(?), 36-56(?), 36-66, 36-68(cf.), 41-29, 41-39, 41-42, 41-47, 60-26 and 60-52(cf.). Specimens from unit 36-68, a horizon near the boundary between the Morrowan and Atokan, are transitional between *S. welleri* and *S. santafeensis.* Figured specimens: OU 7710-7714.

Sandia welleri variant A

Pl. 8, figs. 18-22

DISCUSSION—At a few localities in the lower part of the Morrowan sequence in northern New Mexico, occur specimens similar to *S. welleri,* but much more highly spinose on both valves. Such specimens are common only at unit 90-2 but occur sparingly at a few other localities. They overlap the range of more typical specimens of *S. welleri* (which occur most commonly in the middle and upper part of our Morrowan rocks) and are considered to represent only a variant of *S. welleri.* In units 90-14 to 17, representing a collection from several different layers, both types of shells are present in the same collection, with an apparent gradation between the two types.

MATERIAL AND OCCURRENCE—Our collection from unit 90-2 includes 24 specimens of this form. A total of 6 specimens are from units 61-2, 61-11, and 90-14 to 17. Figured specimens: OU 7715 to 7719.

Family ECHINOCONCHIDAE
Subfamily ECHINOCONCHINAE
GENUS *CALLIPROTONIA*

***Calliprotonia* n. sp. A**
Pl. 9, figs. 1-3

DESCRIPTION—The small- to medium-sized shells are subtriangular in ventral outline. The largest of our specimens is 18.5 mm long and 17.5 mm wide.

The pedicle valve is subequal in length and width, with the maximum width occurring slightly anterior to the midlength. The hinge area is poorly preserved but appears to be distinctly narrower than the greatest width. The shells are strongly convex, thus giving a spiral appearance in side view. The beak is small, slightly incurved, and apparently does not overhang the hinge by more than 1 mm. The umbo is narrow. One specimen has a rounded umbo but another is slightly flattened on the venter and has the faintest suggestion of a sulcus.

The brachial valve is slightly concave, not geniculate, and lacks a median fold.

Surface ornamentation on both valves consists of flattened, concentric bands, on each of which occur 3 or 4 alternating rows of small prostrate spines. On the pedicle valve, these bands are 1 to 1.5 mm wide near the beak, become progressively wider anteriorly, and attain a maximum width of 2.5 to 3 mm at the margin. On the brachial valve, however, they are much narrower and reach a maximum width of only 1 mm at the anterior margin.

Interiors are lacking.

DISCUSSION—Calliprotonia n. sp. A differs from *C. renfrarum* Muir-Wood and Cooper, from the Virgilian of northern Texas, in having a much sharper and narrower umbo, in being narrower, and in being distinctly more highly convex.

MATERIAL AND OCCURRENCE—This species is rare in our collections. We have only 8 specimens from unit 36-150 and locality 78, occurring in the middle part of the La Pasada Formation. Unit 36-150 is lower middle Desmoinesian (Fusulinid Zone IV), but the associated brachiopod fauna of locality 78 suggests a probable upper lower Desmoinesian correlation for that locality. Figured specimens: OU 7720 to 7722.

GENUS *ECHINARIA*

***Echinaria* n. sp. A**
Pl. 10, figs. 12, 13

DESCRIPTION—The shell is of moderate size with the two largest specimens being about 50 to 55 mm in both length and width.

The profile and shape of the pedicle valve is commonly obscured by distortion, but the sulcus is broad and shallow. The surface is marked by closely spaced bands numbering about 5 to 6 in 10 mm at 50 to 60 mm surface length. They bear 2 series of fine prostrate spines in 1 to 3 rows. The posterior spine series is a relatively uniform row of coarser spines and the anterior spines are finer and more irregularly placed. Laterally where the bands become narrow, the spines become finer and more dense. Bands are of irregular width but average 2 to 4 mm wide mesially.

The brachial valve is slightly concave. The bands are narrower than on the pedicle valve, and bear spines in two series, relatively coarse and fine, alternating along the band. The coarser spines are slightly posterior; between each pair are 1 or 2 finer spines located in the middle of the band.

The pedicle valve interior is unknown. The brachial valve interior is well shown by 3 specimens and parts of a fourth. The cardinal process is long shafted and narrow, one being 6 mm in length and up to 2 mm in diameter. It is strongly deflected dorsally so that the posterior side of the shaft forms an angle of about 100 to 110 degrees with the valve surface. The shaft is deeply grooved along a median line and terminates in a short, trilobed face. The process is supported laterally by strong ridges that nearly parallel the posterior margins. These ridges are depressed along the anterior side. Anteriorly the process is supported by a thick swelling. This rapidly thins anteriorly to form a narrow median septum that continues forward beyond the muscle area. Laterally, the median ridge is bounded by deep, sharp grooves that set off the raised, elongate, dendritically sculptured muscle scars.

DISCUSSION—The available specimens of *Echinaria* n. sp. A are fragmentary, but is included because species of *Echinaria* are not well known from Morrowan and Atokan rocks. The OU collections from the Morrowan in northwestern Arkansas include the same species. The fragmentary specimens referred by Easton (1962, pl. 4, fig. 28) to *Echinoconchus* aff. *E. alternatus* (Norwood and Pratten), from late Mississippian or early Pennsylvanian rocks in Montana, are possibly the same species. His species *Echinoconchus angustus* (1962, pl. 5, figs. 25, 26) from the same area and stratigraphic interval, is much smaller in size, and the concentric bands much more closely spaced.

Echinaria n. sp. A differs from the Desmoinesian species *E. knighti* in being distinctly smaller size, in having more closely spaced concentric bands, and in having a cardinal process more sharply deflected dorsally.

MATERIAL AND OCCURRENCE—Echinaria n. sp. A has been collected from the lower part of the La Pasada Formation, from Morrowan rocks in unit 41-42. Three abraded specimens, and fragments of about 15 others, some with good preservation of surface features, are included. Fragmentary specimens from unit 67-13 (early Atokan) possibly belong to this species. This locality is in the lower part of the Flechado Formation. The species occurs in the Morrowan of northwestern Arkansas. Figured specimens: OU 7747, 7748.

Echinaria cf. *E. knighti* (Dunbar and Condra)
Pl. 9, figs. 4-7

Echinoconchus semipunctatus var. *knighti* Dunbar and Condra, 1932, pl. 26, figs. 1-3.
Echinaria semipunctata var. *knighti,* Sturgeon and Hoare, p. 42, pl. 14, figs. 6-9.

DESCRIPTION—(Based on New Mexico specimens.) The shell is large with the length slightly greater than the width. One of our largest specimens has a length of approximately 77 mm and a minimum width of 74 mm.

The pedicle beak may overhang the hinge for as much as 14 mm on our largest specimens, and varies from moderately to strongly pointed. Posteriorly, the umbo is inflated with steep lateral slopes. A shallow sulcus arises about 10 to 20 mm surface length anterior to the beak and extends to the anterior margin. It then flattens and becomes indistinct farther anteriorly.

The brachial valve is slightly concave, with the greatest concavity near the anterior and lateral margins. The median fold is low and becomes broader and more obscure anteriorly.

The surface of both valves is marked by broad concentric bands. Fourteen specimens average 3.0 bands (range 2.5 to 3.5) in 10 mm on the venter of the pedicle valve at a surface length of 30 to 40 mm. On the brachial valve, 13 specimens average 5.7 bands in 10 mm. On both valves, numerous oblique spine bases are found on these bands. The spines are irregularly distributed, with the largest being along the posterior part of each band. The density of spines on each band varies both from one specimen to another and from one band to another on the same specimen.

The interior of the pedicle valve is unknown. In the interior of the brachial valve the cardinal process is long shafted with observed lengths being up to 8 mm. It extends posteriorly at an angle of approximately 135 degrees to the interior surface of the brachial valve and then curves dorsally with the short myaphore facing dorsally. The principal shaft has a deep median sulcus. The process is continuous with a strong median septum that extends forward past midlength. Lateral ridges, extending from the base of the process, are strong and rounded. The adductor muscle scars are elevated on long, narrow, gently rising platforms separated from the median septum by deep grooves.

DISCUSSION—We have examined Dunbar and Condra' s (1932, pl. 26, fig. 1) holotype of *Echinoconchus semipunctatus* var. *knighti*, from the Desmoinesian of Missouri. Our specimens from New Mexico are similar in shape except for a more narrow umbo and more pointed beak. Also, our specimens are, on the average, larger than the specimens described by Dunbar and Condra but not so large as *E. semipunctata.*

MATERIAL AND OCCURRENCE—Dunbar and Condra (1932, p. 209) report the common occurrence of *ria knighti* in the upper Desmoines of Missouri and adjacent states. Sturgeon and Hoare (1968, p. 43) record its occurrence throughout the Desmoines Series in Ohio. In northern New Mexico, it ranges in age from the lower Desmoinesian (Fusulinid Zone III) possibly to the upper Desmoinesian (Fusulinid Zone V). About 60 specimens are in our collection, of which close to 40 come from the lower middle Desmoinesian unit 36-150. Lower Desmoinesian units included are 29-5, 36-133, and 93-44, all in the La Pasada Formation. Poorly preserved specimens from the upper middle and upper Desmoinesian units 25-24(?), 25-54(?), and 60-252(?) possibly belong here. These units are in the Alamitos Formation. Figured specimens: OU 7723 to 7726.

Echinaria cf. *E. semipunctata* (Shepard)
Pl. 9, fig. 8

Echinoconchus semipunctatus, Dunbar and Condra, 1932, p. 205, pl. 25, figs. 1-3.

DISCUSSION—Extremely abundant crushed specimens and fragments of *Echinaria* are present in parts of the Missourian interval of the Alamitos Formation north of the town of Pecos. One of the largest specimens in our collections, although crushed, has an estimated length of 89 mm and a minimum width of 94 mm. These specimens possibly belong to *E. semipunctata* (Shepard), but poor preservation of our material makes definitive assignment impossible.

Our specimens on the average are much larger than *E.* cf. *E. knighti,* which occurs at a number of our Desmoinesian localities in New Mexico. In addition, the cardinal process of *E.* cf. *E. semipunctata* may be deflected dorsally much more abruptly than the process of the Desmoinesian species.

MATERIAL AND OCCURRENCE—Echinaria *semipunctata* is a common species found in the Missourian of the Midcontinent (Dunbar and Condra, 1932, p. 207). The specimens from New Mexico that we compare with this species form one of the most abundant faunal elements in units 96-40 and 97-60. Both localities are in the Alamitos Formation and are Missourian. Figured specimens: OU 7727.

GENUS *PULCHRATIA*

Pulchratia? pustulosa n. sp.
Pl. 9, figs. 9-13

DESCRIPTION—The shell is medium size. One of our largest specimens has the following dimensions: length 35 mm, width 36 mm, surface length 55 mm. Additional measurements are given in Appendix 3.

The pedicle valve is subcircular in outline, and widest slightly anterior to midlength. It is moderately but decreasingly convex, and not geniculate. The umbo may be inflated, with the lateral slopes rather steep posteriorly. The beak is not strongly inrolled. The transverse profile is subtrapezoidal, the mesial portion being slightly flattened, the lateral slopes being nearly straight but diverging slightly, and the commissure plane being flat. No sulcus is developed. Ornamentation on the umbo consists of spines that rise from the anterior end of elongate, irregularly scattered, and radially oriented nodes. The spines and nodes are subequal in size. Concentric rugae are faint and irregularly spaced. Within about 15 mm (SL) of the beak the concentric bands become progressively more distinct and the spines become confined to them. The elongate nodes become short and the spines differentiate in a size gradient, decreasing in size towards the anterior margin of each band. By midlength this design has become well established. In places the spines occupy crude, irregular rows along the bands; the posterior row has the largest spines, which arise at a low angle from short nodes; the middle part of the band has smaller spines arising at a low angle; and along the lamellose posterior edge of the band are prostrate spines of very small size. The coarser spines are about 1 mm apart along the band; the finer ones are several per mm. Anteriorly the bands narrow slightly; at midlength the width is typically 2 to 3 mm. Laterally, the finest spines disappear from the bands leaving 2 rows of the coarser spines, or occasionally only the coarsest spines persist to the margin.

The brachial valve is very slightly concave. There is no mesial fold. Posterior concentric markings are obscure with concentric lamellose banding arising further forward as on the pedicle valve. The markings rarely exceed 1 mm in width. The coarse posterior spines on each band are less abundantly distributed than on the pedicle valve; generally only one row of finer spines is on the anterior part of each band.

The pedicle interior is unknown. The brachial interior is known from 3 complete and 2 incomplete specimens that show considerable variation in the nature of the cardinal process. The figured specimen (Pl. 9, fig. 13) has a distinctly elongated, narrow process. Two unfigured, larger, possibly older specimens have processes of a similar length but are proportionally wider; they flair at their posterior ends, showing a trilobed, and in the larger specimen, a quadrilobed posterior end. The cardinal process on all specimens has a shallow groove on the ventral surface, forming a faintly bilobed division. At its base, the process is supported laterally by stout, rounded ridges that diverge very slightly from the posterior margin. The process is also supported by a median septum that is low and broad for the first 2 to 3 mm, then becomes thin, rises slightly, and terminates abruptly past midlength. The broad, low posterior part of the median septum is surmounted by a shallow, elongated, rudimentary antron. The adductor muscles were attached to very long, narrow, low, rounded platforms that parallel the septum and are separated from it by a sharp groove. The valve floor is covered anteriorly and laterally by abundant large prostrate pustules.

DISCUSSION—Pulchratia? *pustulosa* is similar to *P.? picuris* in the general pattern of the surface ornamentation. That is, the ornamentation is posteriorly similar to *Buxtonia* and *Juresania* and anteriorly to *Echinaria.* In this general pattern of the ornamentation, they resemble the Permian genus *Bathymyonia,* but the type species of that genus is characterized by an exceptionally large cardinal process and flaring dendritic adductor scars in the brachial valve.

Both *Pulchratia? pustulosa* and *P. ? picuris* are characterized by regularly arranged concentric bands on the anterior slope that differentiates them from *Juresania,* and, to a lesser degree from the type species of *Pulchratia.* In addition, they differ from *Pulchratia* in having a rudimentary antron and long narrow adductor scars in the brachial valve. The generic placement of these species is, therefore, uncertain. (For a comparison of *P. ? pustulosa* with *P. ? picuris* see the discussion of the latter species.)

MATERIAL AND OCCURRENCE—P. ? *pustulosa* is a characteristic species of the *Zia novamexicana* Zone (Morrowan), which occurs in the lower part of the La Pasada Formation in the Santa Fe and Nambe Falls area (fig. 7). About 60 specimens are in our collection, of which 50 come from unit 61-11. Others are from units 41-39, 90-18, and 92-36. Figured specimens: holotype OU 7728, paratypes, OU 7729 to 7732.

Pulchratia? picuris n. sp.

P1. 9, figs. 14-16

Productus Nebrascensis, White (not Owen), 1877, pl. 8, figs. 8c, d. *Pustula nebraskensis,* Mather (not Owen), 1915, p. 169, pl. 9, figs. 6, 7.

DESCRIPTION—The holotype has the following dimensions: length 32.4 mm, width 25.1 mm, height 15.9 mm, surface length 56 mm. Additional measurements are to be found in Appendix 3.

The pedicle valve of a complete shell is distinctly longer than wide; the greatest width is anterior to midlength. The valve is highly convex in the posterior half of the shell, the umbo inflated, and the sides vertical. The umbo is mesially flattened; a sulcus is not developed. Ornamentation on the beak and umbo consists of prostrate spines mounted on elongated nodes that are irregularly and radially oriented. Concentric bands are faintly and irregularly distributed on the umbo, but become more distinct at a surface length of 10 to 20 mm. Band widths are 4 to 5 mm wide at a surface length of 20 to 25 mm but become narrower anteriorly. On each band are 3 distinct rows and sizes of spines, not equally distributed. The posterior half of each band is marked only by large, oblique spines that form a fairly regular row and average about 1 mm apart. The anterior part of each band has 2 rows of progressively smaller sized spines, which are prostrate.

The character of the brachial valve is not well known but its concentric bands are narrower, and its spines smaller, than on the pedicle valve.

The pedicle valve interior is unknown. The brachial valve interior is known from 1 nearly complete (Pl. 9, fig. 16) and 2 incomplete specimens. The internal features appear to be closely similar to those of *P.? pustulosa* except that the cardinal process is comparatively smaller and more steeply inclined dorsally, and the adductor muscle scars, while narrow, are not as elongated.

DISCUSSION—Pulchratia? *picuris* differs from *P.? pustulosa* in being distinctly more elongate, in having much steeper sides to the umbo, in being much more convex, and in having wider and more distinct concentric bands. Also, the spines on the bands are more distinctly distributed in rows. The two are similar in having irregularly distributed spines posteriorly, and the development of distinct concentric bands at midlength and anteriorly. The 2 species occur together in unit 41-39 but *P.? picuris* ranges through most of the Morrowan sequence while *P. ? pustulosa* occurs only in the *Zia novamexicana* Zone.

MATERIAL AND OCCURRENCE—P. ? *picuris* ranges from the lower to the upper part of the New Mexico Morrowan sequence but is most common in the lower part. It is widely distributed geographically in the lower parts of both the La Pasada and Flechado Formations.

About 65 specimens are in our collections but are common only in units 41-47 and 90-14 to 17. Other occurrences are in units 36-38, 41-33, 41-39, 47-19, 60-18, 61-2, 61-6A(?), 65-40, 65-63(?), 90-2(?), 90-7, 92-23 to 27, 92-34. The species has also been observed in undescribed OU collections from the Morrow Series of northeastern Oklahoma. Figured specimens: holotype, OU 7733; paratypes OU 7734, 7735.

Family BUXTONIIDAE
Subfamily BUXTONIINAE
GENUS *BUXTONIA*

Buxtonia grandis n. sp.
P1. 10, figs. 1-8

DESCRIPTION—The shell is large, and is wider than long with the greatest width at or near the hinge. A large specimen has the following dimensions: length 65 mm, width at hinge 84 mm, surface length 95 mm. Most specimens have the cardinal extremities broken, giving the impression of a shorter hinge. Shell measurements are given in Appendix 3.

The pedicle valve has a moderate but decreasing convexity. The beak is well rounded; the umbo is inflated; and the sulcus, which originates about 5 to 10 mm (SL) from the beak, is distinct, narrow and generally shallow. However, specimens from unit 41-42 have sharper, deeper sulci, which are 1 to 1.5 mm deep and about 6 mm wide at 30 mm (SL) (Pl. 10, fig. 7). The ears are not strongly set off, and the valve has no sudden changes in contour. The valve is marked by radial-bifurcating costae. For 7 specimens measured, there are about 7 costae (range from 5 to 9) per 5 mm on the venter at surface lengths of 10, 20, and 30 mm and about 6 costae (range 5 to 7) are present at surface lengths of 40 to 50 mm. New costae are added by bifurcation. On the body of the shell the costae are surmounted at irregular intervals (2 to 8 mm) by spine bases that do not generally show any arrangement into concentric bands. On the trail the spine bases become smaller and are distributed in irregular rows. Concentric rugae are sharp and even on the ears, becoming faint mesially. These rugae are surmounted on the ears by abundant prostrate spines (Pl. 10, fig. 5) more closely spaced than the costae on the body of the shell.

The brachial valve is almost flat. The spines are small and suberect centrally, and become larger, prostrate and irregularly spaced anteriorly. The surface is also marked by numerous pits and closely concentric wrinkles (Pl. 10, fig. 8).

The interior of the brachial valve, known from 4 specimens, has a long, low median septum that extends $^2/_3$ the length of the valve, from the cardinal process to well beyond the muscle area. The median septum is thin except for the 5 mm nearest the process where it is broadened and sculptured by a shallow, obscure, elongated antron. The interior costae are finely pustulose, and become stronger toward the lateral and anterior margins. The muscle platforms, which lie close to the median septum, are low, long, and narrow. The cardinal process has a long shaft. On 2 specimens, it is 7 mm long when measured from the junction with the lateral ridges to the dorsal end of the process. It curves sharply in a dorsal direction, thus lies almost perpendicular to the plane of the shell. Within 4 to 5 mm from the lateral ridges, the shaft is smooth and structureless. However, within approximately 2 mm of the myophore face, the process becomes differentiated into lobes, and the median lobe is grooved and tongue shaped. Although the lateral lobes or flanges curve laterally and follow the contour of the median lobe, the lateral lobes do not meet on the anterior-dorsal side, and thus leave a deep, open-ended, longitudinal groove on that surface (Pl. 10, fig. 4b). Lateral supports for the process consist of sharply defined, raised ridges that follow the hinge.

The shell wall, which is approximately 1.5 to 2 mm thick, is thin for the large size of the shell.

DISCUSSION—Buxtonia *grandis* is a characteristic species of Morrowan strata in the Sangre de Cristo area. It does not compare closely with any other known species of the genus.

MATERIAL AND OCCURRENCE—Buxtonia *grandis* n. sp. occurs in the lower parts of the La Pasada and Flechado Formations, in the lower and middle parts of Morrowan strata. It is widely distributed geographically in the area. We have more than 70 specimens in our collections from the following units: 36-48, 41-33 (type locality), 41-42(cf.), 47-19, 60-18, 60-38, 90-E, 90-7, and 90-14 to 17. This species also occurs in undescribed OU collections from the Morrowan of northeastern Oklahoma and from the Wapanucka Formation of southern Oklahoma. Figured specimens: holotype, OU 7736; paratypes, OU 7737, 7739 to 7742; others, OU 7738, 7743.

Buxtonia n. sp. A
Pl. 10, fig. 10

DESCRIPTION—The specimens described here are crushed and distorted so that accurate measurements cannot be made. They are medium in size and measure about 25 to 30 mm in both length and width. The pedicle valve is marked by numerous elongate spine bases, which only occasionally continue as rough costae. About 8 spine bases occur in 5 mm at the middle part of the crushed specimens.

The brachial valve is almost flat over the visceral disc, being very slightly depressed near the beak. Along the margin of a mature shell, the valve is strongly deflected dorsally. The valve has numerous elongate pits, which are generally shorter and wider than the corresponding ventral nodes. Many suberect spines arise from the elevated parts of the valve; however, near the margins the spines are nearly prostrate.

The interior of the brachial valve has a long, narrow, and low median septum present for about ^{2}A the distance to the edge of the disc. A small, circular antron is present near the base of the cardinal process. The adductor scars are mounted on long, narrow, and low platforms that closely border the median septum. The cardinal process has a long shaft that is slender and slightly deflected dorsally. It is deeply grooved mesially along its entire length. Lateral supports for the process consist of strong, marginal ridges that parallel the hinge line. The margin of the interior surface has low pustules.

DISCUSSION—The available specimens of *Buxtonia* n.

sp. A are too poorly preserved for precise specific identification. A brief description is included because the species has been collected only from the Atokan interval, and represents a different buxtonid shell from either *B. grandis*, from underlying Morrowan rocks, or *B.* n. sp. B from overlying lower Desmoinesian strata. *B.* n. sp. A is distinctly smaller than either and differs from both in having rather discontinuous costae. It also differs from *B. grandis* in having a cardinal process that is not sharply deflected dorsally, and that is deeply grooved mesially along its entire length.

MATERIAL AND OCCURRENCE—B. n. sp. A is represented in our collections by about 25 crushed specimens from Atokan units 62-17 and 18, 62-28 and locality 64. These occurrences are in the lower part of the La Pasada Formation in the Santa Fe Quarries. A specimen from unit 36-79 is possibly the same species. Figured specimen: OU 7744.

Buxtonia n. sp. B
Pl. 10, fig. 9

DESCRIPTION—The shell is large, with the figured specimen having the following dimensions: length 46.5 mm, width 47.5 mm, height 29.3 mm, surface length 80 mm.

The pedicle valve has a strong but decreasing longitudinal curvature. The beak is fairly sharp and strongly enrolled and the lateral slopes are steep. A faint median sulcus arises within 10 mm surface length from the beak. Anteriorly it disappears and the transverse profile consequently becomes quite uniformly convex. The surface of the valve is covered by even costae increasing in number by bifurcation. On the umbo are about 6 costae per 5 mm but this number decreases to about 4 anteriorly. Very low concentric rugae intersect the costae over the entire surface of the valve with the exception of the ears, where the rugae become stronger and more angular. Spine bases occur every 5 to 10 mm along each costa; however, on the anterior portion of the valve, the spines are more abundant and more closely spaced.

The brachial valve is gently concave over most of the visceral disc. Low, broad, and convex ridges are near the posterior margins; a slight mesial fold is also present. Beyond the disc, the shell is gently geniculate. The radial costae are low and the alternating furrows are pitted. Concentric rugae are quite strong, wavy, and more closely spaced than the costae. Scattered erect spines arise mainly on the costae with an average spacing along a given costa of from 2 to 4 mm.

Internal features are unknown.

DISCUSSION—The above description is based on about 10 specimens showing the exteriors only. The material appears to represent a new species, but is inadequate for a proper description. *B.* n. sp. B differs from *B. grandis* n. sp. by having greater convexity, steeper lateral slopes, and coarser, sharper concentric rugae on the ears.

MATERIAL AND OCCURRENCE—B. n. sp. B occurs in the middle part of the La Pasada Formation in the Pecos valley, in the lower and middle Desmoinesian (Fusulinid Zones III and IV) from units 36-133 and 36-150. Figured specimen: OU 7745.

We have collected poorly preserved specimens of *"Buxtonia"* from many of our Desmoinesian strata including units 22-64, 25-54, 29-3 to 10, 36-122, 47-37. 60-228, 60-252, and localities 56 and 78.

Buxtonia? sp. C
Pl. 10, fig. 11

DISCUSSION—Our collection from Missourian rocks contains poorly preserved specimens having surface ornamentation that appear to be similar to the genus *Buxtonia*. Internal features are unknown. Our largest specimen has an estimated length of 35 mm but most of the specimens are smaller and range in length between 25 and 30 mm. Their widths are generally slightly less than the maximum lengths, and the widths of the hinges are, in turn, slightly less than the maximum widths. The ears appear to be small and the cardinal extremities are square.

B. ? sp. C differs from *B.* n. sp. B, which occurs in the middle and lower Desmoinesian rocks, principally in being much smaller in size.

MATERIAL AND OCCURRENCE—We have about 25 specimens of *B.?* sp. C from the middle part of the Alamitos Formation in the Pecos valley area, from Missourian and Virgilian strata. Specimens were collected from units 96-51, 96-57, 97-54 and 97-60. Figured specimen: OU 7746.

Family DICTYOCLOSTIDAE
Subfamily DICTYOCLOSTINAE
GENUS *ANTIQUATONIA*

DISCUSSION—Four species of *Antiquatonia* have been identified from the Pennsylvanian rocks of the southern Sangre de Cristo area: *A. coloradoensis* (Morrowan and lower Atokan), *A. hermosana* (lower and middle Desmoinesian), *A. portlockiana* (upper middle and upper Desmoinesian), *A.* n. sp. A (Missourian). Coarseness of costae increases progressively upward (fig. 24) from an

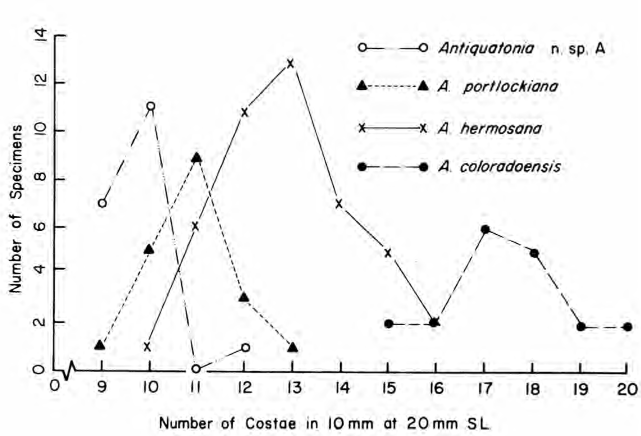


FIGURE *24 Frequency polygons comparing the number of costae per 10 mm measured at a surface length (SL) of 20 mm plotted against the number of specimens for the following species of* Antiquatonia: A. coloradoensis, *Morrowan and lower Atokan (all localities);* A. hermosana, *lower Desmoinesian (unit 93-44);* A. portlockiana, *upper Desmoinesian (all localities); and* A. *n. sp. A, Missourian (all localities). For descriptive statistics see Appendix 2, table 7.*

average of 17.5 in 10 mm at 20 mm surface length in *A. coloradoensis* to an average of 9.7 in 10 mm at 20 mm surface length in *A.* n. sp. A. *A. hermosana* evolved from *A. coloradoensis* (see discussion of latter species), but the two higher occurring species are too inadequately represented to form the basis for phylogenetic conclusions.

The cardinal process in most species of the genus *A ntiquatonia,* when fully developed, is dictyoclostid as described by Muir-Wood and Cooper (1960, p. 27). The median lobe is almost quadrate in outline, and the lateral lobes flare widely. Flaring lobes are late ontogenetic features; however, immature specimens do not have them. Such an ontogenetic progression can be inferred for *A. hermosana.* (Compare figs. 9, immature, and 10, mature, on Pl. 11.) In *A. coloradoensis,* even the largest specimens did not develop the flaring lateral lobes, and the process is small, sessile, rounded, and trilobed.

Antiquatonia coloradoensis **(Girty)**

Pl. 11, figs. 1-5

Productus inflatus, Girty, 1903, p. 359, p1. 3, figs. 1-3 (not McChesney, 1859).
Productus inflatus var. *coloradoensis* Girty, 1910, p. 216.

DISCUSSION—In 1910 Girty proposed the name *Productus in flatus* var. *coloradoensis* for specimens he had described in 1903 (p. 359) as *Productus inflatus* from the basal part of the Hermosa Formation in southwestern Colorado, and from the lower part of the Weber Formation in the Leadville district in central Colorado. He states that this form is closely related to *A. hermosana,* which he described from the middle and upper parts of the Hermosa Formation, but differs in that "as many as 15 or 16 striae occur in the space of 10 mm, while in *Productus semireticulatus* var. *hermosanus* only 9 or 10 are found in the same distance." He states' that some specimens appear to be transitional between the two species.

Our New Mexico specimens from the Morrowan and lower Atokan intervals are closely similar to the Colorado specimens of *A. coloradoensis,* described by Girty, and are distinctly separable from our large collections of *A. hermosana* from Desmoinesian horizons. Girty's observations that *A. hermosana* is less convex, has coarser costae, and is generally larger than *A. coloradoensis* are confirmed. However, there appears to be a gradation upward from typical *A. coloradoensis* in the Morrowan and lower Atokan to typical *A. hermosana* in the lower Desmoinesian. The lower Atokan specimens of *A. coloradoensis* have slightly coarser costae on the average than those in the Morrowan, and the lowest Desmoinesian specimens of *A. hermosana* have finer costae on the average than typical for that species. Although higher in the lower Desmoinesian a few specimens have finer costae approaching those of *A. coloradoensis,* the average specimen is much coarser (fig. 24).

To Girty's description we add the following comments based on specimens from northern New Mexico. The costae are fine and somewhat irregular in size and spacing, primarily because of inconsistent branching or spreading of the costae anterior to the large scattered spine bases. The costae increase in coarseness from the umbonal region to the trail. At 20 mm surface length they average 17.5 in 10 mm (n =19), decreasing to an average of 13.7 at 30 mm (SL) (n =18) and to 13.3 at 40 mm surface length (n=7). Descriptive statistics are given in Appendix 2, table 7.

A single incomplete specimen showing the interior of the pedicle valve (Pl. 11, fig. 5) has dendritic adductor scars beginning 7 to 8 mm from the beak and lacks a median septum in the umbonal region.

There are 10 partial brachial valve interiors. The median septum is broad and low near the cardinal process, but becomes narrow and elevated anteriorly away from the muscle field and extends about $^2/_3$ the way across the visceral disc. The muscle area is broader than long and slightly elevated anteriorly. It is sculptured with an irregular radial dendritic pattern. Fine brachial impressions extend almost to the lateral edge of the visceral disc. Endospines are closely spaced at the geniculation and on the trail. The cardinal process is small, sessile, short, low, and rounded. It has a small median lobe that is medially grooved and curves dorsally, and is flanked by two curved lateral lobes that surround distinct pits. None of our 7 specimens with cardinal processes preserved have the thick secondary deposits that result in flaring lateral lobes.

MATERIAL AND OCCURRENCE—A. *coloradoensis* occurs in northern New Mexico in the Morrowan and lower Atokan parts of the La Pasada and Flechado Formations. It is rare in the Morrowan and is represented in our collections by a total of about 35 specimens from units 36-38, 36-63, 36-68, 41-33, 41-39, 41-42, 41-58, 60-38, 61-11, 90-7, 90-14 to 17 and 92-23 to 27 and locality 68. It occurs commonly in Atokan units 67-13(cf.) and 67-23(cf.), but the costae are coarser than typical. It occurs rarely in the Atokan unit 36-71(cf.). Specimens which probably belong to this species have been found in the Kessler Limestone Member of the Bloyd Formation (Morrowan) in northwest Arkansas. Figured specimens: OU 7751 to 7755.

Antiquatonia hermosana **(Girty)**

Pl. 11, figs. 6-12

Productus semireticulatus var. *hermosanus* Girty, 1903, p. 358, pl. 2, figs. 1-4.
Antiquatonia sp., Muir-Wood and Cooper, 1960, pl. 94, fig. 10, pl. 95, figs. 4, 5.

DISCUSSION—This species is one of the most common in our lower Desmoinesian collections. Girty's original figures show the external characters well; however, he neither described nor figured the internal features. To Girty' s description we add the following comments based primarily on material from lower Desmoinesian unit 93-44. Measurements from figured specimens are given in Appendix 3. The lateral spines characteristic of the genus are well displayed in this species. They arise from a strong wrinkle, which begins as a sharp ridge at the point where the lateral slopes meet the posterior margin. They continue anteriorly near the base of the slopes; the wrinkle broadens and flattens and may not persist onto the trail. The spines increase in size and spacing away from the beak, the last few being the largest spines on the shell. Costae cover the entire shell surface and become slightly coarser anteriorly. For a sample of 45 specimens from unit 93-44 the number of costae in 10 mm at 20 mm surface length averages 12.9 (fig. 24), at 30 mm surface length 12.2 (range 10-14), at 40 mm surface length 11.2 (range 10-13), and at 50 mm surface length 10.6 (range 9-12). Concentric rugae are well developed on the umbo but become obsolete anteriorly. The average surface length to the anterior end of the reticulation on the umbo is 34.2 mm for a sample of 25 specimens.

The interior of the pedicle valve, known from 7 incomplete specimens, shows a strongly raised, elongate pair of adductor scars having grooved dendritic sculpture. Laterally, are large, deep impressions of the diductor attachments, which, in turn, are strongly striate longitudinally. The delthyrial floor and adjacent area is finely but distinctly striate transversely.

The brachial valve, known from 6 incomplete specimens, is uniformly concave, and slightly geniculate. A thin median septum extends nearly to the edge of the visceral disc and separates, in its posterior half, two adductor platforms that are strongly raised, oval in outline and dendritically sculptured. The cardinal process varies in size and character depending upon the size and presumably the age of the shell. Large specimens have much thickening of the shell structures and possess the short-shafted, large, massive, and strongly trilobed process, with flaring lateral lobes, described by Muir-Wood and Cooper (1960, p. 27) as the dictyoclostid type (Pl. 11, fig. 10). Smaller, presumably immature, shells lack the secondary thickening that typifies this type and instead have a process that is small, short, rounded and trilobed (Pl. 11, fig. 9). Lateral ridges diverge from the cardinal process and initially are nearly parallel to the hinge line. Laterally they deflect rather abruptly in an anterior direction as angular ridges, and die out on the lateral flanks.

Girty based his description of *Productus semireticulatus* var. *hermosanus* on specimens from the middle and upper portions of the Hermosa Formation (Desmoinesian) in southwestern Colorado. Our material from any given locality shows considerable variability in the coarseness of the costae; a few specimens in our large collection from unit 93-44 approach the Morrowan species *A. coloradoensis* in having finer costae than typical. Specimens from the lowermost Desmoinesian (unit 36-97) have finer costae on the average than typical and appear to be transitional forms from *A. coloradoensis.* Specimens from the middle Desmoinesian (unit 40-52) have coarser costae than typical and approach in coarseness of costae the upper Desmoinesian species *A. portlockiana.*

MATERIAL AND OCCURRENCE-In the southern Sangre de Cristo area this species occurs abundantly in the upper part of the lower Desmoinesian (Fusulinid Zone III), but ranges in its occurrence from lowermost Desmoinesian (Fusulinid Zone II) to lower middle Desmoinesian (lower part of Fusulinid Zone IV). Our collections include over 275 specimens from units 10-7, 10-11, l0-31(?), 29-3, 29-4, 29-5, 29-8, 36-97(cf.), 36-103, 36-128, 36-133, 36-150, 40-28, 40-52(cf.), 42-27, 67-55, 67-63, 93-44 (abundant), and locality 105. Figured specimens: OU 7756 to 7762.

Antiquatonia portlockiana (Norwood and Pratten) Pl. 11, fig. 13

Dictyoclostus portlockianus, Dunbar and Condra, 1932, p. 215, pl. 33, figs. 1-3.
Antiquatonia portlockiana, Sturgeon and Hoare, p. 46, pl. 11, figs. 8-13.

DISCUSSION-We have examined Dunbar and Condra's figured specimens of *Dictyoclostus portlockianus* and their two figured cotypes of *Dictyoclostus portlockianus* var. *crassicostatus* (1932, pl. 33, figs. 6, 8). Our collections are small and the specimens are not very well preserved but appear to agree closely with those described by Dunbar and Condra as *D. portlockianus.* However, the umbo on some of our specimens is apparently more highly arched and somewhat narrower and the costae on a few specimens are slightly finer. Dunbar and Condra (1932, p. 215) state that " on the middle of the anterior slope the costae normally number about 8 in a space of 1 cm." On our specimens, at surface lengths of 30 mm, the number of costae averages 9. 3 in 10 mm (n=6). Some specimens in our collection approach *A. crassicostata* in developing several very coarse, irregular costae on the anterior slope.

The New Mexico specimens referred in this paper to *A. portlockiana* occur only in the higher Desmoinesian strata and can be readily distinguished from the earlier occurring *A. hermosana*, in being smaller, in having a narrower and more inflated umbo, and in having more irregular, angular, and coarser costae surmounted by more abundant spines. Although there is an overlap in the number of costae in 10 mm measured at 20 mm surface length (fig. 24) the average number is 12.9 in *A. hermosana* compared to 10.9 in *A. portlockiana.*

MATERIAL AND OCCURRENCE-Dunbar and Condra (1932, p. 217) state that in the Midcontinent *D. portlockianus* is characteristic of the Desmoinesian. Sturgeon and Hoare (1968, p. 42), however, record its occurrence in Ohio as ranging from middle or upper Desmoinesian strata to Missourian and possibly into the lower part of the Virgilian sequence. In the Sangre de Cristo area, our specimens occur in the lower part of the Alamitos Formation, in the highest middle Desmoinesian and the lower upper Desmoinesian (upper part of Fusulinid Zone IV or base of Zone V). The species occurs commonly at some localities, but many specimens are crushed. It is found in units 10-57, 10-58, 25-24, 25-27, 25-54, 60-232, 60-252, 60-255 and locality 56. Figured specimen: OU 7763.

Antiquatonia n. sp. A

Pl. 11, figs. 14, 15

DESCRIPTION-The shells are large and attain a maximum length of approximately 43.5 mm and a maximum width of 49.2 mm. Generally, the shells appear to be slightly wider than long, although the trail is commonly broken. The greatest width appears to occur anterior to the hinge, although the hinge, when preserved, closely approaches the greatest width. The pedicle valve is moderately and evenly convex, and the convexity becomes progressively slightly weaker anteriorly. The shells have a broad umbo, and the small beak overhangs the hinge no more than 1 to 2 mm.

The surface of the pedicle valve is ornamented with coarse, bifurcating costae that average 9.7 in 10 mm measured on the venter at 20 mm surface length for 19 specimens measured; and decrease to an average of 8.6 at 40 mm surface length and 8.2 at 50 mm surface length. Concentric ornamentation consists of coarse rugae on the umbo that are approximately the same strength as the costae, consequently producing a strong reticulation. The rugae are commonly present for a distance from 25 to 30 mm surface length. Beyond this, the costae of a few specimens (Pl. 11, fig. 15) become strongly fasciculate and unevenly spaced. Although most of the costae are rounded, a few specimens have costae that are distinctly angular. Spine bases are found scattered over the entire surface. The spines on the umbo are small, erect, and unevenly spaced, occurring approximately 3 to 7 mm apart. Anteriorly and toward the margins, they become larger, less erect, and are spaced from 10 to 14 mm apart. Near the anterior margin, they may become as large as 1 mm in diameter at the base. A row of spines is found on the ridge that delineates the ears. On this ridge, the spines are erect, very small near the beak, and become progressively larger anteriorly.

A broad, shallow sulcus begins within 20 mm surface length, and on the few specimens that are strongly fasciculate, the sulcus tends to be narrow and angular. Such specimens tend to have a sulcus no more than 5 to 10 mm wide at the anterior margin and no deeper than 2 to 3 mm. However, on the less fasciculate specimens, the sulcus is characteristically broad, shallow, and continues onto the trail where it rarely reaches widths of greater than 10 to 15 mm.

Although only 2 well-preserved brachial valves are included in our collection, they indicate that the brachial valve is gently and almost uniformly concave and only slightly geniculate. A gentle fold is present on those specimens that have a sulcus on the pedicle valve. The flat ears are each set off by a small ridge. The brachial valve has a reticulate ornamentation except on the trail; the valve lacks spines. Interiors are lacking.

DISCUSSION—Antiquatonia n. sp. A (Missourian) differs from *A. portlockiana* (middle and upper Desmoinesian, Sangre de Cristo area) in having coarser costae, and in being larger in size, and broader, and in having a less strongly inflated umbo. It is similar in the coarseness of the costae to *A. crassicostata* Dunbar and Condra (1932, pl. 33, figs. 4-8), from the Missourian and Virgilian of Nebraska, but very few of our shells have strongly irregular and raised costae on the trail; the shell is larger and less strongly arched with a broader umbo.

MATERIAL AND OCCURRENCE—*Antiquatonia* n. sp. A occurs in the middle part of the Alamitos Formation in the Pecos River area, in Missourian strata. Our collection includes about 40 specimens; none show the internal features. The species occurs commonly in units 96-30 and 96-40 and rarely in units 96-51 and 97-60. Figured specimens: OU 7764, 7765.

GENUS *TESUQUEA* Sutherland and Harlow, n. gen.

DESCRIPTION—The shell is small to medium in size, and the pedicle valve is strongly convex. The umbo is inflated, rounded, and projects slightly beyond the hinge. The brachial valve is concave and slightly to strongly geniculate. The pedicle valve is ornamented by fine costellae over the whole shell surface and by well-developed, concentric rugae only on the umbo. Erect spines are scattered over the pedicle valve; a single or double arched row of spines is also present on each flank of the umbo but is not related to a wrinkle or ridge. In addition, erect spines may be irregularly distributed near the hinge line, and on some valves these form a distinct row. The costellae on the brachial valve are similar to those on the pedicle valve, but spines are lacking.

The interior of the pedicle valve is unknown. The brachial valve has a trilobate cardinal process that is sessile, small, and has rounded lateral lobes that do not touch dorsally. Ridges extend laterally from near the cardinal process and curve around, inside the ears. Anteriorly to the geniculation is a low ridge or flange that may be continuous with the lateral ridges, although the connection on the lateral slopes is commonly faint.

TYPE *SPECIES—Tesuquea formosa* n. sp., Morrowan, La Pasada Formation, New Mexico.

OCCURRENCE—Lower Pennsylvanian, New Mexico, Oklahoma, Arkansas, Montana.

SPECIES OTHER THAN TYPE SPECIES ASSIGNED TO *GENUS—?Productus morrowensis* Mather, 1915 (Morrowan) northeastern Oklahoma and northwestern Arkansas; *"Marginifera" planocosta* Easton, 1962 (Lower Pennsylvanian) Cameron Creek Formation, Montana.

DISCUSSION—Tesuquea is closely similar to the genus *Antiquatonia* in the presence of an inflated umbo with reticulate ornamentation, steep sides, and the presence of a lateral row of spines on each flank. Externally it differs from that genus only in the smaller size and the lack of any supporting ridge for the lateral rows of spines. Internally, the cardinal process is similar in *Tesuquea* and in smaller species of *Antiquatonia,* such as *A. coloradoensis,* the process being small, sessile, trilobed and rounded in both cases. Internally *Tesuquea* differs from *A ntiquatonia* in the presence of an internal ridge or low flange on the trail of the brachial valve commonly connected to the lateral ridges. The distinct lateral row of spines separates *Tesuquea* from any other genus of the Dictyoclostidae, while the absence of a supporting ridge for the spines reflects considerable difference from *Antiquatonia* in internal pedicle valve structure. The two genera appear to represent collateral evolutionary trends, perhaps descendant from a common ancestor.

Productus morrowensis Mather (1915), from the Morrow Series of Oklahoma and Arkansas, is similar to the type species of *Tesuquea* in major external features. *P. morrowensis* lacks any supporting ridge for the lateral spines. Its internal characteristics are unknown; whether Mather's species has a marginal ridge or flange on the interior of the brachial valve has not been determined.

***Tesuquea formosa* n. sp.**

Pl. 6, figs. 1-11, 17, 18

DESCRIPTION—The shell is small to medium in size, a large specimen having a length of 24 mm, a maximum width of 26 mm and a surface length of 47 mm. Specimen measurements are given in Appendix 3. The shell is oval in umbonal view, and subquadrate when viewed from the trail.

The pedicle valve is strongly convex posteriorly, the umbo is inflated and the beak is arched over the cardinal area. The umbo is transversely flattened, and on some specimens a broad, shallow sulcus up to 1 mm in depth begins on the umbo and extends onto the trail. The shell surface is covered with fine, radiating costellae, which increase mainly by intercalation and maintain an average of about 10 to 10.5 in 5 mm along the venter on the umbo and trail. The umbonal region is reticulate with 16 to 20 concentric rugae that extend anteriorly for an average surface length of 18 to 19 mm (range 16-22, n=24). Erect body spines, which have the width of 1 or 2 costellae, are spaced 2 to 4 mm apart on the umbo and 4 to 8 mm apart on the trail. A single, slightly irregular row of erect spines begins on each side of the beak and continues forward, curving up the side of the umbo and onto the trail. These spines are tiny near the beak and, anteriorly, become as large or larger than the largest body spines. The row tends to be irregular and may be developed for part of its length as an irregular double row (Pl. 6, fig. 6). These spines extend to the anterior margin of the trail on most specimens but are lacking on the most anterior part of the trail on a few specimens. This row of spines is not related to a ridge. The ears bear a few small scattered spines. Adjacent to the hinge line, spines are uncommon, irregular in distribution, and do not form a distinctive row.

The brachial valve is slightly concave on the visceral disc, becomes strongly geniculate, and follows the trail of the pedicle valve. The surface is finely costellate, the costellae being similar to those found on the pedicle valve. Concentric wrinkles are present on the visceral disc, and the valve is spineless but pitted.

By means of studying large specimens that reveal both valves, and by sectioning specimens along the plane of symmetry, the approximate location and dimensions of the body cavity in relation to the exterior features of the pedicle valve can be determined. On the venter of the pedicle valve the anterior end of the body cavity occurs, on the average for 32 specimens measured, at 2.4 mm surface length beyond the last concentric ruga on the venter and at a surface length from the beak of 21.3 mm. The lateral margin of the cavity is located approximately at the most anterior concentric ruga on the lateral flank of the umbo. Such rugae die out on the venter but a growth line projected onto the venter from the last ruga on the flank corresponds on the venter approximately with the end of the body cavity. External measurements of the pedicle valve at the estimated margins of the body cavity, for 32 specimens, average 15.7 mm in length and 20.4 mm in width. For the same specimens the average pedicle valve length is 20.7 mm, width is 23.2 mm, and surface length is 35.0 mm. The thickness of the shell averages 6.9 mm for 8 specimens measured.

Twelve complete or partial brachial interiors show the following characteristics. The median septum is long, low and narrow, and extends from the center of the muscle field to almost the edge of the visceral disc. The median septum is most elevated anteriorly. The adductor muscle platforms are small, distinctly elevated anteriorly, and slope posteriorly. Brachial impressions are low and faint on the one specimen on which they are preserved. The trilobed cardinal process is sessile, short, and stout. The posterior face slopes dorsally and is rounded or heart shaped (Pl. 6, fig. 4a). The median shaft is deeply grooved longitudinally. The lateral lobes curve dorsally around distinct pits on each side of the median lobe; however, the dorsal ends do not touch. The process is supported laterally by stout ridges that parallel the hinge line and are then abruptly deflected to about 30 to 40 degrees from the hinge line at the margins of the ears. At the point of their deflection, the ridges become subangular and curve slightly laterally, setting off the ears from the visceral disc. They continue faintly around the anterolateral part of the valve and are continuous with a broad, low ridge located on the trail, 6 to 8 mm beyond the geniculation. This low ridge has an observed range in width from 1.5 to 3 mm. On some weathered specimens, it has the appearance of a low ridge only a fraction of a millimeter in height, but in thin sections heights of 0.6 and 0.8 mm have been recorded. This raised band is vertically striated and in some specimens has the structure of a flange or prostrate flap or ramp that is deflected anteriorly (fig. 25; Pl. 6, figs. 9, 17 and 18). The interior surface of the trail of the pedicle valve is thickened opposite the flange on the brachial valve, sharply narrowing the space between the two valves along this line (fig. 25)

DISCUSSION—Tesuquea *formosa* n. sp. differs from *"Productus" morrowensis* Mather, from the Morrow Group of northeastern Oklahoma, in being smaller in size and more sharply convex, and in having slightly finer costellae. Internal characteristics of *"P. " morrowensis* are unknown. Preliminary studies of large OU brachiopod collections from the Morrowan of northeastern Oklahoma indicate that both *T. formosa* and *"P. " morrowensis* occur in that area but their stratigraphic distributions have not yet been determined.

T. formosa is similar in size and shape to *"Marginifera" planocosta* Easton, from the Cameron Creek For-

FIGURE *25 Drawing of thin section along plane of symmetry of* Tesuquea formosa *n. sp. showing flange or ridge on interior of brachial valve and corresponding thickening of pedicle valve, x3. Morrowan, unit 90-2.*

mation of Montana. It differs from that species in having finer costellae, about 20 instead of 13 per 10 mm, on the anterior slope. In *"M. " planocosta*, spines are more numerous bordering the hinge line; the spines forming the row on the lateral flanks of the umbo are fewer and more widely spaced, and the internal circumvisceral ridge is not as well developed.

MATERIAL AND OCCURRENCE—Tesuquea *formosa occurs* in the lower part of the La Pasada Formation in the southern Sangre de Cristo area and in the lower part of the Flechado Formation in the Rio Pueblo valley. This species has been found only in the Morrowan part of the sequence, and is widespread in its geographic occurrence. Our specimens come from the following units: 41-27, 41-33, 47-19, 60-18, 60-26, 61-2, 61-6A, 65-40, 90-2 (type locality), 90-14 to 17 and 92-19. In our collections are 125 specimens of which 54 came from units 90-2 and 90-14 to 17.

T. formosa occurs commonly in the Morrowan of northeastern Oklahoma and may possibly occur in the Wapanucka Formation of southern Oklahoma. Figured specimens: holotype OU 7659; paratypes OU 7660, 7662-7669, 7749; other specimens OU 7661, 7750.

GENUS *RETICULATIA*

***Reticulatia* sp. A**

Pl. 13, fig. 13

DESCRIPTION—The shell is very large, our largest specimen having the following dimensions: length 56 mm, width about 65 mm, surface length 90 mm.

The pedicle valve is moderately and evenly convex and a well-developed, broad sulcus begins on the umbo and extends to the anterior margin. Surface features are not well preserved but the umbo has wide, low concentric rugae that extend anteriorly for a surface length of 40 to 50 mm. On 2 specimens, costae number 9 and 10 in 10 mm at a surface length of 50 mm. Hinge line features are not well preserved but a marginal row of spines, characteristic of the genus *Antiquatonia,* is lacking.

The brachial valve is flat on the visceral disc and distinctly geniculate. The body cavity is exceptionally thin for a shell of this size.

DISCUSSION—Moore (1965, p. 497) reports the range of *Reticulatia* to be from Upper Pennsylvanian to Lower Permian. The rather poorly preserved shells described here are from the lower Desmoinesian but seem referable to this genus. They have been compared with Dunbar and Condra's (1932, pl. 34, fig. 4) holotype of *Dictyoclostus americanus,* from the Lower Permian of Nebraska, with which they appear to be congeneric. The New Mexico specimens differ in having a broader, shallower sulcus, wider rugae and lower convexity.

MATERIAL AND OCCURRENCE—This species occurs in the middle part of the La Pasada Formation, in lower Desmoinesian strata (Fusulinid Zone III**).** There are 8 poorly preserved specimens from units 36-133, 42-27, and locality 78(?). A single crushed specimen from the lower part of the middle Desmoinesian (unit 36-150) differs from the specimens described in having coarser, more irregular costae. Figured specimen: OU 7812.

Subfamily HORRIDONIINAE
GENUS *HORRIDONIA*

***Horridonia? daltonensis* n. sp.**

Pl. 11, figs. 16-19

DESCRIPTION—The shell is small. The holotype, one of the largest specimens, has the following dimensions: length 11.2 + mm, hinge width 13.8 mm, surface length 21+ mm. Shell measurements are given in Appendix 3.

The pedicle valve is highly convex, the umbo is broad and inflated but the beak projects only slightly beyond the hinge line. The sides of the umbo are vertical and the triangular ears sharply set off. The greatest width is at the hinge but the ears are broken off on many specimens. The umbo and anterior slope are flattened and about one-third of the specimens have a faint to shallow sulcus that begins at a surface length of 5 to 7 mm and extends to the anterior margin. The surface ornamentation is more or less smooth but consists in detail of a fine granular texture and is not lamellose. Occasional constrictions along growth lines give the shell an irregularly banded surface. Faintly developed, coarse, rounded costae can be seen on the anterior slope of a few specimens. They number 9 to 11 in 5 mm at surface lengths of 12 to 15 mm. Large erect spines have the following distribution: 1) a few irregularly distributed near the hinge line and on the ears but not forming a consistent row, 2) an arched, widely spaced row beginning near the beak and continuing along the lower flank of the umbo, with a progressive increase in the size of the spines, and 3) rarely scattered over other parts of the valve. In addition, the surface has scattered pustules of varying sizes that do not appear to be the result of later alteration.

The brachial valve is gently concave and faintly geniculate. Spine bases have been observed only adjacent to the hinge line. These spine bases are scattered and do not appear to be present on all specimens. The surface is smooth to finely granular, except for irregularly spaced growth constrictions that are more closely spaced than on the pedicle valve. Small pustules of varying sizes are scattered over the surface.

The pedicle interior is known from a single fragment that shows an elongated, elevated adductor muscle platform. Three complete specimens cut along the plane of symmetry show a thickening of the pedicle valve on the trail.

The brachial interior is known from 2 poorly preserved specimens. The cardinal process is broad, short, bilobed anteriorly and trilobed posteriorly. A thin, narrow, median septum extends from the base of the process forward past midlength. Anteriorly are large pustules. The muscle scars are not well preserved. Three complete specimens sectioned along the plane of symmetry confirm that a marginal ridge is not present.

DISCUSSION—The small species described here probably represents a new genus but doubtless it belongs in the subfamily Horridoniinae and is closely related to the Permian genus *Horridonia.* Similarities are: the unusual smooth to granular shell surface, the presence of large erect spines scattered over the pedicle valve, the presence of faint, coarse costae anteriorly on some specimens, and the lack of spines on the brachial valve except adjacent to the hinge. The internal features of *H. ? daltonensis* are not well known but do not appear to differ significantly from *Horridonia.* The cardinal process, in particular, is similar. Our species differs from *Horridonia horrida,* the type species, as redescribed by Gobbett (1961, p. 43), from the Permian of England, in being of much smaller size and in having a more inflated umbo with almost vertical sides and a short nonprotruding beak, and in lacking consistently developed cardinal spines on both valves.

Moore (1965, p. 498) gives the range of the genus *Horridonia* and the subfamily Horridoniinae as being Lower to Upper Permian. Logan (1966, p. 199), makes reference to a horridonid brachiopod from the Upper Carboniferous of Russia, and Nelson and Johnson (1968, p. 723) describe as a new genus, *Baillaena,* a horridonid brachiopod of uncertain age but believed to be from the Middle or Upper Pennsylvanian or Lower Permian. *Horridonia? daltonensis* is possibly the earliest member yet reported for this subfamily.

MATERIAL AND OCCURRENCE-Our collection includes about 40 specimens, with both valves preserved to a somewhat greater or lesser degree. All are from unit 36-133, which occurs in the middle part of the La Pasada Formation. This horizon is early Desmoinesian in age (Fusulinid Zone III). Figured specimens: holotype OU 7766; paratypes OU 7767 to 7769.

Family LINOPRODUCTIDAE
Subfamily LINOPRODUCTINAE

GENUS *LINOPRODUCTUS*

Linoproductus nodosus (Newberry)
Pl. 12, figs. 1-6

Productus nodosus Newberry, 1861, p. 124, pl. 1, figs, 7, 7a-b; 1876b, p. 140, pl. 3, figs. 3, 3a-c; Price, 1916, p. 699, pl. 30, figs. 9-11. *Productus gallowayi* Morgan, 1924, p. 184, pl. 44, figs. 1, la. *Linoproductus nodosus,* Plummer, 1950, pl. 11, fig. 13.

> ORIGINAL DESCRIPTION-(Newberry, 1861, p. 124). Shell of medium size, strongly revolute; antero-posterior diameter less than its breadth; beak pointed, extending slightly beyond the cardinal border; wings very small, much plaited, like the entire surface of the ventral valve, covered with numerous fine, distinct and uniform thread-like striae; ventral valve without sinus, but the mesial line is marked by a row of large and remote nodes, which extend from the beak to the anterior margin, and toward which the contiguous striae converge. The striae are scarcely more numerous on the anterior border than on the beak; a few are introduced without bifurcation, but the increased space is covered by a gradual enlargement of the striae and a widening of the space between them. Visceral region arched and without reticulation; entire surface spineless, unless the nodes of the mesial lines are the basis of large spines. Dorsal valve striated like the ventral, often without nodes or spines. Antero-posterior diameter 1.08; breadth 1.50.
>
> This beautiful species has some resemblance in form and markings to *P. Cora,* to *P. Altonensis,* N. & P., and to *P. Hildrethianus,* N. & P., and may be grouped with them; but by the entire absence of spines, the parallel and uniform striae, and paticularly by the row of nodes along the mesial line, it is distinctly separated from all known species.
>
> Locality and formation-Limestone of Carboniferous age; Santa Fe, New Mexico.
>
> SUBSEQUENT DESCRIPTION-(Newberry, 1876b, p. 140). This fine *Productus,* first collected on a former expedition, and described in my report to Lieutenant Ives (Colorado Expedition, Geology, p. 124, plate 1, figs. 7-7b), we found in large numbers at Santa Fe, and in many localities along our route quite to the Colorado. Indeed it is perhaps as common as any other species of the genus in Western New Mexico and Southern Utah.
>
> The figures now given of it will convey a much better impression of its true character than those before published. From these it will be seen that, with a near approach in form and markings to *P. cora* and *P. aequicostatus,* it is distinguished from these and other species by the single line of conspicuous nodes, the bases of large spines, which mark the median line of the ventral valve. In some specimens a corresponding line of tubercles marks the dorsal valve; but they are always less distinctly marked and are often entirely wanting.
>
> Figures 3c and 3d show a somewhat remarkable variation in the length of the cardinal border, but the wings are usually quite short, as in figures 3b and 3c.

DISCUSSION-Our study of *Linoproductus nodosus* from the Santa Fe area agrees with most of the detail of Newberry's (1861, p. 124) original description given above; the identity of this distinctive species is not doubted. Most specimens have the fragile ears broken off thus accounting for his error in stating "wings very small."

Newberry's (1861, pl. 1, figs. 7, 7a-b) poor original illustrations are of a specimen with a much broader umbo than is characteristic for this species. In 1876 (1876b, pl. 3, figs. 3, 3a-c), he figured additional specimens that illustrate the narrower, rounded umbo found on most of the specimens in our collections.

Newberry's figured specimens are lost. Sutherland made a careful search, during July, 1967, in the collections of both the U.S. National Museum and the U.S. Geological Survey in Washington, D.C., and did not find any of the specimens figured by Newberry in 1861 and 1876. His figured specimens were never cataloged into the USNM collection (G. A. Cooper, personal communication). Newberry listed his figured specimens as being only from " Santa Fe, New Mexico." However, he (1876a, p. 43-45) gives 2 stratigraphic sections that list the occurrence of *L. nodosus:* No. 1, "in the hills immediately back of Santa Fe" and No. 2, "in the gorge of the Santa Fe River." (See our discussion of early surveys in the Santa Fe area.) Newberry' s locality No. 2, almost certainly close to our measured section 90, is the only locality known to us where *L. nodosus* occurs commonly. About 75 specimens of this species are in our collection, mostly from unit 90-7. We consider specimens from that unit to be topotypes, and we designate one the neotype (Pl. 12, fig. 5).

Our specimens of *L. nodosus,* particularly from unit 90-7, have the following characters. Near the beak, the pedicle valve is strongly convex, decreasing uniformly anteriorly. The umbo is most commonly narrow and not inflated. A few specimens have a broader, flatter umbo; a sulcus is not developed. Its lateral slopes are gently and distinctly set off from the ears, which are flat, medium sized, triangular and commonly broken off. The length of the hinge line is less than the greatest width of the shell. Only 1 or 2 large specimens are complete enough to show the flaring trail illustrated by Newberry (1876b, pl. 3, fig. 3). The valve surface is covered with very regular, fine radiating costellae, which increase in number by intercalation. The average number of costellae is 15.1 per 5 mm at 10 mm surface length for 12 specimens measured and 12.0 per 5 mm at 20 mm surface length for 8 specimens measured. The median line has a row of large erect spine bases up to 1 mm in diameter, toward which the adjacent costellae distinctly converge (Pl. 12, fig. 3a). The spines are closely spaced near the beak but the distance between spines progressively increases anteriorly; some specimens do not have spines on the trail. Near the beak the spines are 1 to 2 mm apart. Away from the beak much variation is observed in spine spacing between individual specimens with 8 mm being the least and 13 mm the greatest distance between successive spines observed at surface lengths of about 30 to 40 mm. The greatest number of spines observed is 12, but more commonly 8 to 10. On most specimens the medial row of spines is almost straight, but on a few this row is more irregular with one or more spines out of line or tending to a low zig-zag pattern. The few specimens that have the hinge line preserved show a row of vertical or oblique spines along the hinge. Most specimens lack spines on parts of the shell other than along the hinge and medial line, but a small number have an additional few small spines scattered over the remainder of the surface.

The nongeniculate brachial valve is gently concave on the visceral disc, and curves more sharply on the trail. The ears are strongly wrinkled and the strongest ones pass around the entire valve. Costellae are similar to those seen on the pedicle valve and spines are lacking. A row of faint pits may be present along the plane of the symmetry (Pl. 12, fig. 4), corresponding to the spines on the pedicle valve. Internally, the muscle scars are inconspicuous; the median septum is low and narrow but long, and posteriorly thickens to a low platform that is faintly striated transversely. A row of faint nodes along the median line may be present. The cardinal process is small for the size of the shell, being very short shafted and trilobed. The median lobe is deeply sulcate, and the lateral lobes curve anteriorly close to the median lobe.

Accurate measurements of *L. nodosus* are difficult to obtain because parts of the trail and ears are broken off from most specimens. A large specimen has the following dimensions: length 37 mm, surface length 60 mm, maximum width 36 mm, and incomplete hinge length 25 mm. A specimen with a length of 32 + mm and surface length of 50 + was sectioned along the plane of symmetry. It has a body cavity length of about 20 to 21 mm and a shell height of 6 mm.

Easton (1962, p. 50) described, as an unnamed subspecies of *L. nodosus*, specimens from Montana that have a more erratic distribution of spine bases on the pedicle valve than is typical for the species. He states: "A few (1 to perhaps 5) extremely stout spine bases occur on the front half of the shell. Some specimens have 1 to 3 large spine bases lying along or near the midline, but others have an isolated excentrically located spine base or have as many as 5 spine bases scattered around the surface asymmetrically." Specimens from the type locality of *L. nodosus* in New Mexico most commonly lack spine bases on the front half of the shell except for 1 or 2 along the medial line. The Montana specimens come from the Heath, Cameron Creek, and Alaska Bench Formations, apparently ranging from Late Mississippian to possibly Atokan.

MATERIAL AND OCCURRENCE—L. *nodosus* occurs in the lower part of the La Pasada and Flechado Formations in Morrowan strata. The species has been collected from units 36-38, 41-27, 41-29, 41-33, 41-39, 41-47(?), 47-19, 60-33(?), 60-38(?), 61-2, 61-6A, 65-40, 65-63, 90-2, 90-7, 90-14 to 17, 92-19, 92-23 to 27, and 92-34. It occurs commonly in units 90-2 and 92-23 to 27 but abundantly only in unit 90-7 where we collected more than 70 of the 110 specimens from all localities in our collection. Unit 90-7 is possibly close to Newberry's (1876a, p. 45) Section No. 2 and is hereby designated the type locality. Our specimens from there are considered topotypes.

L. nodosus is widely distributed in rocks of Morrowan age. It occurs uncommonly in the upper part of the Morrow Group in northeastern Oklahoma and northwestern Arkansas and has been figured by Plummer (1950, pl. 11, fig. 13) from the lower part of the Marble Falls Formation in central Texas. Morgan (1924, p. 184) gave a new species name, *Productus gallowayi*, to specimens of this species from the Wapanucka Formation (Morrowan) in southern Oklahoma. Price (1916, p. 699) records the species from the Dingess Limestone (Pottsville Series) in West Virginia. Figured specimens: neotype OU 7770; topotypes OU 7771 to 7773.

Linoproductus devargasi **n. sp.**

Pl. 12, figs. 7-11

DESCRIPTION—The medium-sized shell is distinctly elongated, and the largest shells attain lengths of greater than 50 mm, with maximum widths, which occur near the midlength of more than 40 mm. The hinge line is shorter than the greatest width. The body chamber is exceptionally thin for the size, and thicknesses do not exceed about 7 to 8 mm. Shell measurements are given in Appendix 3.

The pedicle valve has a very low convexity for the genus. The beak is low and obscure and protrudes little if any beyond the hinge line. The umbo is only slightly swollen. In longitudinal profile, the shell has a low and even curvature. However, in transverse section, a slightly greater variation in the degree of curvature is seen. Some shells are almost flat while others have moderately inclined lateral slopes anterior to the ears. There is no flattening in the umbonal or mid-shell region. The ears are flat with small wrinkles near the posterior margin. The wrinkles become obscure anteriorly. The costellae are fine and increase in number by intercalation, and the coarseness increases very slightly with growth. For 6 specimens the costellae average 12 per 5 mm at 10 mm surface length, 11.7 per 5 mm at 20 mm surface length, 10.9 per 5 mm at 30 mm surface length and 10.3 per 5 mm at 40 mm surface length. Spines are absent except along the posterior margin where a single row of coarse spines, numbering about 5 or 6 on each flank and spaced a maximum of 1 mm apart, are deflected at an angle of about 30 degrees from the hinge line (Pl. 12, fig. 7c).

The brachial valve is gently and regularly concave except for flatness at the ears. The costellae are fine and similar in character to those on the pedicle valve. Concentric wrinkles are obscure except near the posterior margin.

Our collections include 5 incomplete brachial interiors. The cardinal process is exceptionally small for the size of the shell, is extremely short shafted, narrow, low and of the linoproductid type. The process is supported by stout ridges that diverge from the posterior margin at approximately 30 degrees. The ridge broadens and disappears before reaching the lateral margin but sets off broad, flat ears. A few millimeters in front of the process, a low, flat-topped median ridge arises, then thins gradually to form a low, sharp septum that continues about half way to the anterior margin. Muscle scars are not well preserved but appear to be small, low, elongated and longitudinally grooved.

DISCUSSION-Linoproductus devargasi is characterized by extremely low convexity with a resulting thinness of the body chamber, fine costellae, no body spines, and a row of large, oblique spines on the posterior margin. This species differs from any known to us and possibly represents a new genus. The lack of well-preserved interiors makes adequate evaluation impossible at this time.

MATERIAL AND OCCURRENCE-This species has been found to occur commonly only in unit 61-11, Santa Fe Quarries, from which there are about 25 specimens in our collection. One specimen comes from unit 41-39 at Nambe Falls. Both localities are Morrowan and occur in the lower part of the La Pasada Formation. The species is restricted to the *Zia novamexicana* Zone. Figured specimens: holotype OU 7774; paratypes OU 7775 to 7778.

Linoproductus planiventralis Hoare

Pl. 12, fig. 12; Pl. 13, figs. 14, 15

Linoproductus planiventralis Hoare, 1960, p. 228, pl. 32, figs. 1-3; 1961, p. 66, pl. 8, figs. 7-9: Sturgeon and Hoare, 1968, p. 50, pl. 17, fig. 13.

?Linoproductus echinatus Hoare, 1960, p. 228, pl. 33, figs. 15-19; 1961, p. 67, pl. 8, figs. 10-14.

DESCRIPTION-(Based on New Mexico specimens.) The medium-sized shell attains a maximum length of 40 to 50 mm and a maximum width of 35 to 40 mm. The convexity of the pedicle valve is strong and uniformly decreases. The umbo is inflated and well demarked by steep lateral slopes. The beak is blunt and the umbo is fairly broad and flattened at its crest, or depressed into a low, rounded sulcus that does not commonly persist onto the trail. An anterior fold is not indicated. The surface is marked by even, fine costellae that arise by intercalation. The number of costellae in 5 mm is variable but generally decreases slightly away from the beak. For 20 specimens measured there is an average of 10.7 costellae in 5 mm at 10 mm surface length, 9.1 at 20 mm, 8.5 at 30 mm, 8.4 at 40 mm and 7.7 at 50 mm. Strong and coarse concentric wrinkles are present on the ears but persist only faintly onto the lateral slopes. Within a single collection the number of body spines may vary from a few to many. Some collections have a predominance of spiny or nonspiny forms. Unfortunately the surfaces are not preserved well enough to make accurate spine counts. The spines on the posterior margin are small and arranged irregularly in a single row or several rows.

The concave brachial valve has a small visceral disc, and the gentle geniculation is marked by 2 or 3 strong concentric wrinkles. The living chamber is relatively thin. In a specimen in which this cavity is 24 mm in length, the thickness of the shell is 5.5 mm.

The interior of the brachial valve appears to be characteristic of the genus. The cardinal process has not been observed, but its supports are strong ridges that diverge in gentle curves from the posterior margin.

DISCUSSION-Hoare (1960, p. 228) based his description of *Linoproductus planiventralis* on an unstated but apparently small number of specimens from the Sevelle Limestone (lower Desmoinesian, Krebs Group) in southwestern Missouri. His type locality is also the type locality for a second species, *L. echinatus* that differs only in being somewhat more spiny. Probably the two represent the extremes of one highly variable species because in some of our collections the two types occur together and appear to intergrade. At other localities one or the other type is more common. Most of the New Mexico specimens described here appear to compare closely with Hoare's species with the exception that some specimens have a broad, shallow sulcus developed on the umbo.

L. planiventralis differs from *L. magnispinus* Dunbar and Condra, that occurs in the Virgilian strata of Nebraska and adjacent areas, in having distinctly smaller body spines. *L. planiventralis* may be the form reported by Dunbar and Condra (1932, p. 245) from the Pawnee Limestone (Desmoinesian) of Oklahoma.

MATERIAL AND OCCURRENCE-Sturgeon and Hoare (1968, p. 50) report the occurrence of this species to be from Atokan to middle Desmoinesian strata in Ohio. In the Sangre de Cristo area, it occurs most commonly in the lower Desmoinesian but ranges from the Atokan, where the species is rare and the spinier forms tend to predominate, to the middle Desmoinesian. In our collections are 35 specimens from Atokan units 36-79 and 62-17 and 18. We have over 100 specimens from lower and middle Desmoinesian units 10-7, 10-19, 22-64, 29-3 to 5, 29-10, 36-109, 36-133, 36-150, 40-52, 42-15, 60-l24(?), 93-44 and localities 78 and 105. It occurs most commonly in unit 22-64. Figured specimens: OU 7779 to 7781.

Linoproductus cf. *L. platyumbonus* Dunbar and Condra

Pl. 13, figs. 16, 17

Linoproductus platyumbonus Dunbar and Condra, 1932, p. 254, pl. 31, figs. 1-5.

DISCUSSION-Dunbar and Condra (1932, p. 254) state that *L. platyumbonus*, from the Missourian of Missouri, is characterized by a pronounced mesial flattening over the ventral umbo, by the development of a fold on the anterior margin of the trail, and by the sparseness of spines. They did not describe the internal features of the species; we do not have interiors in our collections.

Our shells are large, the largest attaining a length of about 67 mm and a surface length of 93 mm. On most specimens the broad, shallow sulcus begins at approximately 15 mm surface length and continues for an additional 20 to 30 mm surface length as either a distinct flattening of the venter or as a very shallow sulcus. The development of a slight mesial fold on the trail of the pedicle valve occurs in several of our larger specimens at a surface length of 50 to 70 mm. Dunbar and Condra state that the hinge line is apparently equal to the greatest shell width; on some of our specimens the greatest width possibly lies anterior to the hinge line because of the distinct flaring of the trail and lateral slopes. This flaring is directed dorsally as well as anteriorly, causing the pedicle valve to be highly arched in cross section at midlength. The shell is longer than wide with the trail, accounting for approximately $^1/_2$ of the total length. The ears were apparently large and had 4 or 5 strong wrinkles that die out anteriorly. A row of small spines is found near the hinge line, but there are very few spines on the body of the shell. The shell surface is covered with fine costellae that average 8 to 10 per 5 mm over the anterior slopes. Anteriorly the trail is characterized by very irregular shell repair, and the costellae tend to converge and overlap irregularly.

MATERIAL AND OCCURRENCE—Dunbar and Condra (1932, p. 255) state that this species is apparently confined to the Kansas City and Lansing Groups (Missourian) in the Midcontinent. Our New Mexico specimens, which number 23, come only from unit 96-51, which is also Missourian. Figured specimens: OU 7782, 7783.

Linoproductus pumilus n. sp.

Pl. 13, figs. 7-12

DESCRIPTION—The shell is very small and globular. Most specimens measure about 10 mm in both length and width, with the largest specimen being 12.8 mm long and 12.2 mm wide. Specimen measurements are given in Appendix 3.

The pedicle valve is strongly but decreasingly convex anteriorly, and not geniculate. The transverse profile is strongly convex; the lateral slopes are straight and steep. The hinge length is slightly less than the maximum width, and the anterior margin is circular. Posteriorly, the ears are well defined, and the surface is covered by fine and generally even capillae that increase by intercalation. These capillae are occasionally flexuous. On the anterior slope is an average of 19.7 capillae per 5 mm in the venter, measured at 10 mm surface length. They are gently rounded and separated by sharp but shallow grooves. The ears bear a few strong wrinkles that are perpendicular to the posterior margin, and disappear or become weak on the lateral slopes. Each ear bears approximately 5 to 7 stout erect spines that are irregularly distributed in 2 or 3 rows. On the body, spines that were apparently erect, are scattered 3 to 4 mm apart. Brachial molds indicate that a small depression or cicatrix of attachment is present at the pedicle beak.

The brachial valve is moderately and uniformly concave over the visceral disc, and gently geniculate beyond. Capillae and wrinkles are similar to those found on the pedicle valve, except that the latter may persist to the median portion of the shell. Spines have not been observed. A prominent but small, round bump at the beak is the counterpart of the attachment depression of the pedicle valve. Internal characters are unknown.

DISCUSSION—Linoproductus pumilus appears to be most closely similar to *Linoproductus? duodenarius* Easton from the Otter, Heath, Cameron Creek, and Alaska Bench Formations in Montana (Late Mississippian to Early Pennsylvanian). It differs from that species in being smaller in size and in having much finer capillae. Our specimens average 19.7 capillae in 5 mm at a surface length of 10 mm (n =14). The Montana species averages 12 in 5 mm, presumably on the anterior slope. Also, our species is much more sharply convex.

MATERIAL AND OCCURRENCE—L. *pumilus* has been found only at unit 22-41, in the lower part of the La Pasada Formation, from which we have 45 specimens. This locality is either late Morrowan or early Atokan. This species may be included among poorly preserved specimens in the OU collection from the Morrow Group of northeastern Oklahoma. Figured specimens: holotype 7784; paratypes OU 7785 to 7789.

GENUS *ZIA* Sutherland and Harlow, n. gen.

DESCRIPTION—The shell is wider than long, with the greatest length at or near the hinge. The pedicle valve has a flattened visceral disc, is geniculated and lacks a sulcus. Its lateral slopes are not steep. Its surface is marked by costellae that may become irregular or faint on the trail. Low rugae cover the visceral area only, giving the shell a distinct reticulation. Prostrate or oblique spines are scattered over the entire pedicle valve surface. The brachial valve is concave and geniculated and has a short trail. Surface ornamentation compares with the pedicle valve except spines are lacking.

The interior of the pedicle valve has elongated, raised adductor muscle platforms and large triangular-shaped, longitudinally striated diductor scars.

The brachial valve interior has a small, sessile, posteriorly trilobed cardinal process on which the lateral lobes curve dorsally, uniting with the median lobe. The lateral ridges diverge from the hinge margin, curve inside the ears but do not extend onto the trail. The adductor scars are dendritic and elevated on rounded platforms that are posteriorly placed on each side of a median septum.

TYPE SPECIES—Zia *novamexicana,* n. sp., Morrowan, La Pasada Formation, New Mexico.

OCCURRENCE—Known from the Lower Pennsylvanian (Morrowan), New Mexico and northwestern Arkansas.

DISCUSSION—The classification of the genus *Zia* is not clear. It has been placed in the Family Linoproductidae because of the character of the interior of its brachial valve, particularly the presence of a linoproductid type cardinal process. It differs from most members of this family in having a distinctly reticulated posterior area on the pedicle valve that also has very low convexity bordered by a distinct geniculation.

In having a geniculated pedicle valve of low convexity, *Zia* is similar to the Lower Mississippian genus *Marginirugus*, which differs in having a large trilobed cardinal process, obscure reticulation and much smaller spines except along the hinge. The Mississippian genus *Striatifera* also has low convexity of the pedicle valve but is much elongated, is narrow at the hinge, and has a one-lobed cardinal process.

Zia novamexicana n. sp.

Pl. 13, figs. 1-6

DESCRIPTION—The shell is medium size. One of the larger specimens has the following dimensions: length 30.0 mm, surface length 53 mm, width 36.0 mm, thickness 13.8 mm. Shell measurements are given in Appendix 3.

The pedicle valve is wider than long with the greatest width at or near the hinge line. Many specimens have the cardinal extremities broken, giving the false impression of a short hinge. The umbo has low convexity and on most specimens the beak shows little posterior protrusion over the hinge line. The flanks of the umbo are not strongly set off from the ears. The shell shows 2 distinct changes in anterior to posterior growth gradient. After an early linear stage in which the umbo develops a low convexity, there is a progressive reduction in the vertical growth component relative to the anterior growth component, giving an almost flattened surface across most of the reticulated part of the shell surface. This flattening is followed by a reversal with an increase in the vertical growth component, and a reduction of the anterior component giving a gentle geniculation of the shell. A sulcus is lacking. The umbo is reticulated because of low concentric rugae that end approximately at the geniculation at surface lengths of 25 to 30 mm. These irregular rugae number about 10 to 12 in the 10 mm interval from 20 to 30 mm surface length. On the trail, transverse markings consist of evenly spaced growth lamellae. Costellae increase slightly in coarseness with growth. At 10 mm surface length they average 10.5 mm (n= 4); at 20 mm surface length, 9.4 per 5 mm (n= 7); and at 30 mm surface length, 8.7 per 5 mm (n =6). On the trail the costellae become faint and unequal in strength. Anterior to large spine bases, some costellae become irregularly enlarged. A row of medium-sized laterally oblique spines occur along the hinge margin and a single larger spine projects laterally from each ear. On the reticulated area are numerous bases of medium-sized, oblique spines arising from the costellae and having the same width as the costellae. These spines are mostly 3 to 4 mm apart but become more closely spaced towards the posterior margins. On the area beyond the reticulation the spine bases are large in size, nearly erect, and spaced about 5 mm apart.

The brachial valve is nearly flat over the visceral disc, being gently geniculate beyond. Costellae are similar to those on the pedicle valve but spines are lacking.

The interior of the pedicle valve is known from 2 well-preserved and 2 poorly preserved internal molds. The adductor scars are distinctly elevated, elongated and separated by a narrow groove. The diductors are large, triangular, and longitudinally striated. They extend anteriorly about 1/2 the distance to the geniculation, and past the anterior ends of the adductor platforms. They are bounded laterally by broad, rounded ridges.

The interior of the brachial valve is known from 4 internal molds and 2 incomplete specimens. The cardinal process is of the linoproductid type, being small, rounded, sessile and trilobed on the myophore face where the lateral lobes join the median lobe. The process is continuous with a broad, low, rounded median septum that becomes thin and obscure anterior to the muscle field, and disappears at about I/2 the length of the visceral disc. The adductor scars are compact, rounded and posteriorly placed near the lateral ridges but separated from the median septum by shallow grooves. The adductor scars are marked by a distinct dendritic pattern. Brachial supports are not preserved. Lateral ridges diverge from the posterior margin and cross the ears as distinct, broad, rounded ridges, setting off thin, triangular ears that are commonly broken off. The lateral ridges do not continue onto the anterior part of the shell. Endospines are apparently lacking.

DISCUSSION—No previously described species is closely similar to *Zia novamexicana.*

MATERIAL AND OCCURRENCE—*Zia novamexicana* has been found in Morrowan rocks in the lower part of the La Pasada Formation, in the Santa Fe, Nambe Falls, and Pecos valley areas. It appears to be restricted to a single stratigraphic horizon throughout this area, here termed the *Zia novamexicana* Zone. It is associated in this area with 2 additional productid species that occur only at this horizon: *Linoproductus devargasi* n. sp. and *Pulchratia? pustulosa* n. sp. About 60 specimens are in our collections, of which 50 come from the type unit, 61-11. Other occurrences are units 36-56, 41-39, and 90-18. Z. *novamexicana* also occurs in the Kessler Limestone Member, in the upper part of the Bloyd Formation (Morrowan) in northwestern Arkansas. Figured specimens: holotype OU 7790; paratypes OU 7791 to 7795.

Order RHYNCHONELLIDA
Superfamily RHYNCHONELLACEA
Family CAMAROTOECHIIDAE
Subfamily CAMAROTOECHIINAE
GENUS *LEIORHYNCHOIDEA*

Leiorhynchoidea? rockymontana (Marcou)

Pl. 13, figs. 18-21

Terebratula rocky-montana Marcou, 1858, p. 50, pl. 6, figs. 13, 13a-c. ? *Pugnax rockymontana,* Girty, 1915a, p. 83, pl. 10, figs. 13, 14, 14a-b. ? *Leiorhynchus rockymontanus,* Dunbar and Condra, pl. 37, figs. 23-26.

> ORIGINAL DESCRIPTION—(Marcou, 1858, p. 50.) Shell reniform, sub-triangular, depressed convex; beak sharp and pointed; sinus very wide and shallow, furnished with two or three longitudinal ridges; no lateral ribs. Surface smooth.
>
> I met with but two imperfect specimens that appear to have been laterally compressed. Pecos village, New Mexico, where it is found in company with the *Prod. semi-reticulatus* and the *Ter. subtilita.*

DISCUSSION—Marcou based his species on 2 partly crushed specimens now in the collection of the British Museum, Natural History. Sutherland has examined these specimens. Also, the museum has provided excellent casts here illustrated along with photographs of Marcou's drawings. Meaningful measurements cannot be taken because of the distorted nature of the specimens. One, compressed laterally, is 22.0 mm in length with an estimated width of 20 mm (P1. 13, fig. 18). The other, more badly distorted, is 18 + mm in length and 22 mm in width. Each is smooth on the flanks and has 3 plications on the fold of the brachial valve. One has 2 plications in the sulcus but the other has 3, the third being more faint than the other 2 (Pl. 13, fig. 20). The depth of the sulcus and the thickness and height of the shell cannot be determined. Internal characters are unknown so the generic assignment is uncertain.

Marcou's species name has been widely used by many authors. However, the commonly used concept of the species is based not on Marcou's specimens and description but on a description by Girty (1915a, p. 83) of specimens from the Wewoka Formation (upper Desmoinesian) in Oklahoma. In fact, Dunbar and Condra (1932, p. 285) incorrectly give as "Original Description" for the species not Marcou's description but that by Girty. In the Midcontinent specimens referred to this species have most commonly come from the Desmoinesian but Dunbar and Condra (1932, p. 286) also report occurrences in the Missourian and Virgilian.

Leiorhynchoidea? rockymontana is the type species for the new genus *Corrugatimediorostrum* proposed by Sartenaer (1970, p. 23). We reject the use of this generic name unless valid uncrushed topotypes could be collected to determine the internal character of the type species.

MATERIAL AND OCCURRENCE—Marcou gave the locality for the 2 specimens on which he based this species as "Pecos village." For an interpretation of this locality, see our discussion of Marcou's 1853 Survey. The specimens most probably came from exposure near the Pecos River, at the sharp bend in the river about 0.7 mile west-northwest of measured section 98 (fig. 4), and are from the Virgilian. We did not find specimens of this species along the long bluff at measured section 98. Specimens from Desmoinesian, Missourian, and Virgilian localities from throughout the continent have been referred to this species. Figured specimens: lectotype herein chosen, BMNH B79165 (plastotype OU 7796); paratype BMNH B79166 (plastotype OU 7797).

Family WELLERELLIDAE
Subfamily WELLERELLINAE
GENUS *WELLERELLA*

Wellerella immatura Dunbar and Condra
P1. 14, figs. 1-4

Welleralla osagensis var. *immatura* Dunbar and Condra, 1932, p. 290.

DISCUSSION—Dunbar and Condra (1932) describe specimens of *Wellerella osagensis* from the lower part of the Virgil Series in Nebraska, as typically 10 mm in length and 10 mm in width. From Missourian strata they record W. *osagensis* var. *immatura* as differing primarily in being smaller in size, normally attaining lengths of 6 to 8 mm, widths of 6 or 7 mm, and thicknesses of 4 to 5 mm. We assign the New Mexico specimens included here to the latter species, which they resemble closely in size and external features. Our specimens show considerable variability, but length and width are nearly subequal at about 7 mm, and the thickness is about 4.5 mm. Most specimens have 2 sulcus and 3 fold plications but a few have 3 in the sulcus and 4 on the fold. The brachial valve has 3 or 4 lateral plications on each side.

Dunbar and Condra state that W. *immatura* can be distinguished from young specimens of W. *osagensis* by the fact that the plications arise at about 4 mm from the beak instead of 3 mm. While our specimens do show an average of 4 mm for this distance, so also do some specimens of W. *osagensis* we studied from the same locality as the neotype of that species. In both cases, the measurement is quite variable; there may be a slight distinction in overall average, in the direction mentioned by Dunbar and Condra.

Sections of the posterior region reveal ventral dental plates in the pedicle valve, and a short median septum supporting an undivided hinge plate in the brachial valve.

MATERIAL AND OCCURRENCE—Dunbar and Condra (1932, p. 290) record *Wellerella osagensis* var. *immatura* from the Missourian and possibly from the Desmoinesian. They record W. *osagensis* from the lower Virgilian. The New Mexico specimens, which we include in W. *immatura*, come from units 96-57 and 98-3, and number 45 specimens. In unit 98-3 they occur with Virgilian fusulinids. These horizons are near the top of the Alamitos Formation, near the town of Pecos. Poorly preserved specimens from the upper middle Desmoinesian unit 10-56 may possibly belong to this species. Figured specimens: OU 7798 to 7801.

Small numbers of specimens that appear to belong to the genus *Wellerella* occur at Morrowan unit 61-11, and in Desmoinesian units 10-32, 36-133, and 60-124.

Superfamily RHYNCHOPORACEA
Family RHYNCHOPORIDAE
GENUS *RHYNCHOPORA*

Rhynchopora magnicosta Mather
Pl. 13, figs. 22, 23

Rhynchopora magnicosta Mather, 1915, p. 176, p1. 10, figs. 11, 11a-c.

DISCUSSION—We have examined the 2 specimens, one a fragment, on which Mather based this species. His photographs (pl. 10) do not adequately illustrate the crushed nature of the holotype. That specimen is about 11 mm in length and has 6 plications in the sulcus and 5 or 6 on each side.

This genus is represented in our collections by only 3 specimens and do not appear to differ significantly from Mather's specimen. They are of about the same size, and the maximum number of plications in the sulcus ranges from 5 to 7, with 5 plications on each flank.

The punctae seem to be irregularly distributed on our specimens, about 20 to 25 along a line 1 mm long.

MATERIAL AND OCCURRENCE—This species was based on specimens from the Brentwood Limestone (Morrowan) at Fayetteville, Arkansas. Two of our specimens came from Morrowan unit 41-33. The third specimen is from unit 22-41, either late Morrowan or early Atokan; both units are in the lower part of the La Pasada Formation. Figured specimens: OU 7802, 7803.

Order SPIRIFERIDA
Suborder RETZIIDINA
Superfamily RETZIACAE
Family RETZIIDEA
GENUS *HUSTEDIA*

Hustedia gibbosa? Lane
Pl. 14, figs. 5-9

Retzia Mormonii, White (not Marcou), 1877, p. 141, pl. 10, figs. 7a-c.
Hustedia miseri subsp. *gibbosa* Lane, 1962, p. 906, pl. 127, figs. 38-41.

DESCRIPTION—(Based on specimens from localities 90-2 and 61-2.) The shell is average size for the genus. It is elongate and gibbous. A large specimen has the following dimensions: length 11 mm, width 7.5 mm and thickness 7 mm. For a collection of 61 specimens the mean dimensions are: length 8.6 mm, width 6.1 mm and thickness 5.5 mm. Figures 26A and 26B are scatter diagrams in which width is plotted against length, and thickness against length respectively; on each is plotted the calculated RMA. For additional statistics see Appendix 2, tables 8 to 10.

The pedicle valve has nearly uniform decreasing mesial convexity, the lateral profile being sub-semicircular behind midlength. The valve is extended posteriorly, becoming narrow near the beak. The posterolateral slopes are vertical. The apex is strongly deflected dorsally producing a prominent overhang. The beak is truncated by a large, round foramen. The symphytium is slightly concave and smooth. A faint sinus is present on anterior slope of some specimens. There are 17 to 24 angular costellae arising at the edge of the foramen and extending, evenly spaced, to the margin. For a sample of 38 specimens, the number of costellae averages 20.6 and the mode is 22 (fig. 27).

The brachial valve is triangular to oval in shape, has the same thickness as the pedicle valve, and has the greatest convexity posterior to midlength. Surface ornamentation is similar to that on the pedicle valve. Interior features are unknown.

DISCUSSION—Lane (1962) based the subspecies *dia miseri gibbosa* on an unstated but presumably small number of specimens from the Atokan part of the Ely Group in Nevada. This form is elongated and has 20 to 24 rounded costellae. Lane describes a second species, *H. rotunda,* based on specimens from the same locality, also having 20 to 24 costellae and differing only in being oval in shape and less elongated. A study of a large collection from his locality could show that the two forms belong to the same species.

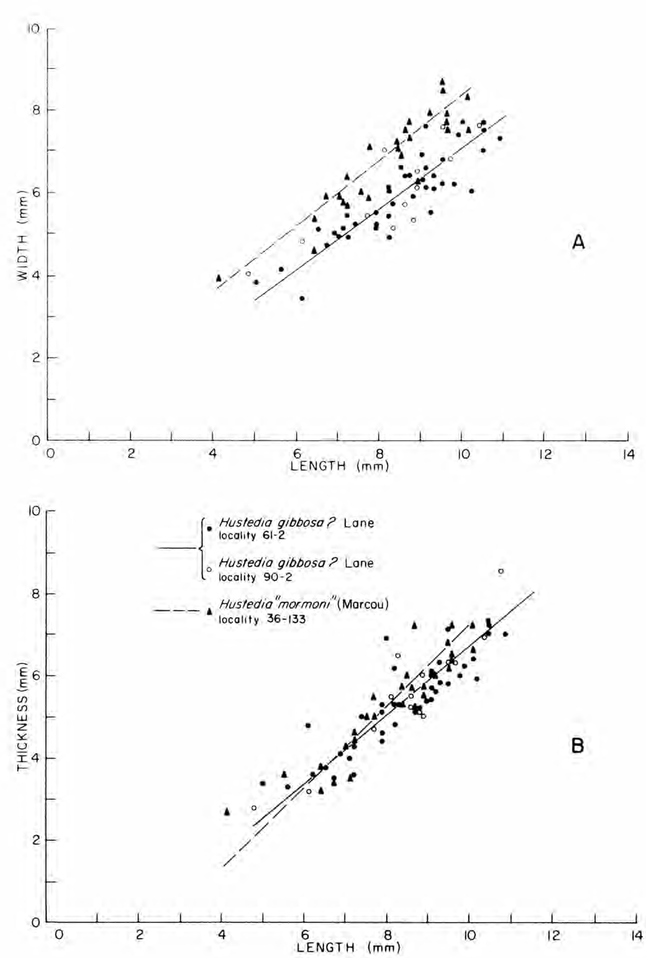


FIGURE 26—**A.** *Plot of width vs length for mature specimens of* Hustedia gibbosa? *from Morrowan localities 61-2 and 90-2, and* Hustedia "mormoni" *from the lower Desmoinesian unit 36-133. The reduced major axis for* H. gibbosa? *is W = -0.35 + 0.75 L, and for* H. "mormoni" *is W=0.31 +0.80L.*

B. *Plot of thickness vs length for same specimens as above. The RMA 's for* H. gibbosa? *and* H. "mormoni" *for thickness and length are T = -1.65 + 0.82 L and T = -2. 67 + 0.98 L, respectively. For a statistical analysis, see discussion of* H. gibbosa?.

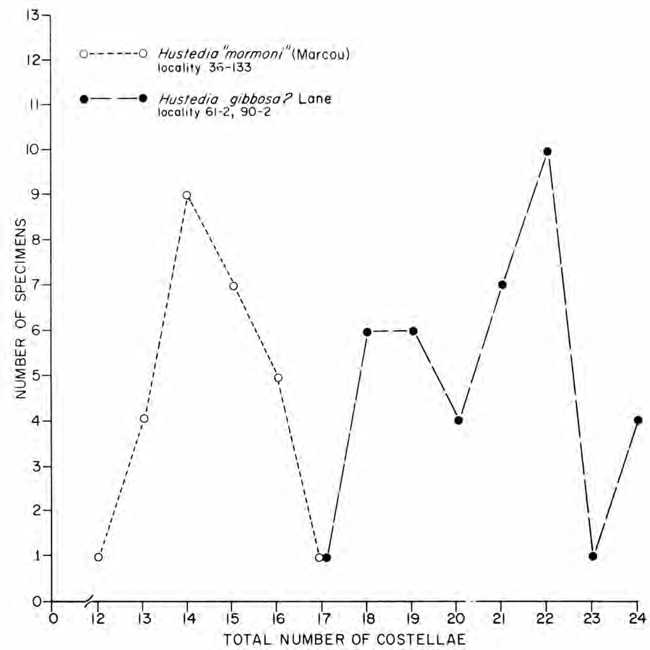


FIGURE 27—*Frequency plot showing the number of specimens plotted against the total number of costellae measured at the anterior margin for specimens of* Hustedia gibbosa? *from the Morrowan units 61-2 and 90-2 and* H. "mormoni" *from the lower Desmoinesian unit 36-133. The mean number of costellae measured at the anterior margin for* H. gibbosa? *is 20.6, with a standard deviation of 1.98; that for* H. "mormoni" *is 14.4, with a standard deviation of 1.10. For statistical comparisons, see discussion of* H. gibbosa?.

We tentatively refer our New Mexico specimens from Morrowan rocks to Lane's species primarily on the basis of having about the same number of costellae and a similar shape. For *H. gibbosa* Lane states only that the range in number is from 20 to 24, and does not give an average or the number of specimens studied. In our collection the number of costellae ranges from 17 to 24, the average is 20.6, and the mode is 22. The costellae may be somewhat coarser in our specimens.

Mather (1915) described 2 species, *H. brentwoodensis* and *H. miseri*, from the Brentwood Limestone (Morrowan) at Fayetteville. The first named species is a small, extremely narrow form with few costellae. *H. miseri* and *H. gibbosa* are more closely similar. We have examined Mather's 4 cotypes of *H. miseri*. Three are very small and presumed to be immature. The fourth (1915, pl. 13, figs. 4a-c; WM 16152) is 9 mm in length; Mather's photographs give a good idea of size, shape and surface ornamentation. The costellae flare slightly at the margin and number 16 (or at most 18), not 20 as stated by Mather. *H. gibbosa?* differs in having finer costellae, in having a more elongate form, and a more extended beak. The difference in coarseness of costellae is substantiated by a comparison of our specimens of *H. gibbosa?* with a sample from the OU collection of 50 specimens of *H. miseri* from the Morrow Group of northeastern Oklahoma. The number of costellae in that collection ranges from 15 to 18 and averages 16.6, with a mode of 16. As stated in our description, *H gibbosa?* averages 20.6 and the mode is 22.

H. gibbosa? differs from lower Desmoinesian specimens that we refer to *H. "mormoni"* in being more elongated and in having finer costellae. We statistically compared the width-length and width-thickness RMA's for samples of the two species as indicated on fig. 26. Both differences in slope are statistically insignificant (z =0.75 and z =1.55, respectively) at 95 percent confidence limits. However, in comparing the position of both the width-length and thickness-length RMA's between the 2 species, a very highly significant statistical difference is indicated (z= 61. 40 and z =23.20, respectively). The first of these statistical differences demonstrates the observable difference that *H. gibbosa?* is the more elongated of the 2 forms (fig. 26A). The average number of costellae in *H. gibbosa?* is 20.6, while in our collection of *H "mormoni"*, 14.4.

MATERIAL AND OCCURRENCE—H. *gibbosa?* occurs widely in the middle parts of our Morrowan strata, and in the lower parts of the La Pasada and Flechado Formations. There are 90 specimens in our collection of which 70 come from units 90-2 and 61-2. Other units are: 41-42, 41-47, 61-11, 65-56, 90-7, 90-14 to 17, 90-18, 92-19 and 92-34. Figured specimens: OU 7804 to 7808.

Hustedia "mormoni" **(Marcou)**

Pl. 14, figs. 10-12

Terebratula Mormoni Marcou, 1858, p. 51, pl. 6, figs. 11, 11a-c.
Hustedia mormoni, Girty, 1915a, p. 103, pl. 12, figs. 5, 6; Dunbar and Condra, 1932, p. 356, pl. 42, figs. 9-11.

DISCUSSION—This species name has been widely used for virtually all Pennsylvanian examples of this genus above the Morrowan. It is not clear what horizon or precise locality is indicated by Marcou's (1858, p. 51) reference to the Mountain Limestone in the vicinity of Salt Lake City. In March, 1972, Sutherland examined the collection of specimens figured by Marcou in 1858, now in the British Museum of Natural History. Marcou's figured specimen of *Terebratula Mormoni* (1858, pl. 6, figs. 11, 11a-c) is one of only two figured brachiopods not included in the BMNH collection, and is assumed to be lost. An attempt should be made to re-establish the type locality in Utah. If acceptable topotypes cannot be collected, then the use of this name should be discontinued. In using the name, most authors have made reference to Girty's (1915a) description based on specimens from the Wewoka Formation (upper Desmoinesian) of Oklahoma, or that by Dunbar and Condra (1932, p. 356). We have no basis for precise comparison but our specimens seem to differ in being only slightly smaller than those presumed to be typical.

A sample of 30 specimens from New Mexico have the following average dimensions: length 8.2 mm, width 6.9 mm, and thickness 5.3 mm. A large specimen is 10.2 mm long, 8.4 mm wide and 6.6 mm thick (fig. 26). For a sample of 26 specimens the number of costellae average 14.4 with a range from 12-17 (fig. 27). (For a comparison of *H. " mormoni"* with *H. gibbosa?* see the discussion of that species.)

MATERIAL AND OCCURRENCE—Marcou's original specimens come from an unknown horizon near Salt Lake City. Dunbar and Condra (1932, p. 358) report the range to be throughout the Pennsylvanian System in the Mississippi valley but we have been unable to verify its occurrence below the Desmoinesian. The 70 New Mexico specimens that we refer to this species are all from the lower Desmoinesian part of the La Pasada Formation in the following units: 29-10, 36-133, 40-3, 93-44(cf.). Figured specimens: OU 7809 to 7811.

Suborder ATHYRIDIDINA
Superfamily ATHYRIDACEA
Family ATHYRIDIDAE
Subfamily ATHYRIDINAE
GENUS *COMPOSITA*

DISCUSSION—Grinnell and Andrews (1964, p. 230) discussed the morphological variations to be expected in large collections of the genus *Composita*, and the stratigraphic distribution of the described Carboniferous species of the genus. They pointed out that these species are typologically defined and do not represent species in the neontological sense. Their proposed phylogony demonstrates the interesting point that the single major change in the composition of the *Composita* fauna in the Pennsylvanian System comes approximately at the end of the Morrowan. Mather (1915) described 7 species of *Composita* from Morrowan strata of northwestern Arkansas. Several represent distinctly different and possibly unrelated species, but only one, *Composita ovata*, has been reported from higher strata. Apparently this single evolutionary stock gave rise to the complex *C. ovata—C. subtilita* species group.

The *Composita* collections from northern New Mexico support the above contentions. We have large Morrowan collections from several localities. The only common form is *C. gibbosa.* Less commonly occurring species are *C. deflecta* and *C. ovata.* All show considerable variation but we consider them to be distinctly separate species (see discussion of *C. gibbosa).*

Our Atokan faunas contain only a few examples of the genus. Most are the *C. ovata* type with a few specimens of the *C. subtilita* variant. Neither *C. gibbosa* nor *C. deflecta* is included.

Our largest and most numerous collections of *Composita* come from the Desmoinesian. *C. ovata* is the most common type but *C. subtilita* is also common and the two types intergrade. Smaller numbers of specimens of the two variants *C. elongata* and *C. argentea* are present. In addition, a single new species, *C. umbonata* is described. It does not occur with specimens of the *C. ovata—C. subtilita* species group, and evidence of inter-gradation is lacking.

Our Missourian and Virgilian brachiopod collections are limited. The Missourian specimens of *Composita* include a higher percentage of the *C. subtilita* type than of *C. ovata.* This is true in our collections from two Virgilian localities but most of the specimens of *Composita* are smaller than those found in lower horizons.

Composita gibbosa Mather
Pl. 14, figs. 13-14

Composita gibbosa Mather, 1915, p. 204, pl. 13, figs. 16-18

DISCUSSION—This species is characterized by its small size, gibbous shape, greater length than width, and greatest width at midlength. It also develops a shallow fold and sulcus only on the anterior part of larger shells. The New Mexico shells agree in most particulars with Mather's description except for being slightly larger, and having the narrow mesial depression developed only rarely on the pedicle valve. At some localities variants are somewhat broader and more oval than typical. Mather apparently based his description on a small number of specimens. The largest of his 4 "typical" specimens is 12.1 mm in length. The average length for 147 specimens from unit 41-33 is 12.1 mm, but one of the largest specimens has a length of 17.3 mm, width 13.4 mm, and thickness 11.3 mm. However, at some of our localities only smaller specimens occur with maximum lengths of 12.5 mm.

C. deflecta differs from *C. gibbosa* in having a subtriangular outline with the greatest thickness anterior to midlength, in being proportionally thinner, and slightly larger in size. *C. gibbosa* was the only species of the genus collected in 11 of our units, but at two units it occurs with *C. deflecta;* at one unit *C. deflecta* occurs alone. From unit 61-11 large collections of both species were separated visually, and the samples were analyzed statistically for the relationship of width to length, and thickness to length (fig. 28). The sample of *C. gibbosa* was also compared with specimens of species from another unit (41-33) where only *C. gibbosa* occurs (fig. 28).

In comparing specimens of *C. gibbosa* from units 41-33 and 61-11 we did not find a statistically significant difference in the slopes of the width-length and thickness-length RMA's (z =0.50 and z= 0.42, respectively) at 95 percent confidence limits. The same is true for the position of the thickness-length RMA between the two units (z=0.03) , tested at the mean length for unit 41-33. However, a very highly significant statistical difference in the position of the width-length RMA exists between the two collections (z =11.67) tested at the mean length of the collection from unit 41-33, indicating that the specimens of the species from unit 61-11 are slightly more elongated for comparative widths than the specimens from unit 41-33. This difference may reflect the fact that unit 41-33 occurs stratigraphically lower than unit 61-1 1, believed to correlate with unit 41-39 at Nambe Falls (see fig. 7).

Our analysis of C. *gibbosa* and *C. deflecta* from a single unit (61-11) supports our contention, based on visual separation, that 2 separate species are present (fig. 3). The difference in the slope of the width-length RMA's (z=0.49) is not statistically significant but the difference in the slope of the thickness-length RMA's (z =7.09) is highly significant statistically. The difference (z =l2.95) in the position of the width-length RMA's is also statistically very highly significant. There is a lack of appreciable overlap between the two species (fig. 28) especially in the thickness-length plot. (For descriptive and RMA statistics see Appendix 2, tables 11 to 13.)

MATERI AL AND OCCURRENCE—Composita *gibbosa* Mather occurs in Morrowan strata of northwestern Arkansas, and has not been reported higher than Morrowan. About 200 specimens are in our Northern New Mexico collections, all Morrowan, from units 41-33, 41-42, 47-19, 61-2, 61-6A(?), 61-11, 65-40, 90-2, 90-7, 90-14 to 17, 92-19, 92-23 to 27, 92-34 and locality 51. Figured specimens: OU 7813, 7814.

Composita deflecta Mather
Pl. 14. figs. 15-17

Composita deflecta Mather, 1915, p. 203, pl. 14, figs. 1-3.

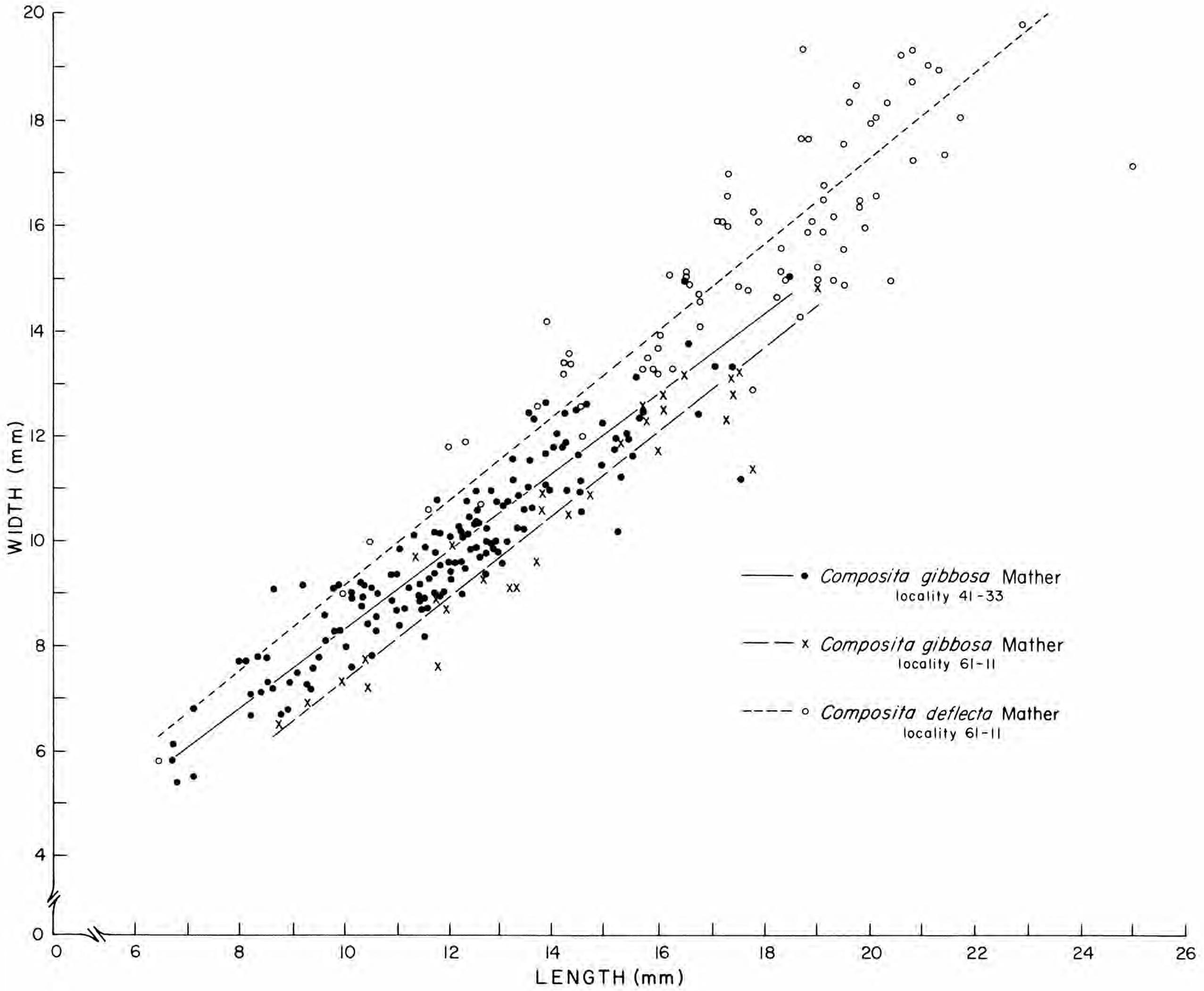
DISCUSSION—This species is medium size, comparatively thin and subtriangular in outline with the greatest width anterior to midlength. It lacks a sulcus at midlength but the anterior margin is commonly truncated by a sharp deflection of the mesial portion of the valve. The New Mexico shells are similar to Mather's specimens in size and relative proportions, but our specimens are less consistently truncated along the anterior margin giving a more oval outline for some specimens. Some have only a faint development of a sulcus near the anterior margin. Also, Mather's illustrations show only faint growth lines whereas many of our specimens are more distinctly lamellose. (For a comparison of *C. deflecta* with *C. gibbosa* see the discussion of that species.)

MATERIAL AND OCCURRENCE—C. *deflecta* was the first described by Mather (1915) from the Morrow Group in northwestern Arkansas. This species is also restricted to Morrowan in northern New Mexico, but is not distributed widely. About 100 specimens are in our collections from the following units, all in the lower part of the La Pasada Formation: 36-38; 61-11 and 90-14 to 17. Figured specimens: OU 7815 to 7817.

Composita "ovata" Mather
Pl. 14, figs. 18-21

Composita ovata Mather, 1915, p. 202, pl. 14, figs. 6, 6a-c; Dunbar and Condra, 1932, p. 370, pl. 43, figs. 14-19.

DISCUSSION—Examples of *Composita "ovata"* are found in our rock units from Morrowan to Virgilian. In



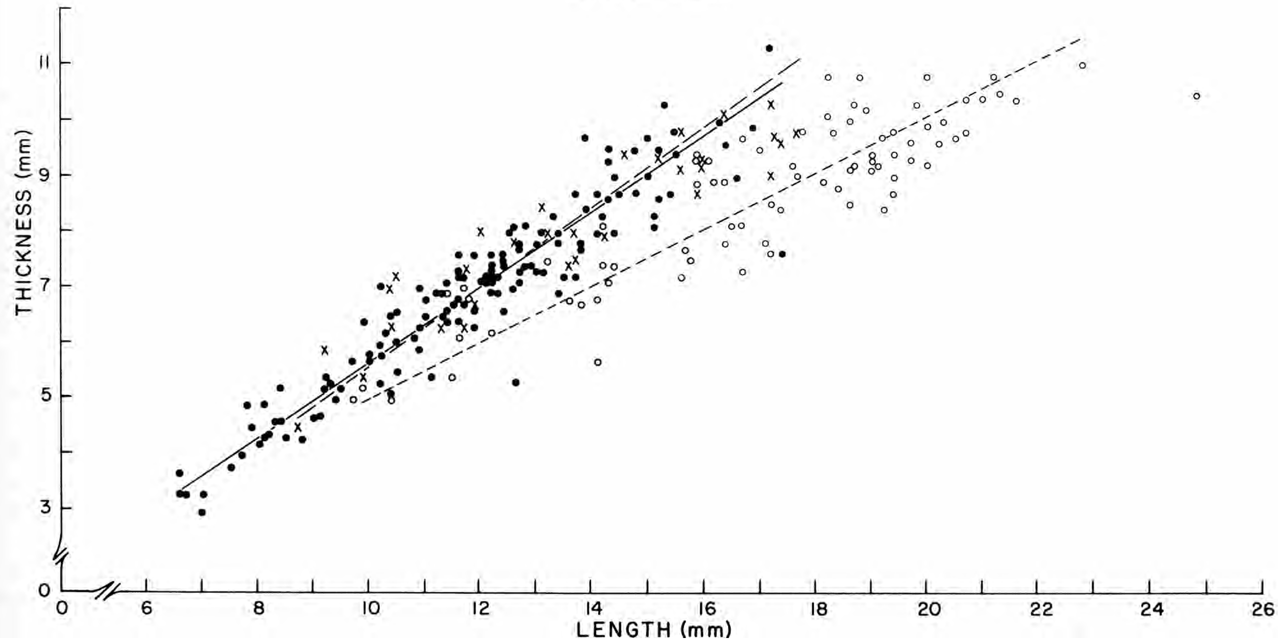


FIGURE 28—**A.** *Plot of width vs length for specimens of* Composita gibbosa *from Morrowan units 41-33 and 61-11 and for* C. deflecta *from Morrowan unit 61-11. The reduced major axis for width and length for* C. gibbosa *from locality 41-33 is W = 0.61 + 0.77L; from unit 61-11 is W = -0.51 + 0.79 L; and for* C. deflecta *is W = 0.95 + 0.82 L.*

B. *Plot of thickness vs length for same specimens as above. The RMA's for thickness and length are T = -1.28 + 0.68 L for* C. gibbosa *from unit 41-33; T =1.63 + 0.71 L for unit 61-11; and T = -0.11 + 0.51 L for* C. deflecta *from locality 61-11. For statistical comparisons, see discussion of* C. gibbosa.

the Morrowan interval they occur with other species of *Composita* with which they appear to be unrelated. Variants of *C. ovata,* such as *C. subtilita*, are not present in the Morrowan of either New Mexico or Oklahoma. In higher strata *C. ovata* shows much greater variation and includes variants that have been described as separate species. Our lower Desmoinesian collections contain the largest numbers of specimens. In these collections variants include approximate percentages that could be ascribed to the following typological species: *C. ovata*, 60 percent; *C. subtilita*, 30 percent; *C. elongata*, 5 percent and *C. argentea*, 5 percent. This distribution represents interpopulation variation. Specimens from unit 93-44 (lower Desmoinesian) are exceptionally well preserved. For a sample of 164 specimens from this unit, including immature specimens less than 4 mm in length, we calculated width-length and width-thickness RMA's (see Appendix 2, tables 12 and 13). The width-length measurements are plotted on fig. 29. On the same figure is plotted the width-length RMA for specimens from Virgilian strata at Jemez Springs, located about 50 miles northwest of measured section 93. In our paper on the Virgilian brachiopods at Jemez Springs (Sutherland and Harlow, 1967) we referred the *Composita* collections arbitrarily to *C. "subtilita"* in that the specimens could be visually separated into the following variants: *C. subtilita* 50 percent; *C. ovata*, 45 percent and *C. elongata*, 5 percent. As stated above, the lower Desmoinesian collections have a higher percentage of the *C. ovata* type, but

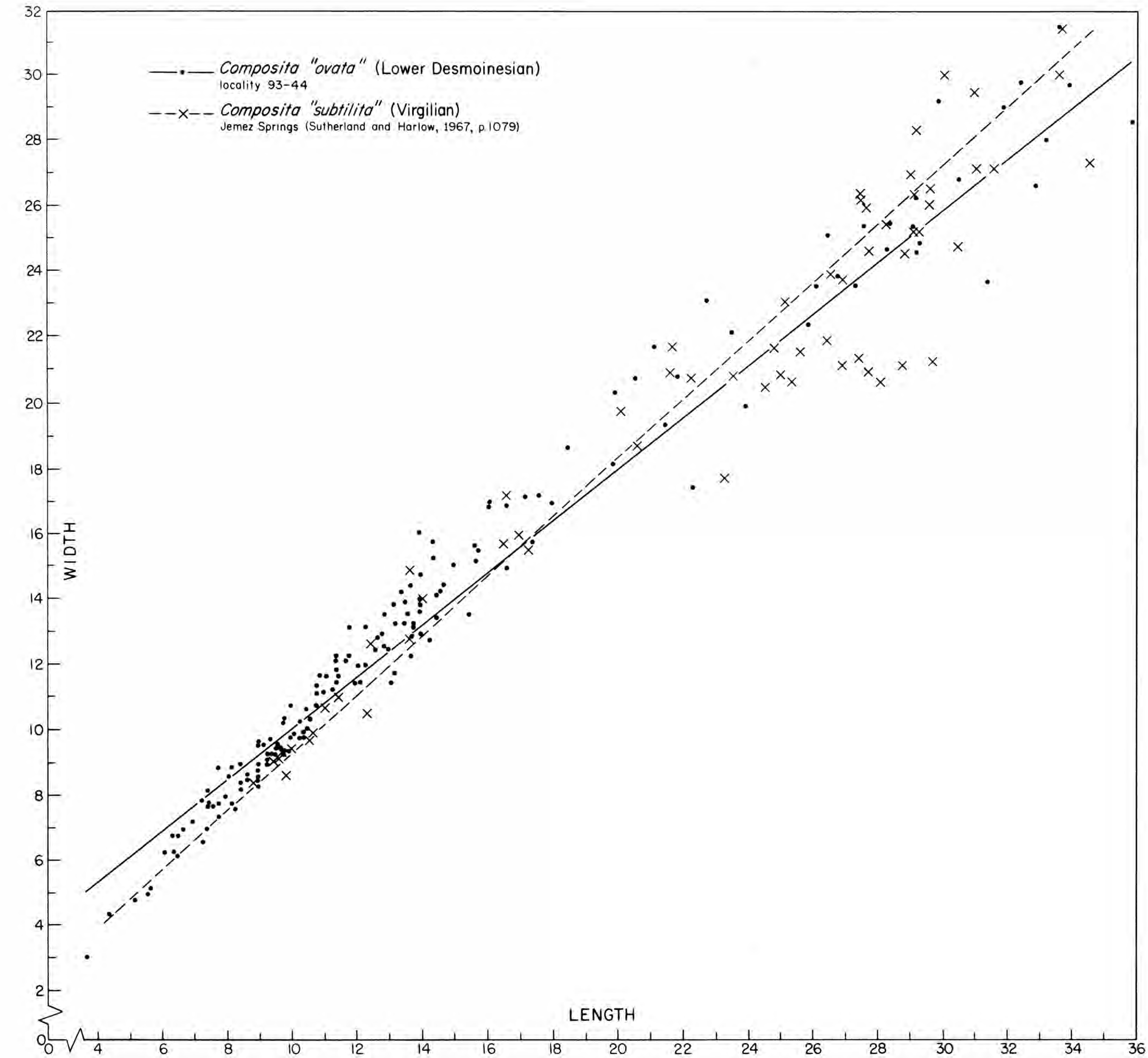


FIGURE 29–*Plot of width vs length for mostly mature specimens of* Composita "ovata" *from the lower Desmoinesian unit 93-44 and C.* "subtilita" *from the Jemez Springs Shale (Virgilian) at Jemez Springs. The reduced major axes for this collection of C.* "ovata" *is W = 1.54 + 0.85 L, and for C.* "subtilita" *is W = 0.36 + 0.88 L. For comparisons, see discussion of* C. "ovata."

individual specimens in the two collections are externally indistinguishable. (We have not studied internal features.) The same range in morphologic types is present except that the Desmoinesian collections have a few specimens of the *C. argentea* type. Statistically we did not find significant differences between the slopes of either the width-length (fig. 29) or the thickness-length RMA's between the Desmoinesian and Virgilian collections (z = 2.36 and z =3.92, respectively) are present but these differences are not highly significant for collections from such different stratigraphic horizons.

The specimens of *Composita* from the Missourian and Virgilian localities in the Sangre de Cristo area are somewhat smaller than those in the Desmoinesian, and the percentage of C. *subtilita* variant has increased.

MATERIAL AND OCCURRENCE-Specimens of the *C. ovata-C. subtilita* species group occur in the following units in the La Pasada, Flechado and Alamitos Formations:

1) Morrowan *(C. ovata* only), 30 specimens: 22-41, 61-2, 92-19, 93-15 and 16, and locality 99.

2) Atokan, 30 specimens: 22-64, 62-17 and 18, 36-71, 36-79, 36-94.

3) Desmoinesian, 350 specimens: 10-19, 10-23, 10-57, 22-113, 29-3, 29-5, 29-10, 36-103, 36-109, 36-128, 36-133, 36-150, 36-185, 40-3, 40-8, 40-52, 42-27, 60-124, 93-44, and localities 56, 78, and 105.

4) Missourian, 100 specimens: 96-30, 97-54, 97-60.

5) Virgilian, 100 specimens: 96-57, 98-3.

Figured specimens: OU 7818 to 7821.

Composita umbonata n. sp.
Pl. 14, figs. 22, 23

DESCRIPTION-The shell is small and globular. A large specimen has the following dimensions: length 17.1 mm, width 16.2 mm and thickness 12.4 mm. The greatest width is anterior to midlength but the greatest thickness is distinctly posterior to midlength.

The pedicle valve is strongly convex, with the umbo highly inflated and the beak curved over the hinge line. A narrow sulcus begins on the umbo and continues forward deepening to a sharp, narrow groove. Near the anterior margin of larger specimens the mesial part of the valve is extended dorsally to produce a distinct marginal flexure.

The brachial valve is strongly but decreasingly convex in longitudinal profile. The umbo is inflated. About half of the specimens possess, on the brachial valve, a narrow, low mesial sulcus, which produces a notch when meeting the ventral sulcus at the margin.

DISCUSSION-This species is characterized by the small size, greatly inflated pedicle umbo, and presence of a sulcus on the brachial as well as on the pedicle valve. It resembles *C. argentea* in size, but that species does not have an inflated umbo.

C. umbonata is the only species of *Composita* present in the 3 localities where found.

MATERIAL AND OCCURRENCE-There are 56 specimens in our collection, from the lower Desmoinesian part of the La Pasada Formation in the Pecos Baldy area. It occurs in units 10-31, 10-36 and at locality 12. Figured specimens: holotype OU 7822; paratype OU 7823.

GENUS *CLEIOTHYRIDINA*

Cleiothyridina pecosii (Marcou)
Pl. 14, figs. 24-27

Orthis pecosii Marcou, 1858, p. 48, pl. 6, figs. 14, 14a-b.
?Athyris orbicularis McChesney, 1859, p. 47.
Cleiothyridina orbicularis, Girty, 1915a, p. 101, pl. 12, figs. 1-3; Dunbar and Condra, 1932, p. 359, pl. 42, figs. 1-4; Sturgeon and Hoare, 1968, p. 55. pl. 10, figs. 14-16.

ORIGINAL DESCRIPTION-(Marcou, 1858, p. 48.) Shell oval, sides semi-elliptically rounded, lateral and front margins in one plane; beak obtuse, prominent; mesial fold indistinct; surface radiatingly striated, very finely, with thread like striae.

This species resembles the young of the *Orthis resupinata* Martin; but it differs in having an oval form, while the other is transverse.

This species is rare; I found only one specimen at Pecos village, New Mexico.

TYPE SPECIMEN-Sutherland has examined Marcou's holotype of this species in the collection of the British Museum of Natural History. That museum has provided us with an excellent cast here illustrated. It is a somewhat abraded specimen and the beak is missing. An estimated restored length is 12 mm. It is 13.4 mm wide and 7.3 mm thick, transversely subelliptical in outline, and the two valves are subequally and uniformly convex. The greatest thickness is slightly posterior to midlength. The surfaces are covered with irregularly spaced concentric lamellae, and superimposed on these are faint radiating grooves which reflect the former location of minute, flat spines.

DISCUSSION-Dunbar and Condra (1932, p. 360) state that only one species of *Cleiothyridina* has been recognized in the middle and upper parts of the Pennsylvanian System in the Midcontinent. They place these forms in the species *C. orbicularis* (McChesney) but recognize that McChesney's (1859) original description is inadequate, fails to give any dimensions and, most serious, does not give any location for the original specimens, now lost. Redescription of McChesney's species, therefore, is not possible. His paper was first distributed in 1859, one year after Marcou's description of *Orthis pecosii.*

Sturgeon and Hoare (1968, p. 56) incorrectly state that *C. orbicularis* is the only species of this genus described from the Pennsylvanian of North America.

We are unable to find any basis for differentiating Marcou's holotype from the specimens described by Girty (1915a, 1915b), Dunbar and Condra (1932), and Sturgeon and Hoare (1968) as *C. orbicularis;* and we consider their specimens to belong to Marcou's species.

Marcou (1858, p. 49) states that his specimen comes from "Pecos village" (see our discussion of Marcou's 1853 survey), where the rocks are early Virgilian age. However, the larger collections we refer to *C. pecosii* come from our Desmoinesian units. This is partly a matter of collecting bias because most of our brachiopod collections are from Desmoinesian and older rocks, and those from Missourian and Virgilian strata are limited. Girty (1915b) lists the occurrence in the Midcontinent of the junior synonym, *C. orbicularis*, to be common in the Desmoinesian and rare in the Missourian and lower Virgilian.

For a comparison of *C. pecosii* and *C. milleri* see the discussion of latter species. Fig. 30 gives scatter

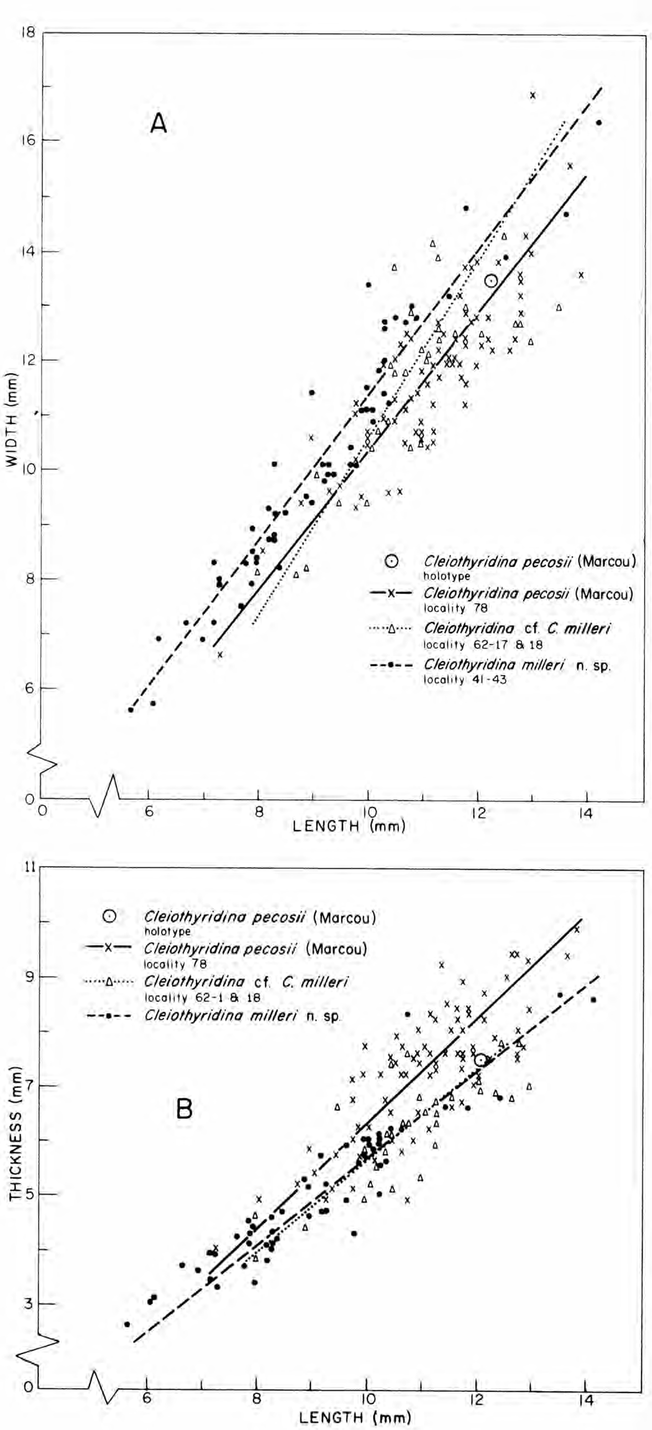


FIGURE 30—**A.** *Plots of width vs length for specimens of* Cleiothyridina pecosii *from the Desmoinesian locality 78.* C. *cf* C. milleri *from the Atokan units 62-17 and 18 and* C. milleri *n. sp. from the Morrowan unit 41-33. The RMA (reduced major axis) for width and length for* C. pecosii *is W = -2.42 + 1.28L; for* C. *cf* C. milleri *is W = -2. 52 + 1.31 L ; and for* C. milleri *is W=-2.14+1.35 L.*

B. *Scatter diagram of thickness and length for specimens from the above-mentioned localities. The RMA for thickness and length for* C. pecosii *is T = -3.42 + 0.97L; for* C. *cf* C. milleri *is T = -2.75 + 0.84 L; and for* C. milleri *is T = -1.95 + 0.77 L. For a statistical comparison, see the discussion of* C. milleri.

diagrams of both species in which width is plotted against length, and thickness against length. For statistics see Appendix 2, tables 14 to 16.

MATERIAL AND OCCURRENCE—Marcou's (1858, p. 49) holotype of *Orthis pecosii* is from "Pecos village," where the rocks are early Virgilian. In the Midcontinent specimens previously referred to *C. orbicularis,* and considered to belong to this species, are common in the Desmoinesian and rare in the Missourian and Virgilian.

In northern New Mexico *C. pecosii* occurs commonly in many Desmoinesian units and localities, from which we have collected over 200 specimens: 29-3, 29-4, 29-5, 29-8, 36-128, 40-3, 43, 78, 93-44. Figured specimens: holotype BMNH B79168 (plastotype OU 7824); other specimens OU 7825, 7826.

Cleiothyridina milleri n. sp.
Pl. 14, figs. 28-30

?Spirigera planosulcata, White (not Phillips) 1877, p. 143, pl. 10, figs. 5a-d.

DESCRIPTION—The shell is small and transversely subelliptical in outline. The holotype has the following dimensions: length 11.9 mm, width 14.8 mm and thickness 6.7 mm. Statistical data and shell measurements are given in Appendixes 2 and 3. The valves are equally convex; the greatest width and thickness are at midlength. The shell is comparatively thin.

The convexity of the umbo of the pedicle valve is low, the umbo is not inflated, and the beak projects only slightly beyond the hinge line. A sinus is lacking. The concentric lamellae are variable in spacing but average about 2 or 3 per mm. Along these lamellae arise the flat, prostrate spines characteristic of the genus.

The brachial valve lacks a fold and has surface ornamentation similar to that on the pedicle valve. Internal features are unknown.

DISCUSSION—C. *milleri* differs from *C. pecosii* in being more transverse and thinner, and in having more widely spaced lamellae. The lamellae average 2 to 3 per mm instead of 4.

C. pecosii occurs commonly in rocks of Desmoinesian age. Our description of *C. milleri* is based on Morrowan specimens. Specimens that are transitional in shape between the two species, but nearer to *C. milleri,* occur in the Atokan. The Atokan specimens identified as *C.* cf. *C. milleri,* differ only in that most specimens are not as wide for the same length (fig. 30A), as indicated by a statistically significant difference in the positions of the width-length RMA's (z =3.88) tested at the mean length for *C. milleri.* The Atokan specimens are comparable with *C. milleri* in thinness. (fig. 30B).

In comparing *C. pecosii* (based on specimens from a Desmoinesian unit with *C.* cf. *C. milleri* from the Atokan) very highly significant statistical differences in the positions of both the width-length and thickness-length RMA's (z =11.69 and z = 32.82, respectively) are apparent. *C. pecosii* is both thicker and less wide than specimens of *C.* cf. *C. milleri* with the same length (fig. 30).

We have examined the holotype of *Composita transversa* Mather (1915, pl. 14, figs. 4, 4a-c) from the

Morrow Group of Arkansas. It is a small, transverse shell that superficially resembles *Cleiothyridina milleri* but it is definitely a *Composita*.

MATERIAL AND OCCURRENCE—C. *milleri* occurs in the lower parts of the La Pasada and Flechado Formations, in both Morrowan and Atokan rocks. However, the Atokan specimens are transitional with *C. pecosii*. About 75 specimens are in our collections from Morrowan units of which about 60 are from the type unit 41-33. Other occurrences are : 41-49, 41-58, 90-7, and 90-14 to 17 and locality 51. Atokan occurrences are: 62-17 and 18 (cf.), 67-13(cf.). and 67-23(cf). Figured specimens: holotype OU 7827; paratypes OU 7828, 7829.

Suborder SPIRIFERIDINA
Superfamily CYRTIACEA
Family AMBOCOELIIDAE
GENUS *CRURITHYRIS*

Crurithyris planoconvexa (Shumard)
Pl. 17, figs. 14-16

Ambocoelia planoconvexa, Dunbar and Condra, 1932, p. 344, pl. 42, figs. 12-14.
Crurithyris planoconvexa, Sturgeon and Hoare, 1968, p. 60, pl. 19, figs. 21-25.

DISCUSSION—This small species is abundant at one locality. Although few specimens are complete, they show enough detail to identify the species as described by Dunbar and Condra (1932). One internal mold shows the faintly impressed dorsal muscle scars to be located well behind midlength, and the narrow, paired ventral adductor scars to be parallel depressions. The ventral diductor scars appear to be large depressions at the anterior outside of the adductor depressions, thus lying at about valve midlength. On pedicle valves the spine bases are found to lie in concentric rows that are highly irregular and sometimes scalloped. There are about 5 of these rows per mm and about 12 spines per mm along each row. Occasionally a specimen shows a very faint ventral sulcus or flattening. Some specimens, especially the more elongate ones, show a few rather distinct anterior growth lines. Only a few of the specimens have fragmentary dorsal valves remaining, with the low convexity typical of the species.

MATERIAL AND OCCURRENCE—In the Midcontinent this species ranges from the Desmoinesian to the Virgilian (Dunbar and Condra, 1932, p. 348). In the Sangre de Cristo area we have found it only in the lower part of the Alamitos Formation in units 10-57 and 10-58, in the upper part of the middle Desmoinesian. About 80 specimens are in the collection, mostly from unit 10-58. Figured specimens: OU 7830 to 7832.

Superfamily SPIRIFERACEA
Family SPIRIFERIDAE

Sulcal formula. In an earlier paper (Sutherland and Harlow, 1967, p. 1081) we used the following scheme modified from Sadlick (1964, p. 142) for recording bifurcation patterns of the sulcal costae of spiriferid brachiopods:

Costae	Symbol	Definition
Primary	P	Originate at beak; bound the sulcus at all stages
Secondary	M	Median costa in sulcus
	A	First bifurcation of P-costa in sulcus
	B	Second bifurcation of P-costa in sulcus
	C	etc.
Tertiary	mm	Equal bifurcation of M-costa
	a	First bifurcation of secondary costa
	b	Second bifurcation of secondary costa
	c	etc.
Quaternary	1	First bifurcation of a tertiary costa
	2	Second bifurcation of tertiary costa
	3	etc.

Many spiriferid species, particularly those with small numbers of nonbifurcating costae, have symmetry in the pattern of the sulcal costae, as in *A. newberryi* n. sp. (fig. 42) in which the formula is almost invariably PA,M,AP. Spiriferid species with secondary bifurcation of the costae commonly have irregular asymmetry both in the sulcus and on the lateral slopes. An example is a specimen of *Anthracospirifer mcalesteri* n. sp. (fig. 47C) in which the sulcal formula is PBa,Aa,mM,aABCP. The latter type of irregularity also holds true for most species of *Neospirifer*.

GENUS *SPIRIFER*

DISCUSSION—In recent years the tendency has been to restrict the use of the generic name *Spirifer* to what are presumed to be forms similar to the type species *S. striatus* Martin, from the Lower Carboniferous of Great Britain. That species is not adequately known but apparently is a large form that has generally rounded cardinal extremities, that has numerous fine bifurcating costae on the sulcus, and has numerous lateral costae that also commonly bifurcate. Some of the numerous North American Mississippian species that can be included in *Spirifer* (s.s.) are: *S. missouriensis* Swallow, *S. pikensis* Rowley, *S. incertus* Hall, *S. grimesi* Hall, *S. rowleyi* Weller, *S. gregeri* Weller, *S. logani* Hall, and *S. tenuicostatus* Hall. In these species the lateral costae nearer the sulcus mostly split to form 2 equal or unequal branches but Dunbar (1955, p. 131) states that "in *S. striatus* and related species costae occasionally split into three instead of two branches, and a moderate degree of fasciculation is commonly visible near the beaks. "

Spirifer missouriensis Swallow, from the Chouteau Formation (Lower Mississippian) of Missouri, is extreme in this respect for a Mississippian species, and irregularly developed trifurcation and fasciculation are characteristic features of the species. This moderately fasciculate species apparently represents an isolated and independent development during the early Mississippian. During the early Pennsylvanian distinctly fasciculate species became firmly established and later reached worldwide distribution.

Spirifer goreii Mather, from the Morrowan of New Mexico and Oklahoma, is the only Pennsylvanian species of the genus known to occur in North America. It differs from the Mississippian species listed above only in the slightly greater tendency for the lateral costae to subdivide. *S. goreii* has only the slightest tendency to develop fasciculation. The Pennsylvanian and Permian genus *Neospirifer* Fredericks apparently evolved from *Spirifer* and *S. goreii* is considered to be a transitional species between the two genera.

It is rather curious that species morphologically somewhat similar in the character of the costae to the more fasciculate Mississippian and Lower Pennsylvanian species of *Spirifer* occur in Permian rocks primarily in the Arctic regions (Dunbar, 1955, p. 131). The evolutionary relationship of such species to those described here is not clear, but likely the reduced fasciculation results from atavistic variation of *Neospirifer* rather than from descent from the much earlier species of *Spirifer.*

Spirifer goreii Mather
P1. 15, figs. 1-4

Spirifer goreii Mather, 1915, p. 186, pl. 12, figs. 10, 10a, 11, 11a.

DESCRIPTION—(Based on New Mexico specimens.) The shell is large and distinctly transverse. A typical larger specimen has the following dimensions: length 31.7 mm, width 44.2 mm, thickness 20.9 mm and surface length 47 mm. The anterior margin is semielliptical and the lateral margin approaches the hinge line at about 80 degrees, but nearer the hinge most specimens show more acute, small, lateral, wing-like extensions that join the hinge at 20 to 30 degrees (fig. 31). The

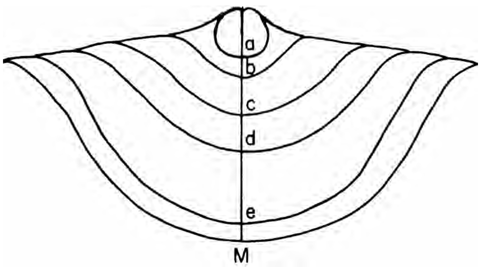


FIGURE *31—Sketch showing change in relationship of width to length with growth in a specimen of* Spirifer goreii. *At "a" the width/length ratio is about 1.0. At "b, " "c, " and "d, " it is 2.0 to 2.5, but at "e" it has decreased to about 1.5.*

growth sequence is illustrated by fairly prominent growth lines, and by a few small specimens in our collections. When the shell is less than a centimeter wide its hinge line is slightly less than the maximum width that, in turn, is only slightly greater than the length (W/L, 1.25). Fig. 31 shows the changes in the relationship of width to length with growth. At a width of 3 to 4 cm, the width is more than twice the length (W/L, 2.0 to 2.5), but the larger shells decrease in width/length ratio to approximately 1.5. The reduced major axis for width and length (fig. 32) has a very high coefficient of linear correlation (r=0.97) and reflects the relatively constant W/L ratio for the specimens between 30 to 50 mm in width. For additional statistics see Appendix 2.

The pedicle valve has a low to moderate convexity and the umbo is not strongly inflated. The beak is small and narrow, curving only slightly over the delthyrium. The interarea is slightly concave and is approximately orthocline in attitude. It is about 4 mm in height or about 1/9 the total length of the shell. The sulcus is shallow and fairly narrow posteriorly but expands rapidly and flares somewhat near the margin where it is extended anteriorly producing a strong marginal flexure. The two sides of the sulcus are symmetrical in all specimens studied. The M-costa originates within 4 to 6 mm from the beak, and, in 8 of 18 specimens studied, it bifurcates equally at a surface length of about 20 mm. The A-costae bifurcate from the margin of the sulcus at a consistent distance of 3 to 5 mm (SL) but the B, C, and D costae originate at varying distances from the beak. A single tertiary costa bifurcates from the median side of each Acosta in 17 of 18 specimens studied, and in one specimen the B-costa bifurcates in a similar manner. Thus, the total number of costae at the anterior margin of the sulcus in a mature specimen is 8, 9, 10, or 11, and the six variations in the sulcal pattern observed in the 18 specimens studied are shown as follows:

Sulcal formula	Total specimens	Fig.
PCBAa.mm.aABCP	7	33B
PCBAa.M.aABCP	6	33A
PDCBAa.M.aABCDP	2	
PCBa.Aa.M.aA.aBCP	1	
PDCBA.M.ABCDP	1	
PBAa.mm.aABP	1	

The two most commonly occurring patterns are illustrated in Fig. 33. The costae are fine, low and rounded and are approximately equal in strength with the exception of the M-costa, which is broader near the anterior margin on specimens on which it does not bifurcate.

The costae on the lateral slopes are fine and number about 6 per 5 mm adjacent to the sulcus at a surface length of 20 mm. The first lateral costa bifurcates from the P-costa on both flanks at a surface length of 2 to 3 mm. This costa may in turn bifurcate. On 5 of 17 specimens studied, the P-costa is observed to bifurcate laterally a second time at varying surface lengths, and on one specimen the lateral product of this division also bifurcates. Several of the next 3 to 6 lateral costae may bifurcate irregularly once or twice or may occasionally trifurcate. One marked feature of the species is the irregularity with which the splitting of the lateral costae occurs. There is no consistency as to which of the first 3 to 5 lateral costae will subdivide most extensively. Some among these may not divide. The total number of daughter subdivisions at the anterior margin from a principal lateral costa that does divide may be 2, 3, or 4. Examples of 3 specimens are given in fig. 34. Most specimens are asymmetrical from one flank to the other, and no two specimens have the same lateral bifurcation pattern. Faint fasciculation is observable only in the umbonal region on some specimens. The costae become progressively fainter laterally and cannot clearly be seen on the cardinal extremities of most specimens where the remaining lateral costae do not divide. The faintness of the costae on the extremities makes an accurate count difficult. About 18 to 20 can be easily seen on each flank not including the lateral extremities; however, one exceptionally well-preserved specimen (Pl. 15, fig. 4;

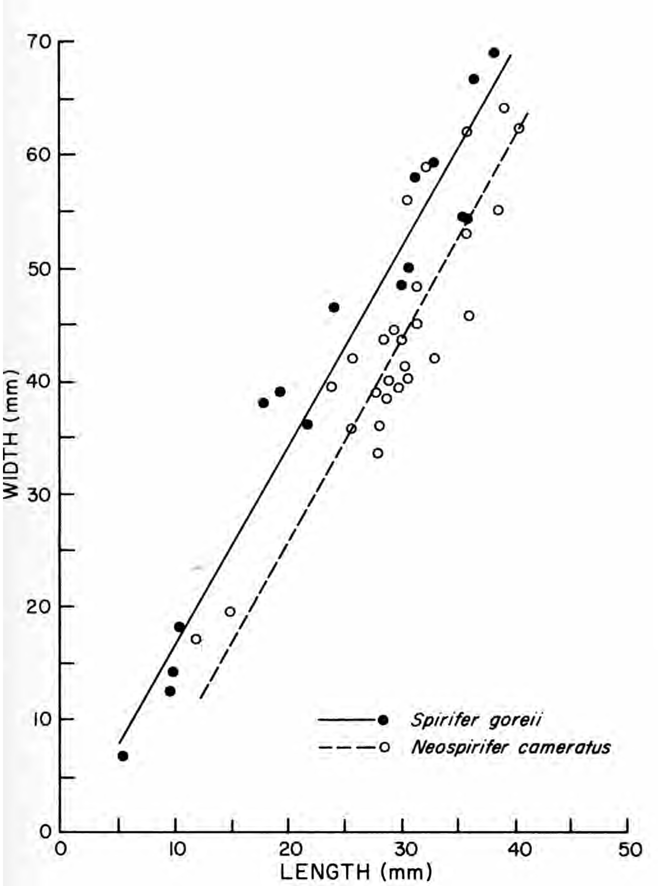


FIGURE *32 Plot of width vs length for 16 mature specimens of* Spirifer goreii *from units 41-33, 41-42, and 90-5 and for 28 mature specimens of* Neospirifer cameratus *from units 29-8, 29-10, 36-109, 36-133, 43, 93-44. The RMA for* S. goreii *is W = -1.96 + 1.79L; that for* N. cameratus *is W = -10.55 + 1.81 L. For a comparison see discussion of* N. cameratus.

also fig. 34B) has 33 lateral costae on one flank including the fine, faint, simple ones on the extremities.

The brachial valve is moderately convex posteriorly and almost straight anteriorly along the median line. The interarea is narrow and slightly concave. The fold is low except at the anterior margin where it is highly arched in cross section and smoothly rounded. The costae on the fold split irregularly and the number at the anterior margin varies from 8 to 12. The pattern of bifurcation of the grooves on the lateral slopes of the brachial valve is similar to that of the costae on the pedicle valve.

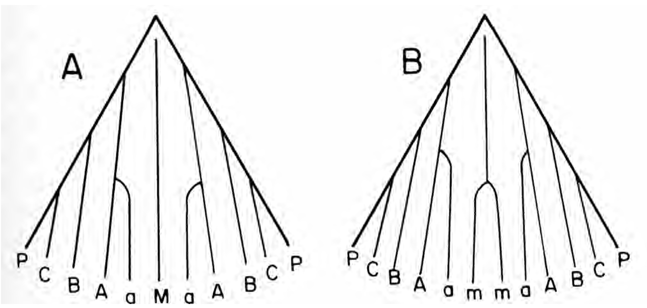


FIGURE *33—The two most commonly occurring sulcal bifurcation patterns for* Spirifer goreii *from New Mexico. See text for symbols.*

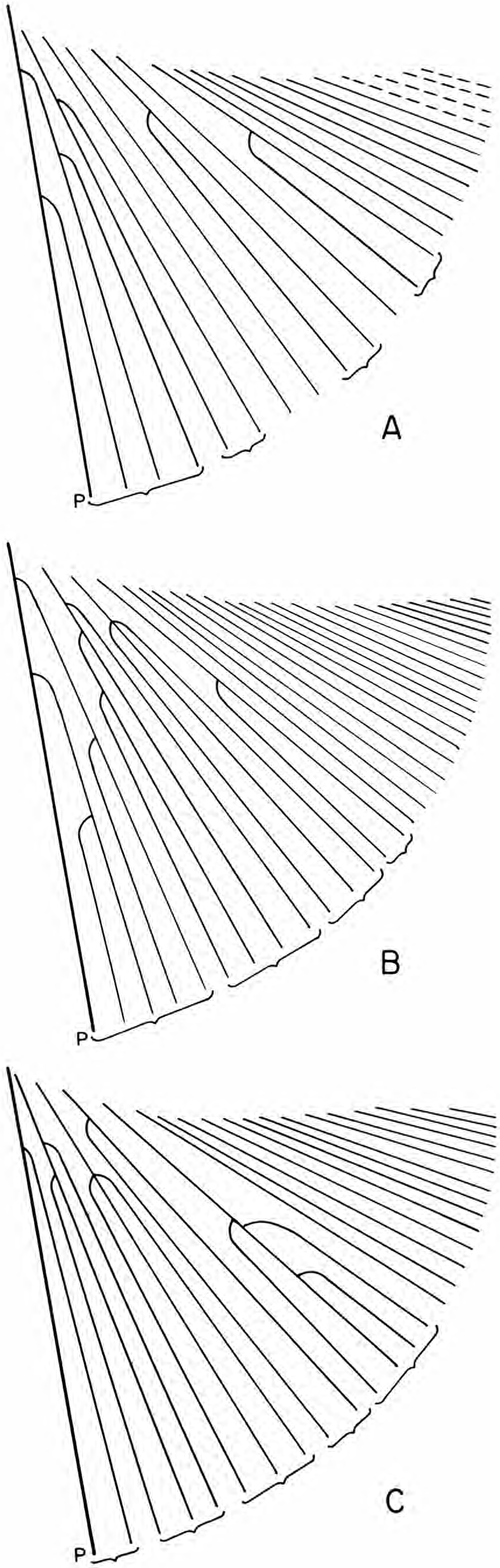


FIGURE *34—Examples of three patterns of lateral bifurcation for New Mexico specimens of* Spirifer goreii. *No two specimens are alike.*

B *represents the left side of fig. 4 on Pl. 15.*

The pedicle valve interior has marked variation in the shape and depth of the muscle attachment area. Of the 8 well-preserved interiors studied we have figured 2 extreme examples (Pl. 15, figs. 2, 3). In both specimens the muscle area is about 16 to 17 mm in length, but in one the area is about 8 mm in width and deeply impressed posteriorly while, in the other, the area is about 13 mm in width and comparatively shallow. In all specimens the adductor scars form a narrow linear mesial tract bounded by narrow ridges but are not enclosed anteriorly by the striated diductor scars. The delthyrium is bounded by thick, short dental plates that are free at the base in some specimens, but in others extend to the posterior border of the muscle area as thin, narrow ridges.

Fragmentary specimens show that the brachial interior has anterior adductor scars that are faintly impressed, long, and diverging. The part of the shell that might show the posterior adductor scars is not preserved. The cardinal process is a small, triangular-shaped plate with a longitudinally grooved surface.

The shell surface is marked with fine radiating capillae, numbering 12 to 14 per costa on the anterior slopes of the shell. The capillae are intersected by equally spaced but much weaker low concentric fila forming a minute reticulation. Occasional strong growth lamellae are also present.

Close examination of disarticulated valves of *S. goreii* shows the shell to be exceptionally thin for the overall size. The anterior part of the shell has a thickness less than 0.5 mm and as a consequence, about 80 percent of specimens from all of our New Mexico localities are crushed.

DISCUSSION-We have examined Mather's small collection of figured and unfigured specimens of *Spirifer goreii* from the Morrowan of northeastern Oklahoma. All of these, including the figured holotype and paratype (Mather, 1915, pl. 12, figs. 11 and 12; WM 16144) are strongly exfoliated, and the nature of the finer costae is not clearly shown. Mather evidently based his description of minute surface features (1915, p. 186) on an unfigured external mold (WM 16500), which we do not believe to be a specimen of *S. goreii.* The OU collection contains several hundred specimens of *S. goreii* from the Morrow Group of northeastern Oklahoma. Also included are over 100 specimens of the species from the Wapanucka Formation (Morrowan) of southern Oklahoma. About 90 percent of the specimens from the Morrow Group and about 70 percent of the Wapanucka specimens are crushed. Our specimens from New Mexico agree in all observable aspects with specimens from the Morrow Group and Wapanucka Formation.

This species was placed in the genus *Neospirifer* by Dunbar and Condra (1932, p. 341), but the almost complete absence of fasciculation makes that assignment unsupportable. The species bears a resemblance in size and pattern of sulcal costae to the early *Neospirifer* species *N. cameratus* with which it has been at times compared. *S. goreii* differs from that species in its almost complete absence of fasciculation, in having costae that are finer and lower and bifurcate less frequently on the lateral slopes, in being thinner, and in having a shallower, less angular sulcus. For additional discussion, see *N. cameratus.* Spencer (1967, fig. 5) and Sturgeon and Hoare (1968, pl. 21, figs. 9-12) incorrectly figure as *Neospirifer goreii* fasciculate Desmoinesian specimens that are apparently *N. cameratus.*

MATERIAL AND OCCURRENCE-Spirifer *goreii* is known only from Morrowan rocks and was first described from the Morrow Group in northeastern Oklahoma, where it is a common species. It is also common in the Wapanucka Formation (Morrowan) in southern Oklahoma. In the Sangre de Cristo area, it is restricted to the Morrowan interval but is widespread in its occurrence. About 80 specimens are in our collections from the following units and locality: 36-46, 41-27, 41-33, 41-42, 41-47, 41-56, 41-58, 47-19, 61-2, 61-6A, 65-40, 68, 90E, 90-G, 90-5, 90-14 to 17, and 92-23 to 27. It occurs most commonly in units 41-42 and 41-47. These units occur in the lower part of the La Pasada Formation in the south and the Flechado Formation in the northern part of the study area. Figured specimens: OU 7833 to 7836.

GENUS *NEOSPIRIFER*

Neospirifer cameratus **(Morton)**
Pl. *15,* figs. 5-8

Spirifer cameratus Morton, 1836, p. 150, pl. 2, fig. 3; White, 1877, pl. 10, fig. la; Girty, 1927, pl. 27, figs. 24, 25.
Neospirifer cameratus, Dunbar and Condra, 1932, pl. 39, figs. 4a, b; Sturgeon and Hoare, 1968, p. 64, pl. 21, figs. 5-8.
Neospirifer goreii, Spencer (not Mather), 1967, p. 12, pl. 13, figs. 2a-d; Sturgeon and Hoare (not Mather), 1968, p. 66, pl. 21, figs. 9-12.

DISCUSSION-Dunbar and Condra (1932, p. 334) reviewed the status and clarified the type locality for this species. They stated that Morton's specimens apparently came from the Vanport Limestone at Putnam Hill, Zanesville, Ohio. M. T. Sturgeon (personal communication) states that the Vanport Limestone is no longer exposed at Putnam Hill, and that the same situation must have existed when Dunbar visited the locality, inasmuch as Dunbar and Condra based their observations on specimens collected by Dunbar from the stratigraphically lower Putnam Hill Limestone exposed at the locality. However, the Vanport Limestone does crop out at several nearby localities, and a small collection of specimens of *N. cameratus* from these other localities were loaned to us by Sturgeon. In general these specimens support the observations made by Girty (1920, p. 645) and by Dunbar and Condra (1932, p. 335); the specimens compare closely with the Girty specimen from the Putnam Hill Limestone that was refigured by Dunbar and Condra (Pl. 39, figs. 4a, b). The specimens we examined from the Vanport Limestone have the following features: the sulcus is relatively broad, low, and rounded, the anterolateral margins are rounded producing a semicircular rather than a triangular anterior margin; only 8 or 10 costae including the P-costae arise at or near the beak; and on the lateral slopes these subdivide irregularly so that the total number of daughter subdivisions at the anterior margin from a principal lateral plication may be 3, 4, or uncommonly 5 or more; the costae are relatively uncrowded on the lateral surfaces and at a distance of 20 mm (SL) there are typically 4 or 5 costae in a space of 5 mm adjacent to the P-costae; and fasciculation is obscure on the anterior slopes of the shell.

Our Sangre de Cristo collections contain large numbers of specimens that we are assigning to this species. They range in age from early Atokan to late Desmoinesian. Many specimens, particularly from our lower Desmoinesian collections (P1. 15, fig. 5), closely match the description from the type region of the species in Ohio. However, within our large collections, there is more variation in the frequency of subdivision of the costae, in the degree of fasciculation, and in the shape of the shell than is represented in the small number of specimens examined from the type region. Our Atokan specimens on the average have less bifurcation of the lateral costae than occurs in the Desmoinesian specimens. Some Desmoinesian specimens are also more alate than typical (Pl. 15, fig. 6) and some have a more prominent and more sharply defined sulcus.

Twenty-nine well-preserved specimens from various Sangre de Cristo localities were selected for close study of the pattern of the costae particularly to compare the characters of this species with *Spirifer goreii.* The three most common patterns, representing 19 of 29 specimens, are illustrated in fig. 35. Among the 29 specimens, 10 different sulcal patterns are observed:

Sulcal formula	Total specimens	Fig.
Symmetrical:		
PCBA.M.ABCP	6	35A
PCBA.mm.ABCP	6	35B
PCBAa.M.aABCP	1	
PCBAa.mm.aABCP	7	35C
PCBa.Aa.mm.aA.aBCP	1	
PDCBA.M.ABCDP	2	
PDCBA.mm.ABCDP	1	
PDCBAa.M.aABCDP	2	
PDCBAa.mm.aABCDP	2	
Asymmetrical:		
PCBA.mm.aABCP	1	

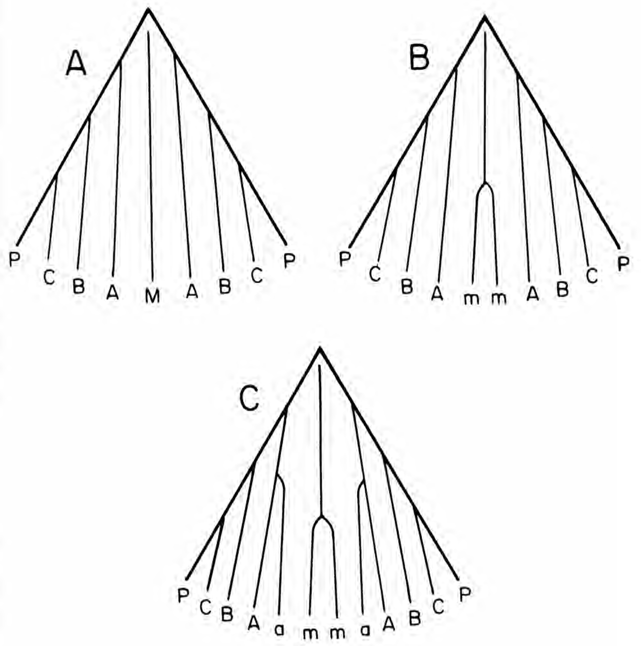


FIGURE 35—*The three most commonly occurring sulcal bifurcation patterns for New Mexico specimens of* Neospirifer cameratus.

The appearance of D-costae and the bifurcation of A-, B- and M-costae apparently are related. Where D-costae are present, the tendency for these costae to subdivide nearer the sagittal plane is less. With one minor exception, the foregoing 10 patterns include the 6 patterns recorded for *Spirifer goreii.* The basic pattern is the same in both species. There are commonly 7 secondary costae, and on a number of specimens a single tertiary costae bifurcates from the median side of each A-costa thus producing a total of 9 costae in the sulcus. Rarely the B-costae or the M-costa bifurcate. Thus, the total number of sulcal costae at the anterior margin for New Mexico specimens of *N. cameratus* is most commonly 7 to 10 but has an observed range of 7 to 12 for mature specimens.

On many of our specimens of *N. cameratus* the groove or saddle between the P-costae at the beak continues anteriorly for as much as $^1/_3$ or $^1/_2$ the length of the shell before the appearance of a definite, elevated M-costa. In contrast, our specimens of *Spirifer goreii* show the M-costa originating 4 to 6 mm from the beak and becoming prominent almost immediately.

Lateral costae are rounded and, at a distance of 20 mm from the beak, number 4 or 5 in a shell width of 5 mm adjacent to the P-costae. Eight or 10 distinct costae, including the P-costae, originate at or near the beak. The bifurcation patterns are highly irregular and all specimens studied are asymmetrical from one flank to the other. No two specimens have identical patterns. Fig. 36B and 36C illustrate the range of variation in our Desmoinesian specimens. The first 3 or 4 lateral costae irregularly subdivide into a total of 3, 4, 5, or more daughter costae, but only a few trifurcate equally at any one point. The costae nearer the cardinal extremities either remain simple or divide only once. One consistent feature in the specimens studied is that the first bifurcation from each principal lateral costa appears to be invariably on the side away from the sulcus (fig. 36). Later subdivision of these costae is irregular and does not follow a pattern. The total number of costae on our specimens averages about 20 to 24 on each lateral slope, but one exceptionally large and elongated specimen (Pl. 15, fig. 8) has a total of 28 costae on one flank. Our specimens from Atokan horizons are similar in other respects to the Desmoinesian individuals in being moderately to distinctly fasciculate, but bifurcation is less frequent on the lateral slopes. They rarely show lateral subdivision of a principal costa into a total of more than 3 daughter costae (fig. 36A). In this respect the Atokan specimens of *N. cameratus,* which number no more than 20 in our collections, suggest a possible evolutionary transition between *Spirifer goreii* from the underlying Morrowan strata, and the overlying Desmoinesian specimens of *N. cameratus.* In other characteristics the transition does not appear gradual. *Spirifer goreii* from New Mexico lacks the regularity of bifurcation of the lateral slopes described here in *N. cameratus;* its lateral costae bifurcate less commonly and more irregularly; it shows limited or no fasciculation even near the beak; and its costae are invariably finer and become fainter on the cardinal extremities. Our Atokan specimens of *N. cameratus* are as fasciculate as those in the Desmoinesian.

Average mature specimens of *Neospirifer cameratus*

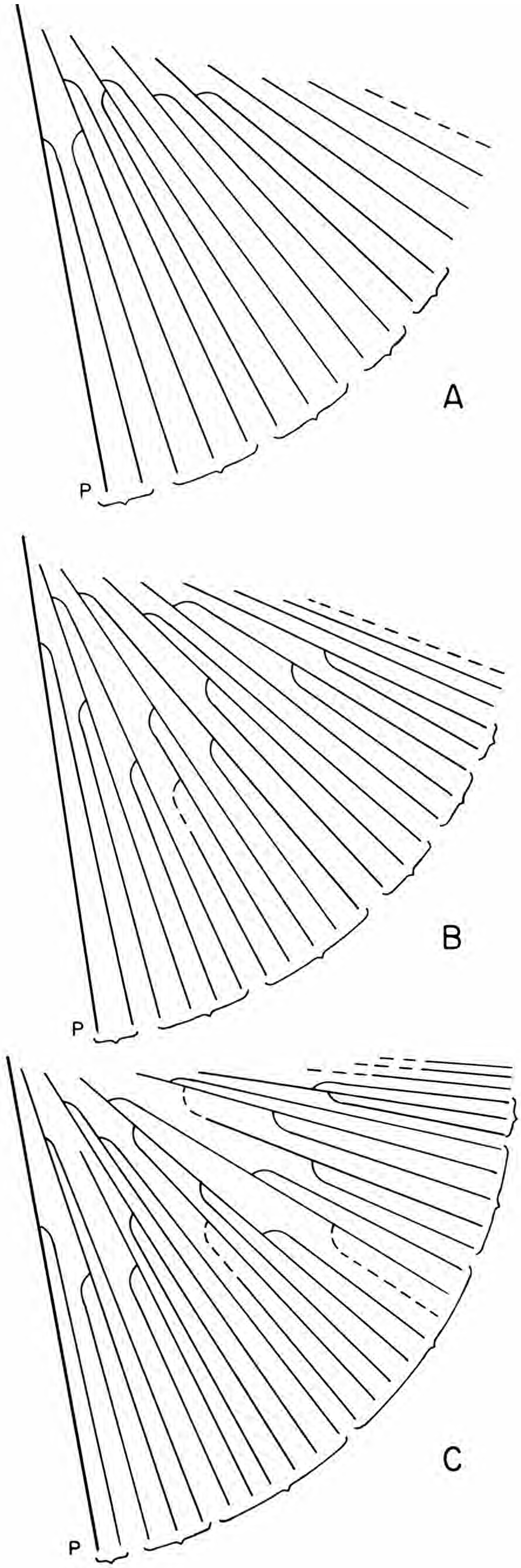


FIGURE *36 Examples of lateral bifurcation patterns for New Mexico specimens of* Neospirifer cameratus. **A** *is from an Atokan specimen and depicts a less complicated pattern;* **B** *and* **C** *are both Desmoinesian.* **C** *represents the left side of fig. 8 on Pl. 15.*

are less transverse in shape than specimens of *Spirifer goreii*, as illustrated in fig. 32. Difference in the slope of the RMA of the two species for width and length is not statistically significant, but the difference in the positions of the lines (z =9.47) that reflects the difference in width-length ratio is very highly significant.

MATERIAL AND *OCCURRENCE—Neospirifer* *cameratus* occurs rarely in our Atokan and commonly in our Desmoinesian collections. About 20 specimens are from Atokan units 62-17 and 18, 67-13, and 67-23. Approximately 150 specimens are from Desmoinesian units and localities 10-11, 10-23, 10-31, 10-58(cf.), 22-89, 29-3, 29-4, 29-5, 29-8, 29-10, 36-109, 36-122, 36-128, 36-133, 40-2, 40-3, 42-15, 60-124, 78, 93-44. All are in the middle to upper part of the La Pasada Formation in the southern and central parts of the area studied, and in the Flechado and Alamitos Formations in the northern region. Figured specimens: OU 7837 to 7840.

Neospirifer tewaensis n. sp.
Pl. 15, figs. 9-11

DESCRIPTION—Mature shells are subquadrate with the width and length subequal and the anterior flanks wide. The holotype has the following dimensions: length 35.2 mm, width 37.4 mm, thickness 23.1 mm and surface length 55 mm. The width-length ratio for shells greater than 25 mm in length is 1.12 (s=0.06). The cardinal extremities tend to be square, and the greatest length may be anterior to the hinge line. The thickness-length ratio averages 0.64 (s= 0. 03).

The pedicle valve is moderately convex. The umbo is not strongly inflated but is distinctly extended posteriorly. The interarea is high and varies from 5 to 6 mm on adult specimens and comprises approximately 1/7 the total length of the specimen. The interarea is distinctly concave and approximately orthocline in attitude. The beak protrudes no more than 1 or 2 mm over the delthyrium. Lateral slopes of the pedicle valve are almost flat. The sulcus is narrow posteriorly and becomes deep and broad anteriorly, producing a strong marginal flexure of the commissure. At the anterior margin the sulcus is rectangular to rounded and the width is equal to, or greater than 1/2 the greatest width of the shell.

In the sulcus are 5 to 9 very low, rounded, and obscure costae. The groove between the P-costae at the beak commonly continues anteriorly for as much as '/3 or 1/2 the length of the shell before the appearance of a definite M-costa, which, in a few specimens, becomes prominently elevated near the anterior margin. The sulcal patterns that have been observed are as follows:

Sulcal formula	Total specimens	Fig.
PBA,M,ABP	3	37A
PBA,mm,ABP	3	
PCBA,mm,ABCP	2	
PCBAa,mm,aABCP	2	37B

In some specimens the anterior part of the sulcus is almost smooth (Pl. 15, fig. 9a), and the sulcal costae tend to be lower and more obscure than the costae on the flanks.

On the lateral slopes the costae vary from low to obscure and are slightly fasciculate only near the beak.

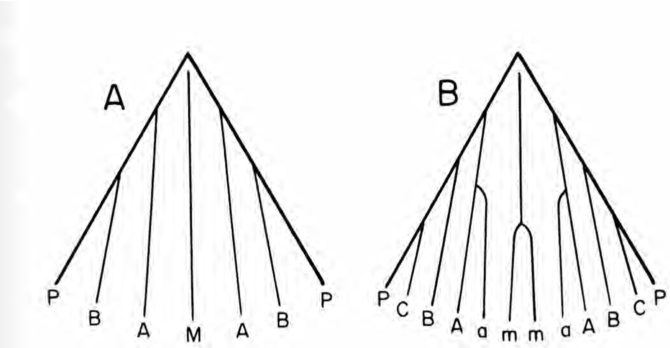


FIGURE *37—The two extreme sulcal bifurcation patterns observed in* Neospirifer tewaensis *n. sp.*

The first 3 or 4 costae birfurcate or trifurcate within a few millimeters of the beak, and a few of these daughter costae may again split. The total number of subdivisions from a single secondary costa is commonly not more than 3 or 4. The total number of costae on a lateral slope is about 20 but a precise count is not possible on most specimens because of the faintness of the plications on the cardinal and anterior parts of the shell. The surface is covered with closely spaced fine concentric fila. The internal characters are unknown.

DISCUSSION—Neospirifer *tewaensis* is characterized by having a length almost as great as the width, and by low, obscure costae. It is not a typical species of the genus. It approaches the genera *Spiriferella* and *Eridmatus* (Branson, 1966, p. 74) in shape; however, the surface pustules or spines that are apparently characteristic of those genera are lacking in this species. The minute surface ornamentation in *N. tewaensis* consists primarily of fine, closely spaced fila and is similar to the surface of *N. cameratus.*

N. tewaensis may be similar to a single pedicle valve described by Hoare (1960, p. 229) as *N. goreii* var. *brevimarginatus* from the Burgner Formation (Atokan) of Missouri. That specimen is even narrower than *N. tewaensis,* having a width-length ratio of 0.91. It is described, however as having a surface ornamentation similar to *S. goreii.*

MATERIAL AND OCCURRENCE—This species **is** rare in our collections from the Atokan (?) and lower Desmoinesian. There are 13 specimens from lower Desmoinesian units 29-3, 40-2 and 93-44. Eight specimens come from unit 93-44. One specimen is from the talus in the Atokan unit 36-79 and could have come from the overlying Desmoinesian. These units occur in the middle part of the La Pasada Formation in the southern and central part of the area studied. Figured specimens: OU 7841 to 7843.

Neospirifer alatus Dunbar and Condra
Pl. 17, figs. 1-5

Neospirifer triplicatus var. *alatus* Dunbar and Condra, 1932, p. 332, pl. 38, figs. 11, 12.
Neospirifer latus Dunbar and Condra, 1932, p. 336, pl. 40, figs. 1-5.
Spirifer cameratus, Mark (not Morton), 1912, p. 304, pl. 14, figs. 1, 2,; Morningstar, 1922, pl. 9, figs. 11, 12.

DISCUSSION—Study of the type specimens of *N. triplicatus* var. *alatus* and *N. latus* led us to the conclusion that they are the young and adult, respectively, of the same species. Significant differences could not be detected at corresponding growth stages; in addition, the two occur together in the Missouri Series. The name *N. alatus* is chosen by page priority in the original publication. A combination of the two descriptions given by Dunbar and Condra is adequate for this distinctive species.

This large species is present in characteristic form in several of the Missourian horizons in the Alamitos Formation in the Pecos and Alamitos valleys. Our specimens are mostly distorted or exfoliated but have the distinguishing features of large size, transverse form, and coarse bundling of the plications. The specimens in our collection, however, show considerable variation for all of these characters. Some specimens are distinctly transverse (Pl. 17, fig. 1) and others are more elongated than typical (Pl. 17, fig. 5) giving great variation in width-length ratios.

The most noticeable variation in this species is in the strength of the fascicles on the lateral slopes that both Dunbar and Condra's type specimens, and our specimens from near Pecos, display. Two specimens from the same locality may be quite different in this respect, one having high angular fascicular ridges and the other having low, rounded, obscure fascicles. A characteristic feature of the more fasciculate specimens is that the lateral fascicular ridges may be as high as the one formed by the P-costae, and fully developed to the anterior margin. In *N. cameratus* the magnitude of the fascicles decreases toward the anterior slopes.

In the sulcus the M-costa originates 4 to 8 mm from the beak and is approximately the same magnitude and elevation or may be somewhat wider in some instances than the other sulcal costae. The sulcal costae are typically symmetrical and commonly number 9 to 11 (fig. 38). Variations observed among 21 specimens studied are as follows:

Sulcal formula	Total specimens	Fig.
Symmetrical:		
PCBA,mm,ABCP	1	
PCBAa,mm,aABCP	1	
PCBAa,M,aABCP	9	38A
PCBa,Aa,M,aA,aBCP	4	
PDCBAa,M,aABCDP	1	
PDCBAa,mm,aABCDP	3	
PCBAbal,lmml,labABCP	1	38B
Asymmetrical:		
PCBa,Abal,mm,aA,aBCP	1	

These specimens compare closely with Dunbar and Condra' s figured type specimens. One large exceptionally transverse specimen, listed above, has a total of 16 sulcal costae by additional bifurcation of the M- and A-costae (fig. 38B).

Laterally 2 or 3 costae commonly split from each of the P-costa. The next 3 principal lateral costae tend to trifurcate irregularly at about 6 to 10 mm (SL) from the beak, and because of further irregular splitting, the total number of subdivisions at the anterior margin is commonly 5 to 7 for each original costa (fig. 39). Farther laterally, several secondary costae may each split into 2 or 3 branches. The costae on the cardinal extremities are simple. On the few specimens in our collections on

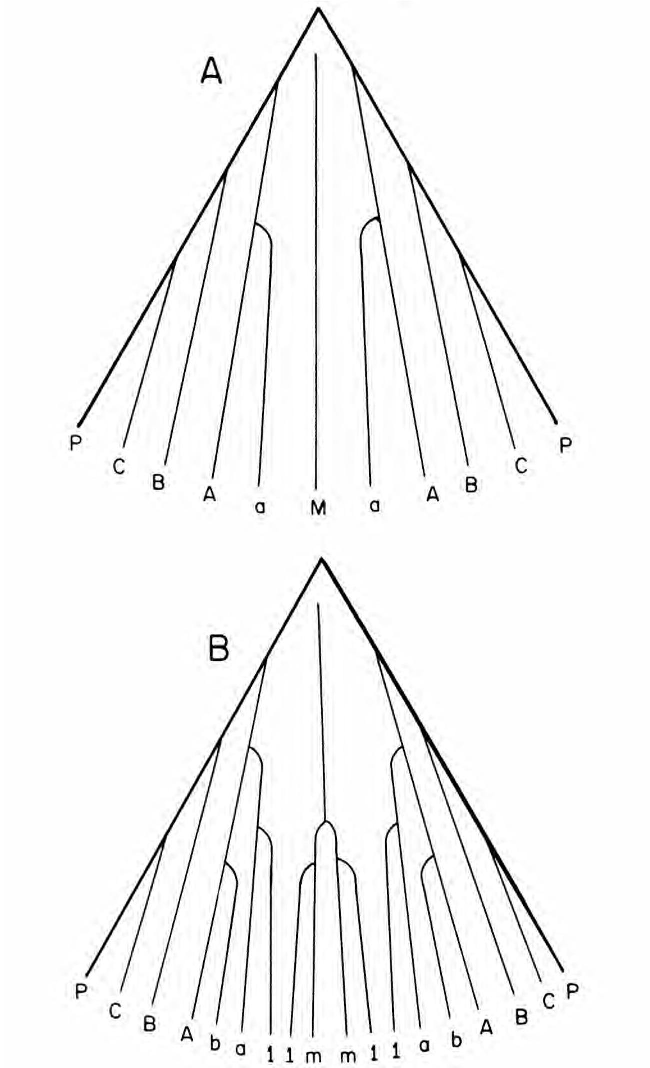


FIGURE *38—Sulcal bifurcation patterns for New Mexico specimens of* Neospirifer alatus. *Compare A with Pl. 17, fig. 4, and B with Pl. 17, fig. 1, the same specimens.*

which the total number of lateral costae can be counted, 22 to 27 or more costae are on each side.

N. alatus differs from *N. cameratus* in being much larger and much more highly fasciculate, in having a greater degree of subdivision of the costae on the lateral slopes, and in commonly being more transverse than typical for the genus. The sulcal formulae for the 2 species is similar but the average number of sulcal costae is greater in *N. alatus.* Variants of *N. alatus* with low fasciculation bear superficial resemblance to some specimens of *N. cameratus* (compare Pl. 15, fig. 8 with Pl. 17, fig. 5) but these specimens of *N. alatus* show a greater degree of subdivision of the costae at the same surface length for both lateral and sulcal costae.

MATERIAL AND OCCURRENCE—N. *alatus* occurs Commonly at several horizons in the middle part of the Alamitos Formation in the southern part of the area studied, the only local area in which fossiliferous Upper Pennsylvanian rocks are exposed. These horizons are Missourian. Good specimens are difficult to extract from the limestones, and most of 70 specimens in our collections are exfoliated or crushed. This species occurs

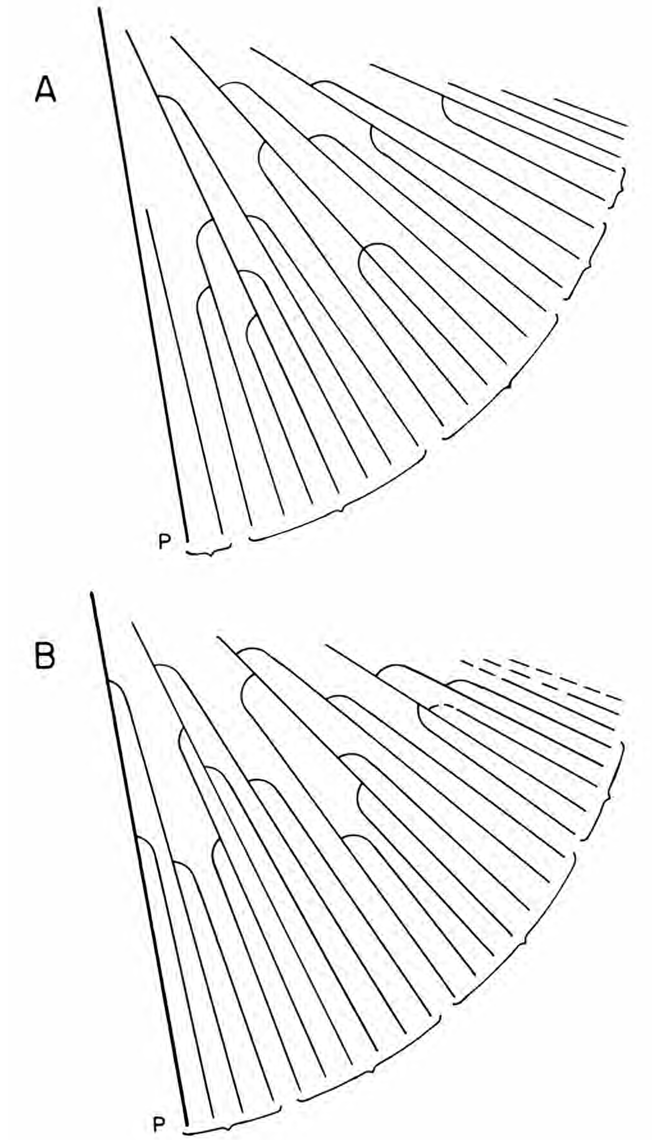


FIGURE *39—Examples of lateral bifurcation patterns for New Mexico specimens of* Neospirifer alatus. A *is the most commonly observed and B is the most complex (same as fig. 1 on Pl. 17).*

commonly in units 96-40, 97-54, and 97-60. It occurs uncommonly in units 96-30 and 96-51. Figured specimens: OU 7844 to 7848.

Neospirifer dunbari? King
Pl. 17, fig. 6

Spirifer triplicata Hall, 1852, p. 410, pl. 4, fig. *5.*
Neospirifer triplicatus, Dunbar and Condra, 1932, p. 328, pl. 41, figs. 1-6.
Neospirifer dunbari King, 1933, p. 441; Sturgeon and Hoare, 1968, p. 62, pl. 20, figs. 8-15.

DISCUSSION—King (1933, p. 443) pointed out that Kutorga in 1842 used the name *Spirifer triplicata* so that Hall's name is a homonym. While King considers that the specimens described by Dunbar and Condra (1932) are typical, he states "the name *Neospirifer dunbari is* proposed for the species originally named *Spirifer triplicata* by Hall." In evaluating this species, therefore, we must return to Hall's original description:

Shell subquadrangular, dorsal valve more gibbous than the ventral; area nearly linear; beak of dorsal valve small, acute, and closely incurved; mesial depression shallow in the upper part, but becoming deeper and expanded toward the base, and produced in front; entire surface, including the mesial sinus and elevation, covered with fine plications, which, being simple in their origin, soon divide into three, which are continued to the base without further division.

This species differs from the *S. striatus*, Sowerby, in its form, and in the circumstance that the plications are less subdivided toward the margin of the shell. Loc. Missouri River, above Weston.

Note the interchange from the modern usage of "dorsal" arid "ventral." Hall emphasized the meager splitting of plications, and, in particular, those that trifurcate do not split further. Dunbar and Condra (1932, p. 329) gave an expanded description of this species in which they pointed out that the 3 costae that subdivide from a main lateral costa did not commonly further subdivide.

Almost all our specimens from the Sangre de Cristo area are poorly preserved and exfoliated but appear to agree in essential aspects with Dunbar and Condra's description and their figured specimens, which we have examined. Most of our specimens are smaller and incomplete.

The costae were examined in 22 Sangre de Cristo specimens and the number of sulcal costae varies from 9 to 13. The pattern for 9 of 22 specimens is: PCBAa,M, aABCP (fig. 40A). There are 10 minor variations from this pattern in the 22 specimens of which 7 specimens have an asymmetrical pattern.

On the lateral slopes the first 3 principal costae subdivide into 3 costae (fig. 40B), and in 20 of 22 specimens there is no further subdivision of these costae. The costae nearer the extremities either bifurcate once or are simple.

N. dunbari differs from *N. alatus* in being much smaller, in having a triangular shape, with much less extensive subdivision of the costae, and in having minor fasciculation. It differs from *N. cameratus* in having a triangular shape, and fascicules, when present, that extend to the anterior margin.

MATERIAL AND OCCURRENCE—Hall's type specimens for this species are from the Virgilian in Missouri. Dunbar and Condra (1932, p. 331) state that it commonly occurs in both the Missourian and Virgilian in the Midcontinent. In the Sangre de Cristo area this species occurs only at two Virgilian localities in the upper part of the Alamitos Formation near the town of Pecos. About 80 poorly preserved specimens are from units 96-57 and 98-3. Figured specimen: OU 7849.

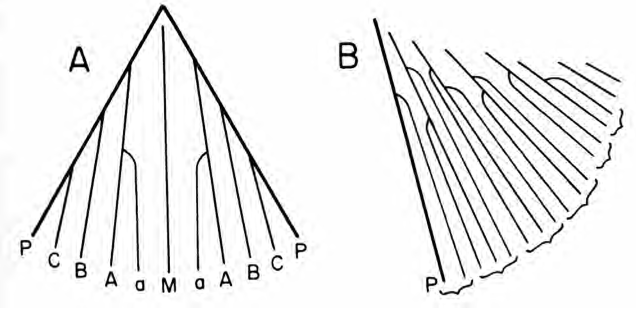


FIGURE *40—Sulcal and lateral bifurcation patterns for New Mexico specimens of* Neospirifer dunbari?. A *is the most common sulcal pattern observed.* **B** *shows the characteristic feature that most lateral costae subdivide no further than three.*

GENUS *ANTHRACOSPIRIFER*

DISCUSSION—A wide variety of species with a small number of mostly simple plications clearly do not belong in *Spirifer* (s.s.) as described in this paper. For forms with strongly extended cardinal extremities, Campbell (1957, p. 67) proposed the generic name *Unispirifer* based on a Lower Carboniferous species from Australia. In North America the Lower Mississippian species *Spirifer forbesi* Norwood and Pratten would be included in this genus.

Lane (1963, p. 387) proposed the name *Anthracospirifer* for a small Lower Pennsylvanian species from Nevada having a small number of simple or sparsely bifurcating plications, and also referred to this genus other Lower Pennsylvanian species as *S. matheri* Dunbar and Condra, *S. opimus* Hall, and *S. occiduus* Sadlick. In addition, we would include in this distinctive group the following North American Mississippian species: *Spirifer pellaensis* Weller, *S. bifurcatus* Hall, *S. increbescens* Hall, and *S. leidyi* Norwood and Pratten. We also include the following new species and subspecies described in this paper from the Lower and Middle Pennsylvanian of northern New Mexico: *A newberryi* n. sp., *A. curvilateralis tanoensis* n. subsp., *A. curvilateralis chavezae* n. subsp. and *A. mcalesteri* n. sp. The genus *Anthracospirifer,* as delineated in this paper, thus ranges from Lower Mississippian to Middle Pennsylvanian.

Both *Brachythyrina* Fredericks (1929) and *Sergospirifer* Ivanova (1952) appear to be similar to *Anthracospirifer;* with additional information, either genus may be shown to be a valid senior synonym of this genus.

The genus *Anthracospirifer* includes small to medium-sized Spiriferidae in which the hinge line is equal to or greater than the greatest width, but in which the shell is not mucronate. The number of plications is few compared with *Spirifer* or *Unispirifer.* The simpler forms have: 1) a median sulcal plica (M) originating near the beak, 2) undivided lateral sulcal plicae (A, B, C, etc.) that originate by splitting from the prominent P-plicae bordering the sulcus and 3) simple lateral plicae, with the exception that the first lateral plicae invariably split from the P-plicae at 1 to 4 mm (SL). These characteristics are typical of most Mississippian and some Lower Pennsylvanian species. In more complicated forms limited bifurcation of sulcal plicae may occur, and the first 1 to 4 plicae on the lateral slopes may bifurcate regularly or irregularly but do not commonly trifurcate (e.g., *A. matheri* and *A. opimus).*

The splitting of the first lateral plication from the P-plica varies so little that this feature is worth noting. Another consistent feature is that this first lateral plica splits from the P-plica nearer the beak than the first secondary plica in the sulcus (A-plica) that splits from the P-plica at 3 or more millimeters. These patterns are not unique to *Anthracospirifer*, and have been observed in at least some species of *Spirifer* and *Neospirifer.* The origin of other lateral plicae is obscure in most specimens. On a few shells the next 3 or 4 appear to originate at or near the beak but, clearly, in most species of the genus *Anthracospirifer,* plicae beyond the 3rd or 4th cannot have originated from the beak.

Anthracospirifer newberryi n. sp.

Pl. 16, figs. 1-4

DESCRIPTION—The shell is medium size and distinctly transverse but not mucronate; the greatest width lies along the hinge line. A larger shell from the type locality has the following dimensions: length 23 mm, width 39 mm, thickness 15 mm, and surface length 32 mm. The fold and sulcus are almost lacking in some specimens and are invariably low and not produced anteriorly. The species shows little variation from one individual to another. No marked change in the width-length ratio with growth is apparent after the shell has reached a width of at least 15 to 20 millimeters. The width-length ratio has a mean of 1.59 and a standard deviation of 0.06 for a sample of 22 specimens from the type locality. A few exceptional shells are more alate in the middle stages of growth. Fig. 41A is a scatter diagram with width plotted against length. The high coefficient of correlation (r =0.94) also indicates a relatively constant growth ratio. See Appendix 2, tables 17-19, for additional statistics. Specimens from other localities are approximately the same size as those recorded from unit 61-11, with the exception that specimens from the Atokan locality 64 are much larger, one specimen having a length of 28.1 mm and a width of about 47 mm.

The pedicle valve has a low convexity and the umbo is moderately arched. The beak is small and projects dorsally only 1 to 2 mm. The interarea is flat and about 1/7 the total width in height. Its attitude is orthocline (Pl. 16, fig. le). In the shallow, obscure sulcus, are 3 plicae in 29 of 30 specimens studied from unit 61-11 (fig. 42). The specimens from this unit have the A-plicae bifurcating from the borders of the sulcus at distance of 4 to 10 mm (SL). In a single specimen a pair of obscure B-plicae are also produced giving 5 plicae in the sulcus. The typical sulcal formula is thus PAMAP. Of approximately 125 specimens from 15 other localities only 6 specimens have obscure B-plicae developed, the others all having a total of only 3 plicae in the sulcus. The M-plica is typically larger and more elevated than the others, and on only one large specimen does it show a tendency to split. On each lateral slope are 10 to 14 plications. They are wide, low, evenly expanding, rounded and number 7 or 8 in 10 mm at midlength. They are simple except that the first splits from the P-plica at a surface length of 3 to 4 mm in a manner typical for the genus. The next 3 to 4 plicae arise very close to the beak. Several specimens show a very faint longitudinal groove along the top of each of the lateral plications.

The brachial valve is more convex than the pedicle with the umbo slightly inflated. The fold is low at the anterior margin. The lateral slopes are slightly concave posteriorly.

Poorly preserved interiors of the pedicle valve from locality 64 show that the dental plates are stout and do not extend to the floor. Adjacent to the interarea the valve is unusually thick for the size of the shell.

Both valves are finely sculptured with fine concentric fila crossed by finer, lower, radial capillae.

DISCUSSION—This species is distinguished by its transverse shape, thinness, simple, low, and broadly

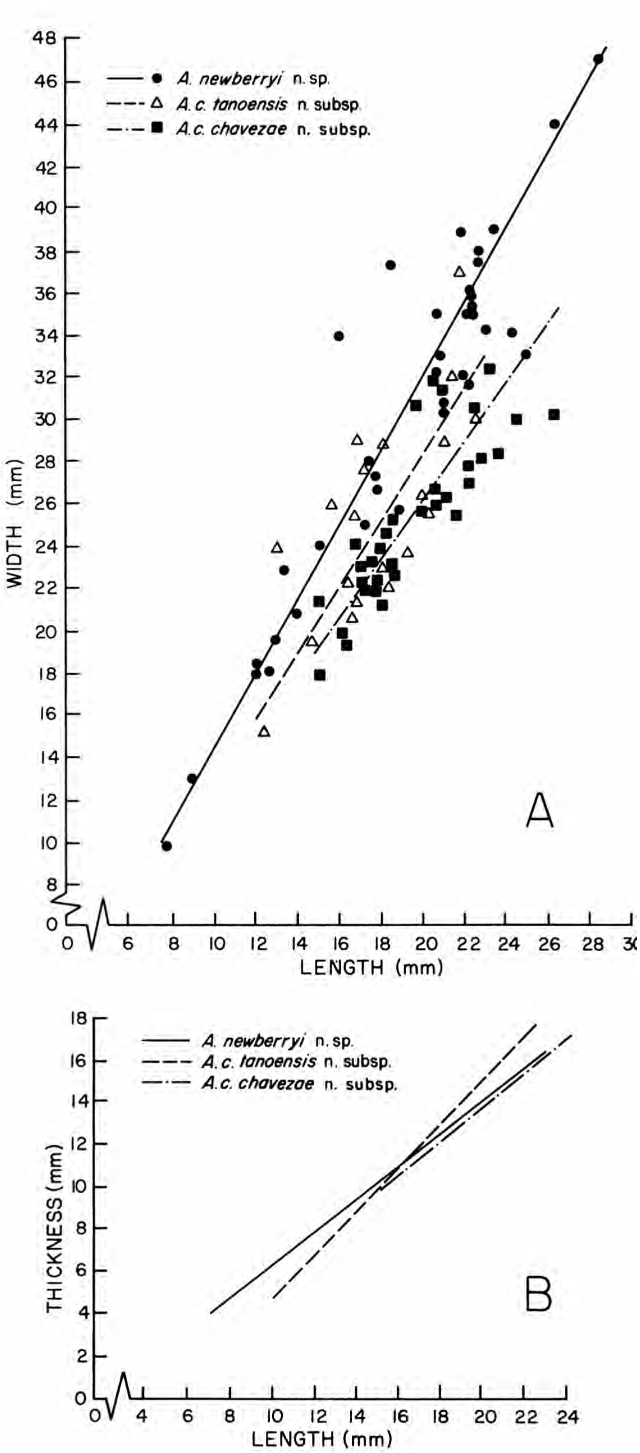


FIGURE 41 —**A.** *Plot of width vs length for 37 specimens of* Anthracospirifer newberryi *from Morrowan locality 61-11, 23 individuals of* A. curvilateralis tanoensis *from various Morrowan localities, and 37 specimens of* A. curvilateralis chavezae *from various lower Desmoinesian localities. The reduced major axes are calculated, respectively, to be as follows:* $W = -3.12 + 1.76 L$; $W = -3.38 + 1.59 L$; *and* $W = -1.71 + 1.40 L$.

B. *Thickness-length diagram showing position of RMA's for* A. newberryi, A. curvilateralis tanoensis, *and* A. curvilateralis chavezae. *They are calculated, respectively, as follows:* $T = -0.46 + 0.67 L$; $T = -5.41 + 1.00 L$; *and* $T = -2.11 + 0.79 L$.

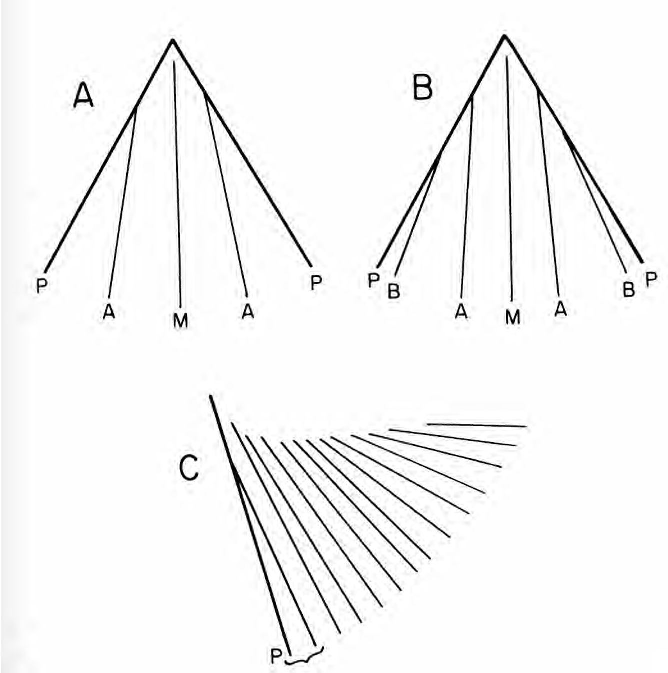


FIGURE *42—Sulcal and lateral bifurcation patterns in* Anthracospirifer newberryi. **A** *is sulcal pattern found in 29 of 30 specimens examined.* **B** *is a single specimen with an obscure pair of B-plicae.* **C** *shows lateral plications are invariably simple.*

rounded plications, and by its shallow sulcus with 3 plications of which the middle one is broad and elevated.

This species most closely resembles *Spirifer washingtonensis* Weller, from the Keokuk (Lower Mississippian) of the Midcontinent in the width-length ratio and in the simple nature and number of the plications. It differs from that species in having less highly arched valves with resulting thinness of shell, a lower fold and sulcus, and a smaller average size.

This species is similar to *A. curvilateralis tanoensis* (with which it sometimes occurs) in having 3 plicae in the sulcus and simple lateral plications. *A. newberryi* differs in being thinner and distinctly more transverse in shape (fig. 41), in having broader, more flattened plications, and in having a consistently shallower sulcus although this feature varies in both species. Statistically, the slopes of the reduced major axes for width and length do not differ significantly between *A. curvilateralis tanoensis* and *A. newberryi* (z=0.85). However, the difference between the position of the lines of the two species (z =13.96) is very highly significant, when calculated at the mean length of *A. tanoensis.* A highly significant difference is present between the slopes of the RMA's for thickness and length.

MATERIAL AND OCCURRENCE—A. *newberryi* occurs widely in Morrowan rocks in the Sangre de Cristo area and also is present at 2 localities in the lower Atokan. About 120 specimens are in our collection from the following Morrowan units: 22-41, 36-38, 36-63, 36-68, 41-39, 41-47, 60-18, 61-6A, 61-11 (type locality) 65-40, 90-7, 90-14 to 17, 90-18, 93-15 and 16(cf.), 93-25. About 60 specimens are from the lower Atokan unit 36-71 and locality 64. All these units and the locality are in the lower part of the La Pasada Formation in the south, or in the lower part of the Flechado Formation in the north. Figured specimens: holotype OU 7850; paratypes OU 7851, 7852; other specimen OU 7853.

Anthracospirifer curvilateralis (Easton)

Spirifer curvilateralis Easton, 1962, p. 68, pl. 9, figs. 14, 17.
Anthracospirifer curvilateralis, McGugan and May, 1965, p. 32, pls. 11-13.

DISCUSSION—Easton (1962, p. 68) based the species *A. curvilateralis* on specimens from the Heath Formation in central Montana but states that the species also occurs in the overlying Cameron Creek and Alaska Bench Formations. The precise age of these formations is not in agreement. Easton considers all three formations to be Late Mississippian but states (1962, p. 15) that most members of the U.S. Geological Survey consider the upper two Pennsylvanian. Maughan and Roberts (1967, p. B3) assigns a Chesterian (Late Mississippian) age for the Heath, a Morrowan age for the Cameron Creek, and a part Morrowan and part Atokan age for the Alaska Bench Formation.

Easton (1962, p. 70) describes the variation in number of plications in the sulcus and on the lateral slopes in 56 specimens of *A. curvilateralis* from the type locality in the Heath Formation. Of these 5 (9 percent) have 3 plicae, 45 (80 percent) have 5 plicae and 6 (11 percent) have 7 plicae in the sulcus. However, he does not state if specimens in the overlying formation show differences from those in the Heath Formation.

McGugan and May (1965, p. 31) describe the variation in shape and in number of plications on the lateral slopes in 381 silicified specimens of *A. curvilateralis* from a single horizon and locality in the lower part of the Tunnel Mountain Formation they consider late Chesterian or Morrowan. They state that their specimens have 3 to 5 plications in the sulcus but do not indicate the specific number of specimens with 3, 4, or 5.

In the southern Sangre de Cristo region, brachiopods similar to *A. curvilateralis* occur in rocks ranging from Morrowan to middle Desmoinesian. The differences between our Morrowan and Desmoinesian forms are distinctive in both the shape of the shell and in number of plications in the sulcus. The Morrowan forms have a comparatively low curvature with an uninflated umbo and commonly have only 3 plications in the sulcus. The Atokan forms are transitional. Our Desmoinesian forms have a more inflated umbo, and typically have 5 plications in the sulcus. Thus, our Desmoinesian and not our Morrowan specimens appear to agree most closely in external characters to Easton's figured type specimens from what are apparently Upper Mississippian strata. Our Desmoinesian specimens differ in not having the beak "sharply enrolled over the cardinal area" (Easton, 1962, p. 68).

The apparent discrepencies implied in this comparison between the exteriors of specimens from New Mexico and from Montana appear to result from either 1) an incorrect age evaluation in one area or the other, or 2) the overall lack of information about the complex interwoven series of evolving lineages found in this stock of brachiopods in the upper Paleozoic. The latter explanation appears more likely, and is compounded by the inability to order and evaluate the highly variable shell features present. Possibly the New Mexico forms have evolved independently from those in Montana; a close comparison of specimens from the two areas could show that the apparent homotaxis, based on exteriors only is invalid.

The meaningful delineation of species must come from the eventual, careful description and evaluation of variation found not only at single horizons but also from series of horizons in the same sequence or local area. McGugan and May (1965, p. 34) report that variants occur in their collections of several hundred specimens of *A. curvilateralis* from one locality that are indistinguishable from *A. opimus* and *A. occiduus.* One can only speculate as to which of the traditional lower and middle Pennsylvanian species *A. opimus, A. occiduus, A. rockymontanus,* and *A. matheri,* all originally defined as typological species and all still inadequately delineated, will survive future study.

We agree with McGugan and May (1965, p. 34) that either supporting or refuting Sadlick's (1960, p. 1213) proposed phylogenies of Late Mississippian-Early Pennsylvanian species of *Anthracospirifer* based primarily on intuitive evaluation is impossible. The recognition of lineages can be based only on the comparison of carefully established local phylogenic sequences.

In this memoir new subspecies of *A. curvilateralis* are designated for the distinctive Morrowan and Desmoinesian assemblages from New Mexico. These forms are considered to be geographical and chronological subspecies in the sense discussed by Sylvester-Bradley (1956, p. 3). The names *A. opimus, A. occiduus, A. rockymontanus* and *A. matheri* are utilized as typological species for the description of small numbers of specimens.

Anthracospirifer curvilateralis tanoensis n. subsp.

P1. 16, figs. 5-10

DESCRIPTION—The shell is medium size and moderately transverse with lateral extremities square or slightly produced. The holotype has the following dimensions: length 22.1 mm, width 23.0 mm, thickness 11. 0 mm and surface length 26 mm. Plots for width against length and thickness against length are given in fig. 41. Additional statistics are given in Appendix 2, tables 17 to 19.

The pedicle valve has a low to moderate convexity. The umbo is not inflated and the beak protrudes over the interarea no more than about 1 mm. The interarea is slightly concave and occupies about '/8 the total length in height. The attitude of the interarea is moderately apascline with the narrow interarea on the brachial valve being approximately orthocline. The sulcus is well developed and moderately deep at the anterior margin. In 41 of 54 specimens studied there are 3 plicae in the sulcus (fig. 43) with the A-plicae arising 3 to 7 mm (SL). Other variants occurring in association are 1) specimens having a faint indication of the development of a B-plica on either one or both sides of the sulcus (5 of 54 specimens), and 2) specimens in which B-plicae are definitely developed but are invariably smaller than the other plicae and remain close to the P-plicae throughout growth (8 of 54 specimens) .

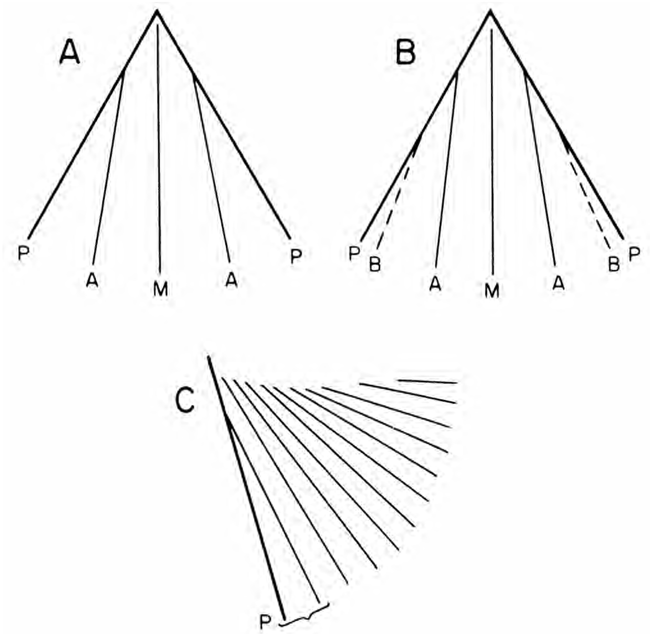


FIGURE *43—Sulcal and lateral bifurcation patterns in* Anthracospirifer curvilateralis tanoensis. **A** *is sulcal pattern found in 41 of 54 specimens examined.* **B** *is rare sulcal pattern in which small B-plicae are present but lie close to the P-plica.* **C** *shows lateral plications are most commonly simple.*

Statistically, the difference (z =2.26) in the number of plicae in the sulcus (fig. 44) between the Morrowan forms of this subspecies (average 3.5 plicae) and the lower Atokan forms (average 4.0) is highly significant. However, we have not placed the lower Atokan forms in a different subspecies because of the lack of additional differentiating characteristics. On each lateral slope are typically 10 plications, 11 are common; one specimen with 12 and one with 13 have been observed. The first lateral plication invariably splits from the P-plica near the beak. The remaining lateral plications are simple in all specimens studied except for 3 of 6 specimens from unit 90-2 in which the second lateral plication splits into equal parts at about 8 or 9 mm (SL).

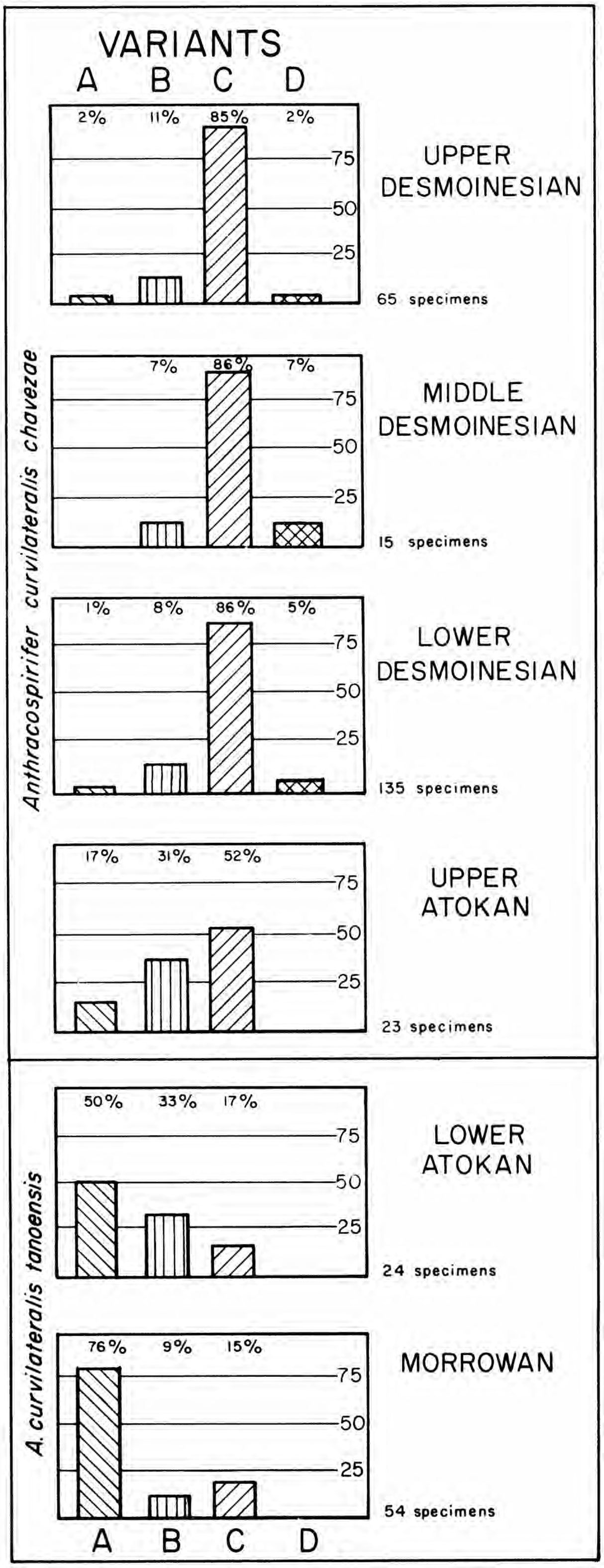
The brachial valve in lateral profile is posteriorly convex, but straight beyond midlength giving a valve of low average convexity. The fold, containing typically 4 plications, is low posteriorly but becomes arched and extended just behind the margin. Lateral slopes are moderately convex except posterolaterally where a slight concavity is present giving the appearance of a dorsal deflection of the extremities. Internal features are unknown.

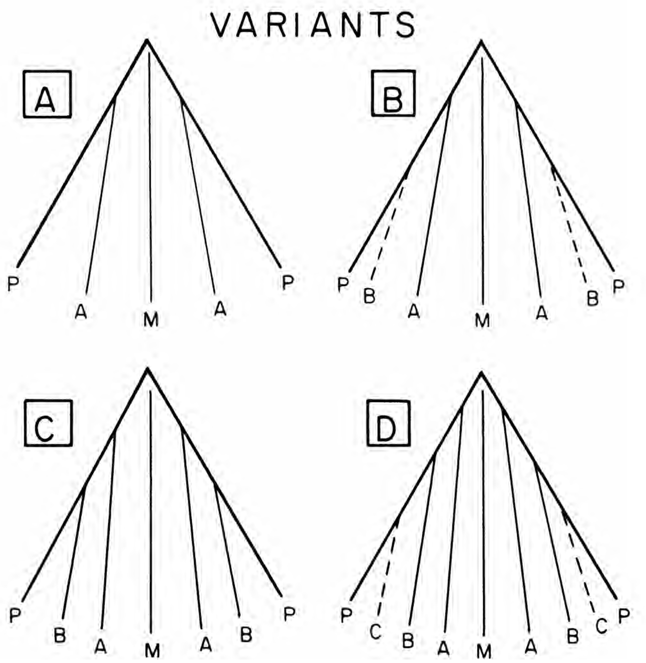
The surface of both valves is marked by fine, evenly spaced, sharply defined fila of which there are 6 or 7 per mm. These fila are crossed by less pronounced, low, parallel radial capillae that make the crests of the reticulations appear fringed with tiny pustules (Pl. 16, fig. 10).

DISCUSSION—A *curvilateralis tanoensis* n. subsp. is closely related to *A. curvilateralis chavezae* n. subsp. but the differences between the two are consistently associated with a difference in age in the Sangre de Cristo area. *A. curvilateralis tanoensis* is present in Morrowan rocks, and at two localities, in early Atokan rocks; while

A. curvilateralis chavezae occurs in later Atokan and Desmoinesian rocks. *A. curvilateralis chavezae* is slightly larger in average size (fig. 41).

The difference in the slopes of the reduced major axes for width and length (z=0.92) between *A. curvilateralis tanoensis* and *A. curvilateralis chavezae* is not statistically significant; however, at 99 percent confidence limits, a difference between the position of the width-length RMA's is detected (z=6.73). Although no significant difference is found between the slopes of the RMA's for thickness and length for the two subspecies (z=0.72), the difference between their positions for thickness and





The six graphs show the percentage variation in the number of plications in the sulcus to be found at different horizons in individuals of A. curvilateralis tanoensis *and* A. curvilateralis chavezae. *These two subspecies form an evolutionary lineage in which the number of plications in the sulcus increases from principally 3 to 5 or more in the interval from Morrowan to Desmoinesian.*

Variant A, *has 3 plications, consisting of a central M- and two A-plicae;* Variant B, *has 4 or 5 plications, in which 1 or 2 indistinct B-plicae are present but remain close to the P-plicae throughout growth;* Variant C, *has 5 plications, all are distinct but in the Morrowan, lower A tokan and upper A tokan intervals the two B-plicae remain close to the P-plicae throughout growth;* Variant D, *has 6 or 7 plications, in which one or two indistinct C-plicae are present that remain close to the P-plicae throughout growth.*

The 54 specimens from the Morrowan interval are from the following units: 36-48, 41-29, 41-33, 41-42, 41-47, 47-19, 60-38, 61-2, 65-48, 65-63, 90-2, 90- 7, 90-14 to 17, 92-29, 92-23, 92-34. The 24 specimens from the lower Atokan interval are from the following units: 62-17 and 18 and 67-13. The 23 specimens from the upper A tokan interval are from the following units: 62-28, 67-23 and 67-30. The 135 specimens from the lower Desmoinesian interval are from the following units: 10-19, 29-3 to 10, 36-97, 36-128, 40-3, 47-37, 93-44. The 15 specimens from the lower middle Desmoinesian interval are from the following units: 10-36, 36-150. The 65 specimens from the upper middle to upper Desmoinesian interval are from the following units: 25-27,

FIGURE 44—*Evolution of* Anthracospirifer curvilateralis tanoensis *and* A. curvilateralis chaveza

length (z =2.60) is highly significant. Typically, *A. curvilateralis chavezae* has a greater number of plications in the sulcus and on the flanks. In *A. curvilateralis tanoensis*, 3 plications are most common; those that have 4 or 5 plications differ from the typical specimens of *A. curvilateralis chavezae* in that the B-plicae are obscure, smaller than the adjacent ones, and lie close to the P-plica throughout growth.

Almost invariably *A. curvilateralis chavezae* has 5 sulcal plicae. A highly significant statistical difference (z =4.70) exists, with respect to the number of plications in the sulcus, between the specimens assigned to *A. curvilateralis tanoensis* (lower Atokan) and the upper Atokan forms placed in the subspecies *A. curvilateralis chavezae* (fig. 44). The lower Atokan specimens have a mean of 4.0 plications in the sulcus, whereas the collections from the upper Atokan average 4.7 plications. Between the two species, the difference in the distance from the beak at which the B-plicae originate is not consistent. *A. curvilateralis chavezae* typically has 11 or 12 lateral plications instead of 10 as in *A. curvilateralis tanoensis. A. curvilateralis chavezae* also has a somewhat more highly inflated umbo producing a thicker shell, and a beak that protrudes more over the delthyrium. We consider *A. curvilateralis tanoensis* to be the direct ancestor to *A. curvilateralis chavezae* and to have given rise to that subspecies by the development of additional sulcal and lateral plications that accompany a slight increase in size and a slight change in shape (fig. 44).

A. curvilateralis tanoensis is similar to *A. newberryi* n. sp., with which it may occur, in having 3 plications in the sulcus and in having simple lateral plications. It differs from *A. newberryi* in being distinctly less transverse, in having smaller more angular plications, and in having a deeper, better-developed sulcus. *A. curvilateralis tanoensis* resembles *A. leidyi* Norwood and Pratten (from the Chester Series of Illinois) in general form and nature of bifurcation of the plications but differs from that species in having a much thinner shell, more and finer plications, and sulcal plications of almost equal magnitude.

MATERIAL AND OCCURRENCE—*Anthracospirifer curvilateralis tanoensis* is widespread in the Morrowan rocks of the Sangre de Cristo area but does not occur commonly at any single locality. It has also been found at two lower Atokan localities. We have 62 specimens in our collections from the following 19 units: Morrowan: 36-48, 36-67, 41-33(?), 41-42, 41-47 (type locality), 41-49(?), 47-19, 47-21, 60-38, 61-2, 65-40(?), 65-48, 65-63, 90-2, 90-7(?), 90-14 to 17, 92-19, 92-23 to 27, 92-34, 93-15 and 16; Atokan: 62-17 and 18(cf.), 67-13(cf). These units are in the lower part of the La Pasada Formation in the south, and the Flechado Formation in the north. Figured specimens: holotype OU 7854; other figured specimens OU 7855 to 7859.

Anthracospirifer curvilateralis chavezae n. subsp.

Pl. 16, figs. 11-16; Pl. 17, figs. 10-12

Spirifer boonensis?, Girty (not Swallow), 1903, p. 381, pl. 6, figs. 1-3.
Spirifer occidentalis, Dunbar and Condra (not Girty), 1932, p. 322, p1. 41, figs. 12-16; Foster (not Girty), 1942, p. 249, fig. 1.

DESCRIPTION—The shell is medium size, and the cardinal extremities have angles that generally range from 70 to 90 degrees; a few specimens have acute extensions. Width-lengh and thickness-length plot are given in fig. 41. For additional statistics, see Appendix 2, tables 17 to 19.

The umbo of the pedicle valve is moderately inflated. The interarea is distinctly apsacline, slightly concave, and is about 1/7 to 1/8 the total length in height. The beak is not strongly incurved over the interarea. The sulcus typically is well defined, but varies in the degree of angularity of its borders. A mature shell almost invariably possesses 5 sulcal plicae (220 of 238 specimens studied) but the range of variation is from individuals with 3 plicae (7 specimens) to specimens with 4 or 5 plicae in which the B-plicae are faint (38 specimens) to, at the other extreme, rare specimens with 6 or 7 plicae in which the C-plicae are faint (fig. 45). The A-plicae are inserted at a surface length of about 4 mm; and B-plicae, at 9 to 13 mm from the beak. A highly significant statistical difference in the number of plications in the sulcus (z=2.60) is computed between the samples from the upper Atokan horizons (fig. 44) and those from the lower Desmoinesian localities. The upper Atokan forms average 4.7 plications; the specimens from the lower Desmoinesian units have a mean of 5.1. Because additional definitive characteristics are not recorded, we have placed the upper Atokan variants in this subspecies. Once the dominance of 5 sulcal plications is established, it persists throughout the Desmoinesian in north-central New Mexico. Eleven or 12 rounded lateral plications most commonly occur on each flank but the number has been observed to vary from 9 to 14. All plications are almost invariably simple with the exception that the first bifurcates from the P-plica near the beak. Only 2 specimens out of 238

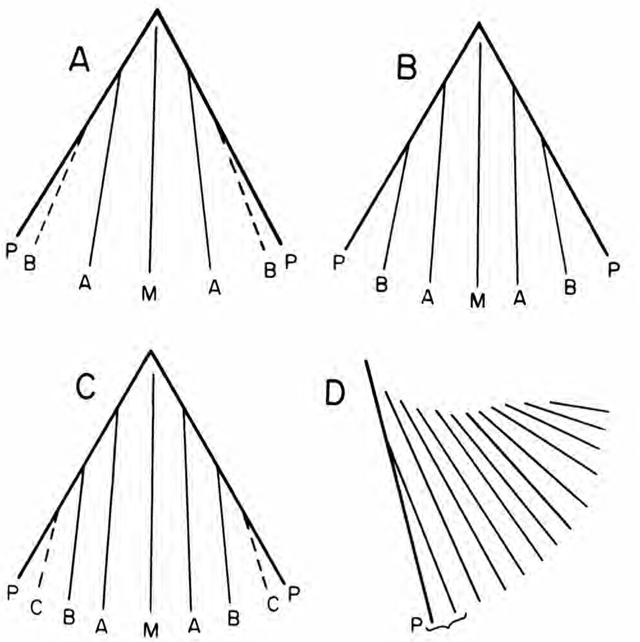


FIGURE *45—Sulcal and lateral bifurcation patterns for* Anthracospirifer curvilateralis chavezae. **B** *is the pattern in most specimens;* **A** *and* **C** *are uncommon. Compare with fig.* 44. **D** *shows lateral plications are most commonly simple.*

studied show an asymmetrical bifurcation of a single additional lateral plication; both were on one flank only.

The brachial valve is moderately convex but the convexity decreases slowly toward the anterior margins. Laterally, the slopes are convex but become distinctly concave near the cardinal extremities. The fold of the brachial valve is distinct and slightly elevated above the level of the shell.

The pedicle interior is unknown; the brachial interior has a low but sharp median septum extending to midlength. The surface is marked by faint, regular concentric fila, about 11 per millimeter, and by faint radial capillae of equal placement but uneven strength.

DISCUSSION-A. *curvilateralis chavezae* differs from *A. curvilateralis tanoensis* primarily in the number of plications in the sulcus; also in size and shape. For a comparison see the discussion of *A. curvilateralis tanoensis. A. curvilateralis tanoensis* most commonly has 3 plications in the sulcus; *A. curvilateralis chavezae* almost invariably has 5. The two subspecies are believed to represent a genetic lineage, the stratigraphic range of which is from Morrowan to upper Desmoinesian. Unfortunately our collections of specimens from the Atokan interval are too small to document properly the transition from one subspecies to the other.

The subspecies described would appear to include the form that Girty (1903, p. 38) referred questionably to *Spirifer boonensis* Swallow from the lower Hermosa Formation of southwestern Colorado. Later, Girty (1927, p. 434) described and illustrated *Spirifer opimus* var. *occidentalis* based on specimens from the Wells Formation of Idaho. He states that several of the lateral plicae, as many as 3, invariably bifurcate. However, in the same paper he states that the earlier form he had referred to *S. boonensis?* "is probably specifically identical" with this new variety. We disagree because the form described by Girty in 1903 has simple lateral plicae.

Dunbar and Condra (1932, p. 322) classify *Spirifer occidentalis* Girty as a separate species from *S. opimus* Hall but describe it, incorrectly, as having costae on the lateral slopes that "are almost always simple." The specimens they incorrectly illustrate as *S. occidentalis* are closely related to *A. curvilateralis chavezae.* Their specimens (1932, pl. 41, figs. 12-16) come from "the Black limestone at Rex bridge over Grand River northeast of Muskogee, Oklahoma." Foster (1942, p. 249) also figured a specimen from this locality as *S. occidentalis* and points out that the locality as stated by Dunbar and Condra is incorrectly given. The locality is under the highway bridge over "the Verdigris River at the town of Okay, formerly known as Rex Bridge." The horizon is in the upper part of the Atokan Formation in what is called the Webber's Falls Member. The 4 specimens from this locality illustrated by Dunbar and Condra appear to have a broader and shallower sulcus than typical for *A. curvilateralis chavezae.* However, in the fossil collections of the University of Oklahoma, a collection made by Foster from the Dunbar and Condra locality includes 9 pedicle valves of which only 2 have a sulcus as shallow as Dunbar and Condra's illustrated specimens. Several of the others have a distinct and moderately deep sulcus. The Oklahoma specimens are larger and more transverse than typical for *A. curvilateralis chavezae* but they fall within the extremes of variation within our New Mexico collections. Of the 9 specimens in the Foster collection, 4 have 5 plications, 2 have 4, and 3 have 3 plications in the sulcus.

A specimen in the de Koninck collection in the Museum of Comparative Zoology at Harvard University (MCZ 8814) is labeled *"Spirifer rockymontanii*, n. sp." Young (1945, p. 171) states that the label to the specimen is apparently in de Koninck's handwriting and that the locality given is "Pri de village de Tegeras, Canon de San Antonio, dans le Rocky Mountans du New Mexico." Apparently this specimen was collected by Marcou and sent to de Koninck. Marcou (1858, p. 32) states that some of his specimens were submitted to de Koninck for identification. We consider this specimen (Pl. 17, fig. 12) to be an example of *A. curvilateralis chavezae.* We also consider the larger of the two specimens figured by Marcou (1858, pl. 7, figs. 4, 4a-b, BMNH B 79154) as *Spirifer rocky-montani* to be a probable variant of *A. curvilateralis chavezae* despite some uncharacteristic splitting of the lateral plications, as shown in fig. 46. Mather incorrectly designated this specimen as the lectotype of *Spirifer rockymontanus* apparently being unaware that Girty (1903, p. 384) had already so selected the smaller of Marcou's two figured specimens.

MATERIAL AND OCCURRENCE-A. *curvilateralis chavezae* is one of the most common brachiopods in the lower and middle parts of the Desmoinesian interval in the southern Sangre de Cristo area. This species also occurs in the upper part of the Atokan sequence, but our collections from this part of the section are small. Our collection includes over 250 identifiable specimens from

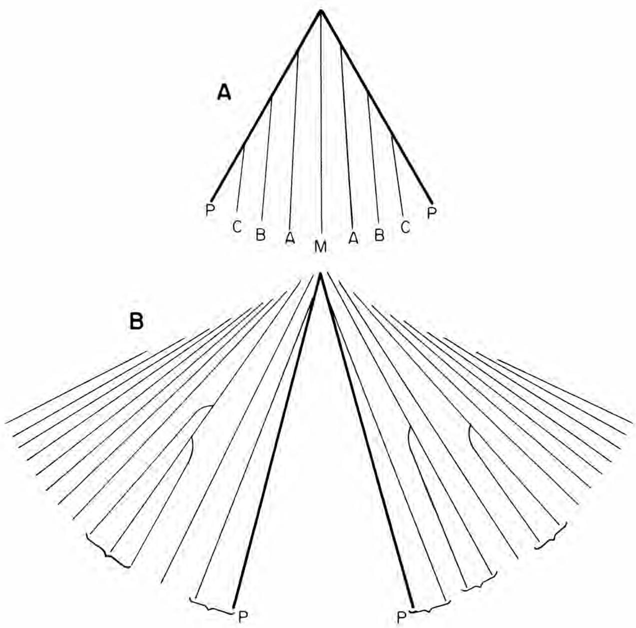


FIGURE 46—*Sulcal and lateral bifurcation patterns of* Anthracospirifer *cf.* A. curvilateralis chavezae . *Drawings based on a cast of the specimen figured by Marcou (1858, pl. 7, figs. 4, 4a-b) as* Spirifer rocky-montani. *Note irregular bifurcation of some of the lateral plications, an uncommon feature in the species. Compare with Pl. 17, fig. 11.*

the following units and localities—Atokan: 62-28(cf), 67-23(cf), 67-30(cf); Desmoinesian: 10-19, 10-36, 22-93, 25-27(cf.), 25-54(cf.), 29-3, 29-4, 29-5 (type locality), 29-8, 29-10, 36-97, 36-109, 36-122, 36-128, 36-133, 36-150, 40-3, 43, 47-37, 56(cf.), 60-124(?), 60-252(cf.), 78 and 93-44. These units are in the middle and upper parts of the La Pasada Formation in the south, and in the Flechado and Alamitos Formations in the north. Figured specimens: holotype OU 7860; paratypes OU 7862, 7865; other specimens OU 7861, 7863, 7864, 7875, and MCZ 8814 (plastotype OU 7878).

Anthracospirifer mcalesteri n. sp.
P1. 15, figs. 12-15

DESCRIPTION—The shell is medium in size and elongate with the length typically slightly greater than the width. The hinge line may equal the greatest width or be slightly posterior to it. The width-length ratio for a sample of 7 specimens, with lengths greater than 27 mm, is 0.93 (s=0.08), and the average thickness-length ratio is approximately 0.6. The holotype has the following dimensions: length 30.9 mm, width 27.3 mm, thickness 20. 1 mm and surface length 51 mm. Additional measurements are given in Appendix 3.

The pedicle valve is uniformly convex longitudinally except near the beak, which is strongly overarched and incurved. The sulcus is moderately shallow to moderately deep and broadly expands anteriorly where it is strongly produced, thus causing a marked flexture in the margin of the shell. The lateral slopes are steep and convex. The interarea is about 5 mm high or about 1/6 of the length of the pedicle valve and is orthocline to slightly anacline in attitude. The interarea is strongly concave at the beak and is marked by well-developed longitudinal grooves, typical for the genus. Considerable variation exists in the nature of bifurcation of the plicae, which are generally subangular in cross section. In the sulcus are most commonly 5 secondary plicae (16 of 34 specimens, fig. 47A). A few adult specimens show 6 or 7 secondary plicae by further bifurcation from the P-plicae at the margin of the sulcus. In some specimens tertiary plicae split from the median side of one or several of the secondary plicae (fig. 47B). The pattern of tertiary splitting in the sulcus is symmetrical in most specimens but 4 of 34 specimens studied are asymmetrical. The total number of plicae at the anterior margin, while most commonly numbering 5, reaches 9 or 10 in a few specimens. The 9 variations in the sulcal pattern observed in the study of 34 specimens are as follows:

Sulcal formula	Total specimens	Fig.
Symmetrical:		
PBA.M.ABP	16	47A
PCBAa.M.aABCP	6	47B
PCBA.M.ABCP	5	
PBAa.M.aABP	1	
Asymmetrical:		
PBA.M.aABCP	1	
PBAa.M.ABP	1	
PCBA.M.aA.aBCP	1	
PBa.Aa.mM.aA.BCP	1 (holotype)	47C

In the specimens examined the first splitting of plicae in the sulcus (A-plicae) from the P-plica occurs consistently at distances of 3 to 5 mm (SL). The distance from the

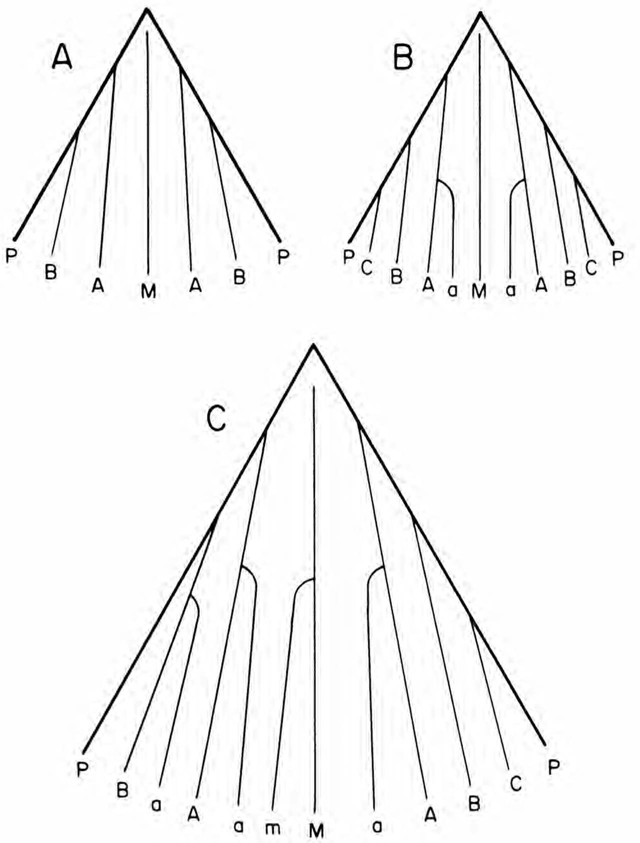


FIGURE 47 —*Sulcal bifurcation patterns of* Anthracospirifer mcalesteri *n. sp.* A. and B *are the most commonly observed patterns and C is the most complex (holotype, Pl. 15, figs. 12a-e).*

beak of the splitting of the B- and C-plicae are much more variable ranging from 5 to 15 mm (SL) for the B-plicae and from 10 to 33 mm (SL) for the C-plicae.

On the lateral slopes of the pedicle valve are a total of 9 to 14 plicae per side, the most common number being 10 or 11. Invariably the first lateral plica bifurcates from the P-plica at a surface length of about 2 mm. Of the 63 sides studied, 46 do not show additional bifurcation of the remaining principal lateral plicae (fig. 48A). Five variations have been observed, the two most common having only the second or the second and the third plicae producing a subdivision from the median side of this plica (fig. 48B). On a single side of one specimen the complex pattern illustrated in fig. 48C is observed. Of the 40 specimens studied 7 show lateral plicae asymmetry. The lateral plicae become smaller towards the cardinal extremities but remain distinct.

The brachial valve is much less convex longitudinally than the pedicle, and is only slightly convex along the length of the fold except near the beak where the umbo is narrow and sharply curved toward the hinge line. The fold is low at the umbo but becomes high and angular anteriorly. The lateral slopes are gently convex.

DISCUSSION—This distinctive species is characterized by its elongate shape, high pedicle interarea, angularity of the plicae in cross section, and the variable nature of the secondary splitting of the plicae both in the sulcus and on the lateral flanks of the shell. Our collections include, at one extreme, specimens with only 5 plicae in

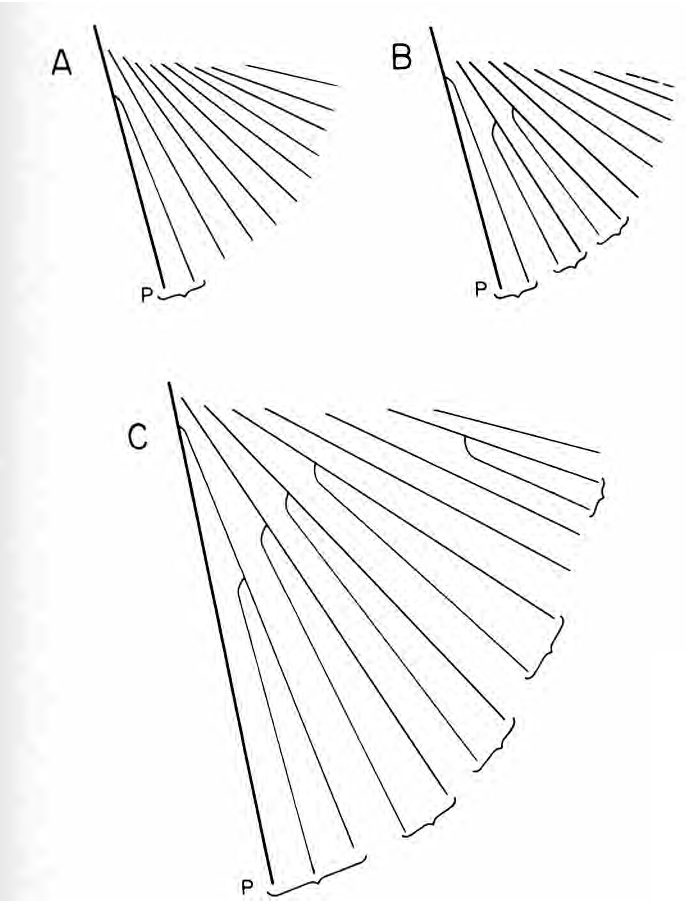


FIGURE *48—Lateral bifurcation patterns in* Anthracospirifer mcalesteri *n. sp.* **A** *is the most common pattern,* **B** *occurs rarely, and* **C** *is a unique pattern found on one side of a single specimen.*

the sulcus that do not split, and have most commonly 10 simple plicae on each lateral slope. Such specimens are similar to *A. opimus* Hall and differ from that species in being distinctly more elongate with width-length ratios of about 0.9, in having a sharper, more produced sulcus, and in having plications. At the other extreme are specimens in which splitting of secondary plicae results in the number reaching 10 in the sulcus at the anterior margin and 13 or 14 on the lateral slopes.

MATERIAL AND OCCURRENCE—Well-preserved shells occur in great numbers in a 6-inch limestone layer at the top of unit 36-133 but the shells are difficult to extract. This horizon occurs in the middle part of the La Pasada Formation (lower Desmoinesian) in the Pecos valley. Our collection from unit 36-133 contains 39 specimens sufficiently complete for study. Single specimens that questionably belong to this species were collected higher stratigraphically, from the middle Desmoinesian units 36-150(?) and 36-165(?). Figured specimens: holotype OU 7866; paratypes OU 7867 to 7869.

Anthracospirifer "occiduus" (Sadlick)
Pl. 16, fig. 20

Spirifer opimus var. *occidentalis* Girty, 1927, p. 433, pl. 27, figs. 28-31.
Spirifer occiduus Sadlick, 1960, p. 1210.

DISCUSSION-This species, according to Girty (1927, p. 434), has a rather large shell that is wider than long, and widest at the hinge line. It has 5 plications in the sulcus and about 12 on each lateral slope—the first 3 may bifurcate. The range of variation has not been described; thus its relationship to other species is impossible to evaluate. Nine specimens in our collections from New Mexico, 8 of them from unit 93-44, apparently have the essential features of this typologically defined species; variation in the bifurcation pattern of the plicae is considerable. Our specimens have lengths of approximately 30 mm, widths of 40 mm, thicknesses of 20 to 22 mm, and surface lengths of 50 to 54 mm. They possess 5, 6, or 7 plications in the sulcus with asymmetrical patterns developed on some specimens either by the presence of a C-plica on one side only, or by the bifurcation of one of the A-plicae. The total number of lateral plications is 11 to 14. In 5 of 9 specimens, there is asymmetry on the lateral slopes. The first lateral plication on all specimens bifurcates from the P-plica near the beak. Of 14 lateral slopes studied, 4 do not show additional bifurcation, and 5 show the second plica bifurcating. The remaining 5 lateral slopes are each different, and show more extensive bifurcation, the most complex example being one that has the P-plica bifurcating a second time and the next 3 plications each bifurcating.

Our specimen of A. *"occiduus"* differ from *A. curvilateralis chavezae* (they occur together) in the distinctly larger size and in the irregular bifurcation of the lateral plications.

The specimens identified by Dunbar and Condra (1932, p. 322) as *Spirifer occidentalis* probably belong to *A. curvilateralis chavezae* (see discussion of that species).

MATERIAL AND OCCURRENCE—Nine specimens are in our collection of which 8 are from unit 93-44 and one from locality 43. These localities are in the middle part of the La Pasada Formation and are early Desmoinesian. Figured specimen: OU 7873.

Anthracospirifer "opimus" (Hall)
Pl. 16, figs. 17-19

Spirifer opimus Hall, 1858, p. 711, pl. 28, figs. la, b.
Spirifer opimus, Dunbar and Condra, 1932, p. 320, pl. 41, figs. 11a-c.

DISCUSSION—Characteristic features of this species, according to Hall (1858, p. 711), are a rotund shell with length and width nearly equal, a highly arched umbo, and a strongly incurved beak. The lateral flanks have 8 to 10 simple plications. Hall described the sulcus as having 3 simple plications but Dunbar and Condra (1932, pl. 41, fig. 11) figured a shell that has 5 plications from the lower Desmoinesian of Missouri. The exact locality and stratigraphic horizon of Hall's types are unknown but the age is possibly middle Pennsylvanian. The range of variation has not been established, and the species can be considered at this time only in a typological sense.

This species is rare in our New Mexico collections and its association in three lower Desmoinesian units with *A. chavezae* led us at first to consider the two to be variants of the same form. However, possibly they are different species in that *A. opimus* has a distinctly more inflated umbo, with the beak well arched over the hinge line. The average length-width ratio of the two also differs.

A. opimus is proportionally narrower with a ratio of 0.9 to 1.0. *A. chavezae* typically varies from 0.7 to 0.85, but extreme variants of that species are narrower and have a ratio greater than 0.9. Such shells are very similar to *A. opimus* but differ, as stated above, in that the shell is thinner and less highly arched. The two species are probably closely related. They each have 5 plications in the sulcus, and our specimens of *A. "opimus"* have 9 to 11 lateral plications, while *A. chavezae* has more typically 11 or 12 that are almost invariably simple.

MATERIAL AND OCCURRENCE—We have 7 specimens, from the middle part of the La Pasada Formation, from the following lower Desmoinesian units: 36-128, 93-44, and locality 78. Figured specimens: OU 7870-7872.

Anthracospirifer rockymontanus (Marcou)
Pl. 17, figs. 7-9

Spirifer rocky-montani Marcou, 1858, p. 50, pl. 7, figs. 4c-e (not 4, 4a-b).
Spirifer rockymontanus, Girty, 1903, p. 383.

> ORIGINAL DESCRIPTION—(Marcou, 1858, p. 50.) Shell transverse, gibbous, subsemi-circular, length and breadth nearly equal, cardinal angles rounded. Beak large, elevated, incurved; hinge line shorter than the width of the shell, straight. Sinus of the dorsal valve shallow, extending from the beak to the margin, covered with ribs, like the other parts of the two valves. The ribs are simple, sharp and very distinct. Area small and triangular. The lines of growth are indistinct on the two valves.

DISCUSSION—Marcou (1858, pl. *7)* figured *2* specimens under the name *Spirifer rocky-montani,* both from the "Mountain Limestone of Tigeras, Cañon of San Antonio, New Mexico" (Marcou, 1858, p. 50). For a description of this locality, see our discussion of Marcou's 1853 survey. We believe these specimens came from Marcou's "grand perpendicular wall" and are Desmoinesian.

Girty (1903, p. 384) selected as lectotype the smaller of Marcou's 2 specimens. Sadlick (1960, p. 1214) incorrectly stated that these specimens are lost. They are preserved in the British Museum of Natural History, numbers B79154 and B79155. Sutherland has examined these specimens and the BMNH has kindly provided us with excellent casts. We consider two species to be included. Girty's lectotype (P1. 17, figs. 7, 8) has the following dimensions: length 14.5 mm, width 16.6 mm, and thickness 9.0 mm. There are 7 sulcal plications showing the following asymmetrical sulcal pattern: PBAa,M,ABCP (fig. 49). On each lateral slope of the pedicle valve, 7 or 8 simple plications are present except

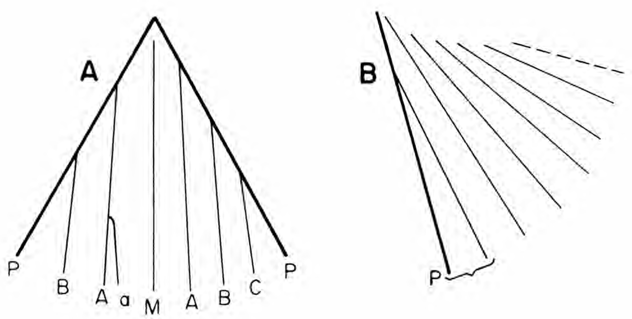


FIGURE 49—*Sulcal and lateral bifurcation patterns for the lectotype of* Anthracospirifer rockymontanus *(BMNH B 79155), PL 17, fig. 7. Note the irregular bifurcation of the sulcal plications.*

for the bifurcation of the first lateral plica from the P-plica. The hinge line is shorter than the greatest width which occurs at midlength. Detailed surface features are poorly preserved. Distinctive features are that the shell is relatively narrow for the length; the number of sulcal plications is large for the surface length; and the greatest width appears anteriorly to the hinge line. A detailed description of this species cannot be given until valid topotypes are collected from Marcou's locality. Until that time, a meaningful comparison of this species with other typologically defined species such as *Anthracospirifer opimus* is not possible.

Specimens similar to Marcou's lectotype are extremely rare in our collections from the Sangre de Cristo Mountains, located 40 to 60 miles northeast of Marcou's type locality. All come from the lower Desmoinesian part of the La Pasada Formation, mostly from near Lamy or from the Pecos valley. A feature more distinctly developed on these specimens than on the possibly distorted lectotype is a narrow sulcus that is distinctly set off (Pl. 17, fig. 9c).

Unfortunately Girty (1903) selected Marcou's smaller specimen as the lectotype, not the larger one (Marcou, 1858, pl. 7, figs. 4, 4a-b) which we compare with a widely occurring species *Anthracospirifer curvilateralis chavezae* (see discussion of that species).

MATERIAL AND OCCURRENCE—Marcou's (1858) lectotype is from "Tigeras Cañon," east of Albuquerque (see our discussion of Marcou's 1853 survey) from strata we believe is Desmoinesian. Our collections contain 8 specimens, all from lower Desmoinesian strata in the La Pasada Formation, from units 29-8(?), 93-44, and localities 43 and 105. Figured specimens: lectotype BMNH B79155 (OU plastotype 7874); other specimen OU 7876.

Anthracospirifer matheri (Dunbar and Condra)
Pl. 17, fig. 13

Spirifer rockymontanus, Mather (not Marcou), 1915, p. 181, pl. 12, figs. 4a-c.
Spirifer matheri Dunbar and Condra, 1932, p. 322; Sadlick, 1950, p. 1212.

DISCUSSION—In their designation of this species name, Dunbar and Condra (1932, p. 322) clearly were referring to the specimens figured by Mather (1915, pl. 12, figs. 1-6) from Morrowan rocks of Arkansas, rather than to the specimen figured by Marcou (1858, pl. 7 figs. 4, 4a-b) from New Mexico—as indicated by the omission of Marcou's figure from the synonymy and by their statement ". . . the species described by Mather requires another name. We propose to call it *Spirifer matheri.* " Sadlick (1960, p. 1212) selected as lectotype the specimen figured on Mather's pl. 12, figures 4a-c, WM 16138.

We have examined Mather's figured specimens. The pedicle valve is strongly convex, with a well-developed, deep, and wide sulcus. Seven to 9 plications are present in the sulcus, and up to 12 plications on each lateral slope. The second and third lateral plications commonly bifurcate. The range of variation in this species is not yet known, but its occurrence is apparently restricted to the Morrowan.

We believe Dunbar and Condra were incorrect in referring Marcou's (1858, pl. 7, figs. 4, 4a-b) larger specimen of *Spirifer rocky-montani* to this species. That specimen, apparently from Desmoinesian strata, is a larger form (with a shallower sulcus) we consider closely related to *Anthracospirifer curvilateralis chavezae* (see discussion of that species).

MATERIAL AND OCCURRENCE—A*nthracospirifer matheri* is widely distributed in the Morrow Group of northeastern Oklahoma and northwestern Arkansas. We have only 2 specimens in our New Mexico collections, both from the basal part of the La Pasada Formation (Morrowan), units 41-24 and 61-2. Figured specimen: OU 7877.

Superfamily SPIRIFERINACEA
Family SPIRIFERINIDAE
GENUS *SPIRIFERELLINA*

Spiriferellina campestris (White)
Pl. 18, figs. 1-4

Spiriferina spinosa var. *campestris* White, 1874, p. 21.
Spiriferina octoplicata White, 1877, p. 139, pl. 10, fig. 8a (not 8b-c).
Spiriferina campestris, Mather, 1915, p. 193, pl. 13, figs. 9-10; Morgan, 1924, pl. 45, figs. 7, 7a.

DESCRIPTION—The shell is medium size with a large specimen having the following dimensions: length 13.7 mm, width 18.0 mm and thickness 10.0 mm. The length-width ratio averages 0.73 for 18 specimens measured. The greatest width is at the hinge line; variation in shape is considerable. The lateral extremities are commonly slightly extended.

The pedicle valve has a deep, simple, angular sulcus equal in depth to about 3/5 the shell thickness. The lateral plications number 4 to 6, and are sharp and angular. The curved interarea is apsacline in orientation, and about 1/6 as high as wide. The beak is somewhat incurved.

The brachial valve is variable in longitudinal profile. The umbo is strongly inflated in some specimens but in others the greatest elevation of the fold is near the anterior margin. The median plication is distinctly higher at the anterior margin than the lateral ones. The small interarea is orthocline.

The micro-ornamentation consists of minute spine bases or pustules that number 5 to 7 per mm, arranged in irregular radial rows. Imbricate growth lamellae are obscure except near the anterior margin of some specimens.

DISCUSSION—In 1877 (p. 139), White referred specimens to *Spiriferina octoplicata* Sowerby that he had in 1874 (p. 21) distinguished by the varietal name *S. spinosa* var. *campestris.* We follow Girty (1903, p. 396) in retaining the latter as the specific name. White based his description on specimens from two widely separated localities, from " near Santa Fe, New Mexico" and "at Camp Cottonwood, Lincoln County, Nevada." Girty (1903, p. 398) states that he had before him White's specimens from both these localities and further states that White's 2 figured specimens, unidentified on White's plate as to specific locality, come one from each of these localites. Only one of White's figured specimens can now be found in the collections of the U.S. National Museum of Natural History, or in the U.S. Geological Survey (Richard Grant, personal communication, 1972). It is USNM 8501, from "near Santa Fe," and matches White's (1877) figure 8a on his plate 10. This specimen is here chosen as lectotype. White's second figured specimen (fig. 8b-c), apparently from Nevada, is presumed to be lost. Based on White's figures, we conclude that that specimen represents a different species from the one found at Santa Fe. The lectotype clearly represents the same species here described based on specimens from near Santa Fe.

We examined the lectotype (P1. 18, figs. 1b-c). It has the following measurements: length 10.8 mm and width 16.8 mm. On each flank of the sulcus are 4 strong, angular plications slightly wider than the spaces between lateral plicae. The brachial valve is badly eroded but the hinge area is preserved.

Spiriferellina campestris differs from *S. ceres* n. sp., which is Desmoinesian, in being smaller in size, in having less coarse plications, in lacking a row of large spines along the axis of the sulcus, and in having obscure growth lamellae. *S. campestris* apparently represents the earliest known occurrence of a genus more typically developed in the Permian.

MATERIAL AND OCCURRENCE—The lectotype of *S. campestris* came from "near Santa Fe" (see our discussion of early surveys in the Santa Fe area). We have found the species to occur commonly in that area in units 61-2 (24 specimens) and 90-2 (17 specimens). We designate unit 90-2 as the type locality in that the gray matrix there is somewhat similar to that found on the lectotype, while all specimens from unit 61-2 are distinctly red. Our collection contains a total of 75 specimens of the species. The species also occurs rarely to commonly in units 36-38, 41-33, 47-19, 47-21, 61-6A, 65-40 and 92-23 to 26. All specimens are from Morrowan strata, from the lower parts of the La Pasada Formation in the south and the Flechado Formation in the north. The species also occurs in the Morrow Group of northeastern Oklahoma and in the Wapanucka Formation (Morrowan) in southern Oklahoma. Figured specimens: lectotype USNM 8501; other specimens OU 7879 to 7881.

Spiriferellina ceres n. sp.
Pl. 17, fig. 17

?Punctospirifer campestris, Lane (not White), 1962, pl. 127, fig. 29.

DESCRIPTION—Estimated dimensions of the holotype are: length 13.2 mm, width 17 mm, and thickness 9.5 mm. The pedicle valve is nearly uniformly convex longitudinally as well as transversely. The interarea is about 1/5 as high as wide. Four strong, sharp lateral plications are present. The sulcus is deep and sharp with a single row of stout, erect, spines along the narrow axis.

The brachial valve is less strongly convex than the pedicle valve. The fold is almost flat toward the anterior, producing a high crest that is much higher than that of the lateral plications. The sulcus is equal in depth at the anterior margin to about 4/5 the shell thickness.

The surface of both valves is minutely granular and irregular restrictions coincide with the imbricate growth lamellae.

DISCUSSION-Spiriferellina ceres may be similar to some of the shells described by Lane (1962) as *Punctospirifer campestris* from apparent late Atokan or early Desmoinesian strata in the Ely Group of Nevada. *S. ceres* differs from *Spiriferellina campestris* (White), which is Morrowan, in being larger, in having coarser plications, in having a much higher median plication on the brachial valve relative to the height of the lateral plications, in having a single row of stout spines along the axis of the sulcus, and in having well-developed but irregularly distributed imbricate growth lamellae.

MATERIAL AND OCCURRENCE-The species is based On a single specimen from unit 29-3, lower Desmoinesian in the La Pasada Formation. Figured specimen: holotype OU 7887.

GENUS *PUNCTOSPIRIFER*

***Punctospirifer morrowensis* n. sp.**
Pl. 18, figs. 5, 6

Spiriferina Kentuckensis, White (not Shumard), 1877, p. 138, pl. 10, figs. 4a-c.
Spiriferina transversa, Mather (not McChesney), 1915, p. 192, pl. 13, figs. 7, 8.

DESCRIPTION-The shell is moderately small, less than twice as wide as long (length-width ratio: 0.5 to 0.7) with the greatest width at the hinge line. Dimensions for specimens are given in Appendix 3.

The pedicle valve is moderately and uniformly convex longitudinally; lateral slopes are flat, and the plicae bounding the sulcus are not elevated above the level of the slope of the lateral surface. Lateral extremities are extended but the margin does not become concave near the tips. The beak is rather narrow and pointed and not strongly incurved. The interarea is catacline in orientation, and has a height equal to $^1/_4$ the width. It is nearly flat but curves sharply at the beak. The narrow sulcus has a low mesial plication that arises near the valve midlength. The lateral plications are simple and number generally 8 or 9 on each flank.

The brachial valve has about the same even convexity as the pedicle valve. The interarea is low but distinct and orthocline. The median fold is low and set off from the lateral slopes by grooves that are deeper and wider than those between the lateral plications. A narrow median sulcus arises on the fold well anterior to midlength.

Most specimens have a tendency to form slightly flattened crests on the low, rounded plications. The surface is further marked by regularly spaced, fine, elevated, concentric fila, the crests of which are marked by extremely fine undulations or frills. Generally, 5 or 6 fila are present per millimeter at valve midlength; they are finer posteriorly and coarser anteriorly.

DISCUSSION-Punctospirifer morrowensis differs from *P. transversa* (McChesney), which is from the Upper Mississippian (Chesterian), in being distinctly smaller in size with correspondingly fewer plications and in being less alate. Weller (1914, p. 298), however, states that *P. transversa* shows considerable variation in the proportional width of the shell. While typical specimens of that species are more than twice as wide as long, some specimens occur whose length is fully ^{2}A the width. *P. morrowensis* is similar in the character of the surface ornamentation except that the concentric fila are slightly finer-if Weller (1914) is correct in his statement of 4 fila per millimeter for *P. transversa.*

P. morrowensis occurs commonly in our Morrowan faunas in association with *Spiriferellina campestris,* and the 2 species apparently had the same environmental preferences.

MATERIAL AND OCCURRENCE-This species is locally common in the Morrowan interval in the lower part of the La Pasada Formation in the south and less common in the Flechado Formation in the north. About 50 specimens are from units 41-47, 61-2 (type locality, 25 specimens), 61-6A, 61-11, 65-40, 90-2, 90-7. The species also occurs in the Morrow Group in northeastern Oklahoma and northwestern Arkansas and in the Wapanucka Formation (Morrowan) in southern Oklahoma. Figured specimens: holotype OU 7882; paratype OU 7883.

***Punctospirifer* cf. *P. kentuckyensis* (Shumard)**
Pl. 18, figs. 7-9

Punctospirifer kentuckyensis, Dunbar and Condra, 1932, p. 351, pl. 38, figs. 1-5.

DISCUSSION-Dunbar and Condra (1932, p. 352) state that specimens of this species from the Midcontinent have extreme variation in the degree to which the cardinal extremities are extended, and that the number of plications on a lateral slope vary from 5 or 6 on an averaged-sized specimen to 8 or 9 on larger specimens. Our specimens from New Mexico show a similar marked variation in length-width ratio. Those with the most-extended hinge lines have ratios of 0.4 to 0.45, but are gradational with specimens having ratios of 0.7. The largest specimens in our collections have widths of about 28 mm and lengths of 11 mm. Our specimens from New Mexico differ from those described by Dunbar and Condra only in having relatively finer plications. The number on the lateral slope of a larger specimen is 10 to 12. Our specimens differ from *P. morrowensis* in having greater size, coarser plications with the plicae bounding the sulcus slightly more pronounced than those on the lateral slopes, and greater acuteness of the cardinal extremities in some specimens.

MATERIAL AND OCCURRENCE-About 60 specimens are in our collections from the Atokan and lower Desmoinesian. Specimens (25) from unit 93-44 show the greatest variation in length-width ratio. Included are Atokan units 62-28, 67-13, and 67-23, and lower Desmoinesian units and locality: 10-11, 29-5, 36-133, 40-3, 78 and 93-44. All are from the lower middle part of the La Pasada and Flechado Formations. Figured specimens: OU 7884-7886.

Superfamily RETICULARIACEA
Family ELYTHIDAE
GENUS *PHRICODOTHYRIS*

***Phricodothyris perplexa* (McChesney)**
Pl. 17, figs. 18-20

Spirifer lineatus, Hall (not Martin), 1856, p. 101, pl. 2, figs. 6-8; Marcou (not Martin), 1858, p. 50, pl. 7, figs. 5, 5a-c.

Squamularia perplexa, Mather, 1915, p. 188, pl. 12, figs. 13, 13a-b; Dunbar and Condra, 1932, p. 313, pl. 42, figs. 5-8.
Phricodothyris perplexa, Sturgeon and Hoare, 1968, p. 67, pl. 22, figs. 10-14.

DISCUSSION-The name *Phricodothyris perplexa* has been used to embrace all Pennsylvanian occurrences of the genus in North America, with the exception of *P. transversa* (Mather), a much larger species known only from the Morrow Group of northwestern Arkansas. *P. perplexa* has been reported from all parts of the Pennsylvanian, including the Morrowan.

The statement by Dunbar and Condra (1932, p. 316) that their Desmoinesian species from the Midcontinent are smaller and more rotund than higher Pennsylvanian forms in that area does not hold true in northern New Mexico. Our Desmoinesian collections include both large and small specimens.

MATERIAL AND OCCURRENCE-Hall (1856) and Marcou (1858) figured specimens (from near Pecos) that must have come from Virgilian strata near the top of the Alamitos Formation. Marcou (1858) also recorded the species as occurring at "Tigeras," east of Albuquerque, probably from Desmoinesian strata. In the southern Sangre de Cristo area, this species is one of the most common and widely distributed in the middle parts of the La Pasada and Flechado Formations (lower and middle Desmoinesian), from which we have collected several hundred specimens. The following units and localities are included: 10-4, 10-19, 10-31, 10-36, 29-3, 29-5, 29-10, 36-103, 36-105, 36-133, 40-2, 40-3, 40-8, 40-52, 42-20, 60-124, 78, 93-44, and 105. The species also occurs rarely at the following Morrowan units, in the lower parts of the La Pasada and Flechado Formations: 41-27, 61-2, 90-2, and 90-14 to 17. Figured specimens: OU 7888 to 7890.

Order TEREBRATULIDA
Suborder TEREBRATULIDINA
Superfamily DIELASMATACEA
Family HETERELASMINIDAE

GENUS *BEECHERIA*

Beecheria millepunctata **(Hall)**
Pl. 18, figs. 10-13

Terebratula millepunctata Hall, 1856, pl. 2, figs. 1, 2.

> ORIGINAL DESCRIPTION OF HOLOTYPE-(Hall, 1856, p. 101.) Shell elongate; curved from beak to base, dorsal [pedicle] valve, with a broad mesial depression, extending the entire length of the shell, obtusely subangular at the sides, which project beyond the margin of the opposite valve; ventral [brachial] valve varying from flat to extremely convex or gibbous along the line from the beak to base; surface minutely but conspicuously punctate.
>
> The specimen in the collection is imperfect, the beak of the larger valve being broken off. The smaller valve is slightly concave, in a longitudinal direction, and somewhat semicylindrical.

DISCUSSION-In the above description Hall's usage of the terms dorsal and ventral is opposite to modern usage. We have not examined Hall's single type specimen. It is apparently lost. We have determined that it is not in the New York State Museum or the Field Museum of Natural History. We have collected 3 poorly preserved specimens we consider to be topotypes. The largest specimen is similar in size and shape to Hall's figured specimen. It has the following dimensions: estimated restored length about 24 mm, width 13.5 mm, and thickness 10.0 mm. A narrow mesial depression is along the full length of the pedicle valve, as on the figured specimen. The other topotypes lack this groove. The brachial valve is broken near the beak on 2 of the specimens revealing a mesially sessile cardinal plate divided into 2 sloping plates that are laterally supported by crural plates, as is characteristic for the genus.

Specimens from lower Desmoinesian strata in the Sangre de Cristo area are similar to *B. millepunctata* in external shape and size except for the lack of a distinct mesial groove along the pedicle valve. Internal features are unknown in the lower Desmoinesian specimens.

MATERIAL AND OCCURRENCE-Hall based the species *B. millepunctata* on a single specimen, now apparently lost, collected by Marcou at "Pecos village" (see our discussion of Marcou's 1853 survey). The strata in the Pecos area are Virgilian and occur near the top of the Alamitos Formation. We have collected 3 specimens at locality 98-west we consider to be topotypes. We also compare with the species, specimens from the La Pasada Formation in the Sangre de Cristo area from lower Desmoinesian units and locality: 36-133 (cf.), 42-13(cf.), 78(cf.), and 93-44(cf.). Figured specimens: topotypes OU 7891, 7892; other specimen OU 7893.

Beecheria daltonensis **n. sp.**
Pl. 18, figs. 15-18

DESCRIPTION-The shell is small, gibbous and widest a little in front of midlength. A large specimen has the following dimensions: length 12.6 mm, width 9.1 mm and thickness 7.7 mm. Shell measurements are given in Appendix 3.

The pedicle valve is strongly convex posteriorly with the beak well overarching the other valve; anteriorly the convexity is moderate. The sulcus originates a little behind midlength, becoming very deep and subangular at the anterior margin. The lateral flanks are sharply rounded anteriorly.

The brachial valve has uniform longitudinal convexity and a uniform, subcylindrical transverse profile without trace of a mesial fold or sulcus, although some specimens show flattening at the anterior margin.

Internal features appear to be typical for the genus. Surfaces of both valves are marked by obscure concentric lines of growth.

DISCUSSION-Beecheria *daltonensis* is similar to the Morrowan species from Arkansas described by Mather, *Dielasma bilobatum,* in the presence of a deep sulcus near the anterior margin, but differs therefrom in being larger and relatively elongated, and in lacking the brachial fold of Mather's species. The internal features of Mather's species have not been described. *B. daltonenesis* differs from *Beecheria* cf. *B. millepunctata* (they occur together in the Sangre de Cristo area) in that *B. daltonensis* is smaller in size, is relatively gibbous, and has a deeper ventral sinus.

MATERIAL AND OCCURRENCE-This species occurs in the lower and lower middle Desmoinesian in the La Pasada and Flechado Formations. About 150 specimens are in our collections from the following units: 10-31, 29-8, 29-10 (type locality), 36-133, 36-150, 40-8, 60-124, 93-44. About 75 of these come from 29-10. Figured specimens: holotype OU 7894; paratypes OU 7895 to 7898.

Beecheria stehlii **n. sp.**
Pl. 18, figs. 19-22

DESCRIPTION—The shell is medium in size for the genus. The holotype, a large specimen, has the following dimensions: length 28.4 mm, width 17.4 mm, thickness 10. 8 mm. Shell measurements are given in Appendix 3. The shell has nearly straight lateral slopes for over half the length, with the greatest width on larger specimens, located about half way between midlength and the anterior margin. The anterior margin rounds uniformly into the lateral slopes and the shell is narrow posteriorly. The shell is smooth except for occasional faint growth lines.

The pedicle valve is moderately convex, most strongly so posteriorly. It is flattened from midlength forward or very slightly depressed mesially into a broad, very shallow sulcus. The foramen is large and dorsally lipped. The pedicle valve interior has long, thin, bladelike dental lamellae extending forward from near the sides of the foramen. Their bases on the valve floor diverge slightly.

The brachial valve is nearly flat longitudinally except for a slight convexity just before the umbo. The transverse profile is everywhere nearly uniformly convex. The brachial valve interior is typical for the genus with a mesially sessile cardinal plate that divides laterally and is supported by extended crural plates. The structure in transverse profile forms a flattened "M" with short lateral legs. The central plates of the structure are sculptured with strong wrinkles that slant posteriorly at 45 degrees from a line parallel to the valve surface. Socket plates are separate.

DISCUSSION—Beecheria *stehlii* resembles the specimens identified by Mather from the Morrow Group of northwestern Arkansas, as *Dielasma subspatulatum. B. stehlii* differs in that some of Mather's shells have the greatest width nearer the anterior margin giving a distinct angularity or squareness to the anterolateral margins.

MATERIAL AND OCCURRENCE—Beecheria *stehlii* has been found only in the lower part of Morrowan strata, from the lower part of the La Pasada Formation, in the Santa Fe and Nambe Falls areas. We have collected 61 specimens from units 41-24, 41-33, 61-2 (type locality, 32 specimens), 61-6A, 90-2, 92-23 to 27, and locality 99. Figured specimens: holotype OU 7899, and paratypes OU 7900 to 7902.

Beecheria gerberi **n. sp.**
Pl. 18, figs. 23-25

DESCRIPTION—The shell is small for the genus. The dimensions of the holotype are: length 10.6 mm, width 8.0 mm and thickness 6.0 mm. Shell measurements are given in Appendix 3. The shell surface is smooth except for faint growth lines.

The pedicle valve is decreasingly convex. A distinct, deep but rounded sulcus begins anterior to midlength, at surface lengths of 6 to 7 mm. Larger shells have 2 short lateral sulci developed only near the anterior margin resulting in a parasulcate development.

The brachial valve is gently convex and the umbo is narrow and inflated. A low, narrow mesial fold is present near the anterior margin; in the larger shells two adjacent lateral folds are present.

The interior of the pedicle valve is characterized by lateral plates supporting the hinge teeth, forming narrow cavities on each side of the umbo. The brachial interior has a pair of diverging sockets; between these arise an anteriorly diverging structure in the form of a compressed " M", as described for the genus by Stehli (1956, p. 299).

DISCUSSION—Beecheria *gerberi* is similar in size and in the presence of a well-developed sulcus to shells from the Morrow Group of northwestern Arkansas described by Mather as *Dielasma bilobatum.* We have examined Mather' s cotypes of this species. His form is relatively broader and the anterior margin is uniplicate and not parasulcate.

MATERIAL AND OCCURRENCE—Beecheria *gerberi* n. sp. has been found only in unit 61-6A, in the lower part of the La Pasada Formation, in the Santa Fe Quarries. This unit is low in Morrowan strata in northern New Mexico. Our collection contains 17 specimens. Figured specimens: holotype OU 7903; paratypes OU 7904, 7905.

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Appendices follow

Appendix 1—Measured Sections and Collecting Localities

INTRODUCTION

Description of all Pennsylvanian stratigraphic sections and collecting localities, with the exception of four stratigraphic sections (36, 60, 96, and 97) measured and described by Sutherland (1963, p. 56), are combined in this Appendix, and listed in numerical order. Faunal lists for all sections are included herein.

All measured sections and collecting localities are shown in fig. 2. All sections were measured and numbered in ascending sequence. Notes concerning lateral shifts in section measurement are in accordance with this procedure.

The primary part of each rock unit description is made up of the field classification. It includes the following characteristics, where pertinent: 1) rock type; 2) color on fresh fracture followed by weathered color; 3) grain size; 4) sorting and roundness; 5) compositional adjective; that is, cements and detrital minerals such as calcareous, siliceous, arkosic; 6) bedding, special characteristics, and topographic expression. Bedding descriptions proposed by Ingram (1954) are used herein:

Very thick bedded	over 3 ft
Thick bedded	from 1 to 3 ft
Medium bedded	from 4 to 12 inches
Thin bedded	from 1 to 4 inches
Very thin bedded	from 1/3 inch to 1 inch
Laminated	less than 1/3 inch

The megascopic description is followed, in some instances, by a thin-section description enclosed in parentheses. The classifications proposed by Folk for the description of terrigenous sedimentary rocks (1954) and for carbonate rocks (1959) is used. The thin-section description commences with its location expressed in the number of feet above the base of the unit. The twofold petrographic descriptions for terrigenous rocks include grain size and mineral composition, followed by an estimate of feldspar percentage.

The most important brachiopod, fusulinid and conodont genera and species are listed at the end of the unit megascopic descriptions.

SECTION 10
RIDGE NORTHEAST OF EAST PECOS BALDY

This section describes the middle and upper parts of the La Pasada Formation and the lower part of the overlying Alamitos Formation. The lower Desmoinesian interval of the La Pasada Formation is faulted against Precambrian quartzite (Jicarilla fault), with the Morrowan and Atokan parts of the formation eliminated. The La Pasada Formation in this section has a much higher percentage of shale and less limestone than is found at measured section 36, Dalton Bluff. Measured sections 10 and 40 are particularly important in interpreting the regional stratigraphy of the area because they are the only extensive exposures of Pennsylvanian strata in the high country around the Truchas Peaks.

Measurements were made in two parts along the ridge crest forming the high divide connecting East Pecos Baldy and South Truchas Peak. It begins on the northeast slope of East Pecos Baldy at the lowest exposed limestone east of the fault. From this point the ridge trends east-northeast for the first 1,000 ft and the rocks dip 30 to 45 degrees to the east-northeast. This part of the ridge exposes units 2 to 37; measured thicknesses are considered reliable. Units 10 to 28 form the low saddle on the ridge due north of Pecos Baldy Lake, and unit 11 forms the lowest point on the saddle. Second, above unit 37 the divide trends northeast for a distance of about 3,000 ft and then swings due north toward the Truchas Peaks. The section ends an additional 5,000 ft northward on the ridge on the highest nob (unit 61) on the divide. This point is about equal distance between Pecos Baldy Lake and South Truchas Peak. Above unit 37 the dip of the strata reduces abruptly to no more than 6 degrees and further north to about 3 or 4 degrees. The high open ridge is above timberline but is mostly grass-covered. Units 38 to 61 are poorly exposed; measurements were achieved by numerous lateral offsets over a distance northward of over 1 1/2 miles. Thicknesses are approximate for this part of the section.

For photographs of the lower part of section 10 and the trace of the Jicarilla fault, from both the south and the north, see Miller, and others (1963, frontispiece and pl. 12, fig. A). Section 10 is graphically depicted by Sutherland (1963, fig. 10). The base of the section is reached by climbing to the low saddle 1,200 ft due north of the west end of Pecos Baldy Lake. For a trail guide to the lake see Mont-

PHOTO 9-*Measured section 10, from the north. Base is at fault with Precambrian Ortega Quartzite at right (west); top is on hill at left. Pecos Baldy Lake lies on other side of ridge.*

gomery and Sutherland (1967, trip 5, p. 41). The section was measured in June, 1956 by P. K. Sutherland and A. Lee McAlester.

Faunal control is good for the section below unit 31. Included are three horizons containing early Desmoinesian fusulinids (Zones II and III); typical early Desmoinesian brachiopods also occur in this interval. Faunal evidence is meager in the interval from unit 32 to 55. Units 56 to 58 contain a distinctive brachiopod fauna of middle or late Desmoinesian age.

Unit	Lithology	Thickness (ft)
	Top of section is highest exposure on nob on divide halfway between Pecos Baldy Lake and South Truchas Peak.	
	Alamitos Formation–partial thickness	268
61	Sandstone, dark-greenish-gray, coarse-grained quartz, poorly sorted, partly conglomeratic; thin layers dark-gray shale, carbonaceous, micaceous in upper part of unit; forms highest point on NE-SW-trending ridge	
	(15 ft above base: coarse sandstone; quartz-overgrowth-cemented, immature, biotite-bearing arkose: 30% feldspar)	20
60	Siltstone, olive-gray, weathers gray, sandy, platy, contains plant fragments	
	(base: fine sandstone; calcite-cemented, clay-bonded, immature, biotite-bearing arkose: 30% feldspar)	8
59	Shale, medium-gray, weathers light tan, silty; grades into siltstone, light-gray, platy, at top of unit	6
58	Shale and limestone: shale, black, weathers same, calcareous, capped by 2 ft of limestone, dark-gray, weathering light gray, thin-bedded, forms bench; *Mesolobus euampygus, Chonetinella jeffordsi, Desmoinesia muricatina, Antiquatonia portlockiana, Crurithyris planoconvexa, Neospirifer* cf. *cameratus*	7
57	Shale and limestone: shale, black, calcareous, hard, platy; forms long, gently dipping, partly covered slope; capped by 2 to 3 ft of limestone, dark-gray, weathers buff, silty, thin-bedded, forms bench; *Mesolobus euampygus, Desmoinesia muricatina, Antiquatonia portlockiana, Composita "ovata", Crurithyris planoconvexa*	30
56	Shale and limestone: shale, black, calcareous; capped by 1 ft limestone, dark-gray, weathering light gray, mottled, fine-grained; *Mesolobus euampygus, Chonetinella jeffordsi, Desmoinesia muricatina*	5
55	Sandstone, weathers reddish brown, medium- to coarse-grained	7
54	Covered, shale and cherty limestone talus	
	(5 ft above base: algal biomicrite; top, talus: silicified, sandy, spicular biomicrite)	25
53	Sandstone, very coarse grained, thin-bedded, partly slumped, thickness approximate	45
52	Covered, shale and sandstone talus; interval approximate	40
51	Sandstone, very coarse grained, upper part contains subangular quartz and quartzite cobbles up to 100 mm; weathers as massive slabs; poorly exposed, thickness approximate	
	(10 ft above base: very coarse sandstone; quartz-overgrowth-cemented, submature subarkose: 20% feldspar)	75
	La Pasada Formation–partial thickness	1,010
50	Covered; probably shale	25
49	Siltstone, dark-gray, weathers medium yellowish brown, calcareous, limonitic, platy	
	(4 ft above base: sandy, foraminiferal, spicular biomicrosparite)	13

Unit	Lithology	Thickness (ft)
48	Shale, medium-gray, silty, partly covered	12
47	Covered; conglomeratic sandstone and shale talus; interval approximate	35
46	Limestone conglomerate, pebbles, medium-gray, fine-grained, up to 10 mm; calcareous matrix	
	(top: partly recrystallized, biointrasparrudite; intraclasts contain coralline algae and pellets)	5
45	Covered	20
44	Limestone, medium-gray, weathering mottled, fine-grained, mineralized fractures	
	(top: algal disbiomicrite interbedded with algal biopelmicrosparite)	6
43	Conglomerate, dark-yellowish-brown, quartz pebbles to 80 mm, poorly sorted: sandy matrix	
	(base: granular very-coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	6
42	Covered; breccia and siltstone talus; interval approximate	40
41	Claystone, yellowish-gray, limonitic; interbedded with chert layers, medium-gray, pitted; weathers as thin flags; forms divide between east- and west-flowing drainage; thickness approximate	
	(top: silty, silicified, spicular biopelmicrite)	25
40	Siltstone, medium-gray, weathers buff, partly calcareous; thickness approximate	30
39	Covered	10
38	Shale, dark-gray, silty in upper part, mostly covered; thickness approximate	35
37	Sandstone, coarse-grained, poorly sorted, quartz and quartzite pebbles to 10 mm; upper layers conglomeratic with quartz pebbles up to 80 mm	16
36	Limestone, dark-gray, fine-grained, upper part silty; irregularly medium-bedded, mineralized veins near top; forms highest point on divide; *Composita umbonata, Anthracospirifer curvilateralis chavezae, Phricodothyris perplexa*	31
35	Covered	4
34	Sandstone, medium-light-gray, weathers buff, coarse-grained, poorly sorted, calcareous; contains scattered pebbles	15
33	Limestone, medium-gray, weathers light yellowish gray, fine-grained, thin-bedded, nodular; mineralized fractures	10
32	Sandstone, light-yellowish-gray, fine-grained, well-sorted, very calcareous; lower part even-bedded, upper part irregularly bedded and containing scattered quartzite pebbles	5
31	Limestone, medium-gray, weathers light yellowish gray, fine-grained, thin-bedded, nodular, fractured, upper 3 ft mineralized; forms prominent cliff on divide; strike N-S, dip 50°E; Fusulinid Zone III; *Fusulina* cf. *F. novamexicana, Fusulina* cf. *F. euryteines, Wedekindellina* cf. *W. euthysepta; Antiquatonia hermosana?, Composita umbonata, Neospirifer cameratus, Phricodothyris perplexa, Beecheria daltonensis*	
	(5 ft above base: sandy, fusulinid biomicrosparrudite)	17
30	Covered; talus from above	18
29	Siltstone, dark-gray, weathers light yellowish brown, some layers very calcareous, thin-bedded; plant fragments in noncalcareous layers, micaceous	
	(12 ft above base: silty, spicular biomicrite)	37
28	Covered; probably siltstone and shale	106
27	Shale, black silty, very calcerous; includes some siltstone layers	30
26	Limestone, medium-dark-gray, weather light yellowish brown silty; thick-bedded	2
25	Shale, dark-gray, some layers calcareous and silty	122
24	Shale and limestone: shale, dark-gray; interbedded with thin, dark-gray limestone layers	16

Unit	Lithology	Thickness (ft)
23	Limestone, medium-dark-gray, medium-grained, irregularly bedded with shale and siltstone lenses; upper 2 ft thick-bedded; *Rhipidomella* cf. *R. carbonaria, Mesolobus striatus, Chonetinella jeffordsi, Desmoinesia* cf. *D. muricatina, Composita "ovata", Neospirifer cameratus*	
	(10 ft above base: foraminiferal spicular brachiopodal pelmatozoan, algal biolithite)	16
22	Sandstone, light-yellowish-gray, medium- to very coarse-grained, very calcareous; cross-bedded	3
21	Limestone, dark-gray, weathers light yellowish brown, fine-grained, becomes sandy at top; partly covered	18
20	Sandstone, light-yellowish-brown, coarse-grained, poorly sorted with scattered rounded cobbles of quartzite and limestone; calcareous; cross-bedded; weathers in thin flags; top 2 ft limonitic; forms highest of several low ridges on saddle	39
19	Limestone, thin-bedded, interbedded with shale; partly covered Fusulinid Zone II (top); *Fusulina* cf. *F. taosensis, Fusulina* cf. *F. pumila, Wedekindellina* cf. *W. minuta; Kozlowskia haydenensis, Linoproductus planiventralis, Composita "ovata", Anthracospirifer curvilateralis chavezae, Phricodothyris perplexa*	14
18	Limestone, medium-light-gray, fine-grained, highly fractured; mottled on weathered surface; top 2 ft sandy	7
17	Shale, dark-gray, calcareous, partly covered	14
16	Limestone, dark-yellowish-brown, fine-grained, sandy, micaceous, thin-bedded	
	(base: sandy, algal biosparrudite)	4
15	Covered; shale and some thin-bedded limestone talus	16
14	Sandstone, dark-yellowish-brown, medium- to coarse-grained, poorly sorted, some layers conglomeratic, subangular quartz pebbles to 50 mm; slightly calcareous near top; cross-bedded	
	(16 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite: no feldspar)	32
13	Covered; probably shale	16
12	Sandstone, medium-light-gray, weathers light yellowish brown, coarse-grained, poorly sorted, calcareous cement, limonitic stain, scattered limestone pebbles to 20 mm	
	(3 ft above base: granular, coarse sandstone; calcite-cemented, submature, fossiliferous orthoquartzite: no feldspar)	12
11	Shale, black, very calcareous, platy; forms lowest point on saddle; units 10-10 and 10-11 contain: *Mesolobus striatus, Chonetinella jeffordsi, Desmoinesia* cf. *D. muricatina, Antiquatonia hermosana, Neospirifer cameratus, Punctospirifer* cf. *P. kentuckyensis*	25
10	Limestone and siltstone: limestone, black, coarse-grained, sandy; interbedded with siltstone; partly covered	
	(5 ft above base: very sandy, algal biosparrudite)	10
9	Covered; siltstone, shale and thin-bedded limestone talus	10
8	Limestone, medium-gray, fine-grained, sandy, coarse-grained, irregularly thin-bedded; strike N. 15 W., dip 55°E.; Fusulinid Zone II; *Fusulina* cf. *F. taosensis*	
	(5 ft above base: sandy, partly recrystallized, algal pelmatozoan biosparrudite: top: fusulinid biomicrite)	15
7	Sandstone, dark-yellowish-orange, medium- to coarse-grained, slightly calcareous; poorly exposed; thickness approximate; *Antiquatonia hermosana, Linoproductus planiventralis*	
	(5 ft above base: very coarse sandstone; quartz-overgrowth-cemented, mature orthoquartzite: no feldspar)	12
6	Covered	11
5	Sandstone, weathers buff gray, coarse-grained, poorly sorted; in lower part scattered, rounded limestone cobbles of unit 4 up to 150 mm	8
4	Limestone, medium-gray, fine-grained, irregularly thin bedded, weathered surface mottled; upper contact highly irregular apparently representing a weathered surface with cracks at least one foot deep filled by sandstone from overlying unit; strike N. 20 E., dip 50-60 SE; *Kozlowskia montgomeryi, Phricodothyris perplexa*	
	(5 ft above base: algal biointrasparrudite, intraclasts contain pellets and granulose structure: 15 ft above base: partly recrystallized algal, bryozoan biomicrudite: 20 ft above base: granular, coarse sandstone; calcite-cemented, mature orthoquartzite; no feldspar)	25
3	Sandstone, medium-gray, very coarse grained subangular, poorly sorted, quartzite pebbles up to 30 mm, slightly calcareous; thick bedding; partly covered, thickness approximate	
	(base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	5
2	Sandstone, light-olive-gray, weathers light yellowish gray, coarse-grained, poorly sorted quartz, quartzite and limestone fragments, calcareous matrix	
	(top: fossiliferous, very coarse sandstone; calcite-cemented, mature, pelmatozoan orthoquartzite; no feldspar)	7
	Fault concealed by quartzite talus	
	Ortega Formation (Precambrian); quartzite	

LOCALITY 12
TRAILRIDERS WALL

This locality refers to the 20 ft limestone ledge exposed at the base of the steep north-trending, east-facing cliffs termed Trailriders Wall on the 7$^{1}/_{2}$" quadrangle. This cliff exposes the upper part of the La Pasada Formation and the lower part of the Alamitos Formation. The precise collecting locality is due east of the high nob on the ridge crest at the top of measured section 10. The limestone ledges at the base of the cliff are the equivalent to unit 31 in measured section 10. These layers are part of Fusulinid Zone III (early Desmoinesian) and include *Fusulina cf. F. novamexicana* and *Composita umbonata.*

LOCALITY 18
WINDSOR CREEK

Exposure of 10 ft of dark-gray, medium-grained, thick-bedded limestone, interbedded with thin shale, at creek level, is on south side *of* Windsor Creek, about 3 miles west northwest *of* Cowles. This exposure is located near the point where a main tributary enters Windsor Creek from the northwest. Up that tributary, the old trail to Stewart Lake left the Windsor Canyon.

This locality is particularly interesting because the limestones contain exceptionally well preserved brachiopods that are middle or late Desmoinesian and compare closely with those found at unit 10-58. Locality 18 is in the lower part of the Alamitos Formation. The following *fossils* are found: *Mesolobus profundus, Mesolobus euampygus, Chonetinella jeffordsi, Desmoinesia muricatina?.*

SECTION 22
TERRERO BLUFF, PECOS VALLEY

Terrero Bluff is on west side of Pecos River, 15.5 miles by road north of the junction of State Highway 63 and Alternate U.S. Highway 84-85 at town of Pecos, and 8.9 miles north of measured section 36, at Dalton Bluff. For a road log see Montgomery and Sutherland (1967, p. 14). The lowest part of the La Pasada Formation (units 20 to 27) was measured on the bluff west of the Pecos River 2,600 ft north of the junction of Holy Ghost Creek and the Pecos River at Terrero. The remainder of the section, from unit 28 upward, was measured in a major draw on the cliff face 1,600 ft farther north, west of a point on the road 0.5 mile south of the junction with the Willow Creek road. This section described the same interval as that exposed at measured section 36, Dalton Bluff, 7 miles to the south. For a discussion of faunal zones see section 36. Section 22 is located 800 ft higher in elevation, in an area of higher rainfall, and is less well exposed. It is important because of the lack of good exposures in the heavily timbered upper Pecos valley. It is the most northerly measurable section in the valley which includes both the base and top of the La Pasada Formation. Here the formation is slightly thicker than at Dalton, has more sandstones at the base, and the percentage of shales has increased. Lithologically it forms a transition section between the sequence composed predominantly of limestones at Dalton and that with a higher percentage of shales at measured section 10 located 11 miles farther north. All of these sections are depicted graphically by Sutherland (1963, fig. 10). Section 22 was described by P. K. Sutherland and A. Lee McAlester, July, 1956.

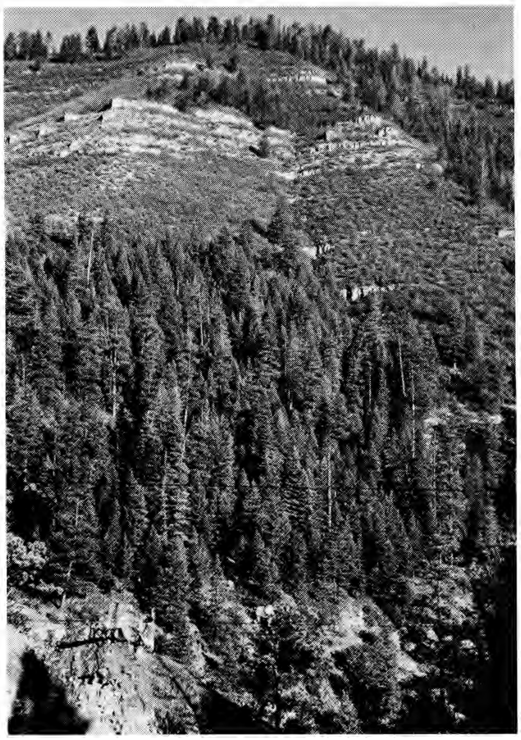

PHOTO *10—Terrero Bluff, measured section 22. Mississippian limestone cliff at bottom, in gorge of Pecos River.*

Unit	Lithology	Thickness (ft)
	Top of section is highest exposure at crest of high bluff on west side of Pecos River 0.5 mile south of point opposite mouth of Willow Creek.	
	Alamitos Formation—partial thickness	195
115	Conglomerate, light-brownish-gray, weathers tan, subrounded quartz pebbles to 30 mm, arkosic, poorly sorted, calcareous cement; weathers in large slabs	
	(base: sandy granule conglomerate; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 30% feldspar)	5
114	Covered, sandstone and arkosic conglomerate talus	44
113	Limestone and siltstone: limestone, medium-gray, weathers buff, fine- to coarse-grained, medium-bedded, nodular; interbedded with thin layers siltstone, platy, calcareous; *Composita "ovata"*	
	(5 ft above base: gastropodal, algal biomicrosparrudite)	9
112	Covered, limestone and sandstone talus	60
111	Limestone, medium-gray, weathers light gray, fine-grained, silty	
	(base: very slightly sandy, gastropodal-pelecypodal biosparrudite)	4
110	Sandstone, gray-orange, weathers tan, medium- to coarse-grained, partly conglomeratic, arkosic, poorly sorted, calcareous cement	
	(basal 1 ft: medium sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 30% feldspar)	7
109	Covered, sandstone and rare limestone talus	27
108	Conglomerate, pale-yellowish-brown, weathers tan, subrounded quartz and feldspar pebbles to 10 mm, poorly sorted	
	(base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose: 25% feldspar)	4
107	Covered	5
106	Sandstone, light-gray, weathers tan, medium- to coarse-grained, poorly sorted, highly arkosic, thick-bedded; partly covered	11
105	Covered, sandstone talus	19
	La Pasada Formation	1,036.5 to 1,037.5
104	Limestone and siltstone: limestone, light-gray, weathers buff, fine-grained; interbedded with thin layers of dark-gray calcareous siltstone	8
103	Covered	16
102	Limestone and siltstone: limestone, medium-gray, weathers buff, very fine grained; interbedded with thin layers of dark-gray calcareous siltstone, partly covered	
	(5 ft above base: partly silicified, foraminiferal-algal, pelecypodal biomicrudite)	11
101	Covered	11
100	Limestone and siltstone: limestone, light- to medium-gray, weathers buff, medium-grained, silty, crinoidal, medium-bedded; interbedded with thin-bedded calcareous siltstone	
	(5 ft above base: slightly sandy, pelmatozoan, brachiopodal biosparrudite)	8
99	Covered	47
98	Sandstone, medium-dark-gray, weathers buff, fine- to coarse-grained, subrounded quartz and feldspar, calcareous cement	
	(granular, very coarse sandstone; calcite-cemented, submature subarkose; 15% feldspar)	1
97	Limestone and siltstone: limestone, black, weathers buff, fine-grained, slightly silty, thin-bedded,	

Unit	Lithology	Thickness (ft)
	nodular; interbedded with thin-bedded dark-gray calcareous platy siltstone	5
96	Covered	3
95	Limestone and siltstone: limestone, medium-gray, weathers buff, fine- to coarse-grained, slightly silty, thin-bedded, nodular, interbedded with thin-bedded dark-gray calcareous platy siltstone (basal 1 ft: slightly sandy, foraminiferal biomicrosparite)	4
94	Covered, talus of thin-bedded limestone and siltstone	130
93	Limestone, medium-gray to black, very fine grained silty, some thin, interbedded shales; units 89 to 93 form highest large cliff on valley wall; strike N. 40 E., dip 6 NW; top 2 ft abundant *Fusulina* sp. (Fusulinid zone III); *Fusulina* sp., *Wedekindellina* sp., *Anthracospirifer curvilateralis chavezae*	12
92	Covered	5
91	Limestone, medium-dark-gray, fine-grained, silty, conchoidal fracture, beds 1 to 4 ft thick; interbedded with shale layers 2 to 4 inches thick (5 ft above base: spicular biosparite)	15
90	Covered	5
89	Limestone and shale: limestone, dark-gray, fine-grained, nodular beds up to 1 ft thick; interbedded with shale, dark-gray, silty, calcareous, friable in beds up to 2 ft thick; sparsely fossiliferous; *Chonetinella jeffordsi, Neospirifer cameratus*	27
88	Covered	5
87	Limestone, dark-gray, weathers gray, very fine grained, silty; thick-bedded	3
86	Covered	2
85	Siltstone, light-gray, weathers buff, calcareous	4
84	Siltstone, buff, weathers same, cherty; irregular bedding; surface pitted by weathering of small limestone concretions	2
83	Limestone, dark- to medium-gray, weathers buff, very fine grained, slightly silty; nodular beds 2 to 4 inches thick; some thin calcareous shale layers	3
82	Covered	10
81	Limestone, medium-light-gray, weathers buff, fine-grained, silty, nodular (3 ft above base: pelmatozoan-algal biosparite)	5
80	Covered	6
79	Limestone, dark- to medium-gray, weathers buff, micritic, silty; nodular beds 2 to 4 inches thick; interbedded with thin calcareous shales	23
78	Covered	5
77	Limestone: light- to medium-gray, micritic with a conchoidal fracture, weathered surface mottled and pitted; thick bedding; upper 2 ft contains limestone cobbles to 80 mm (5 ft above base: algal intrabiosparrudite). This distinctive unit is similar in appearance to unit 36-105	13
76	Covered	48
75	Limestone, medium-gray, fine-grained, conchoidal fracture, thick-bedded; sparsely fossiliferous (7 ft above base: algal biomicrosparrudite)	13
74	Covered	6
73	Limestone, medium-gray, very fine grained, silty	2
72	Covered	7
71	Siltstone, dark-gray, weathers buff, calcareous, hard, platy, banded	3
70	Covered	10
69	Siltstone, medium-gray, weathers buff, slightly calcareous, hard, banded (top 1 ft: slightly silty, partly silicified, spicular biomicrite)	5
68	Covered	2
67	Conglomerate, yellowish-gray, poorly sorted, granular, pebbles up to 20 mm; matrix shaly and slightly calcareous	3
66	Limestone, dark-gray, fine-grained, silty; thick-bedded; thin, interbedded calcareous shales; sparsely fossiliferous	9
65	Covered	9
64	Limestone, medium-gray, weathers buff, very fine grained; *Linoproductus planiventralis, Composita "ovata," "Buxtonia"* sp.	3
63	Covered	6
62	Siltstone and sandstone: siltstone, medium-gray, calcareous; grading upward into sandstone, grayish-orange, weathers buff, fine-grained, well-sorted, becoming feldspathic and conglomeratic near top with scattered pebbles up to 6 mm (sandy, granule conglomerate; calcite-cemented, submature subarkose; 10% feldspar)	3
61	Covered	29
60	Limestone, dark-gray, fine-grained, silty, thick-bedded	4
59	Covered, dark-gray shale talus	6
58	Limestone and shale: limestone, dark-gray, weathers buff, fine-grained, silty, beds 5 inches thick; interbedded with shale, dark-gray, very calcareous; unit forms cliff	14
57	Covered	24
56	Conglomerate and siltstone: conglomerate, subrounded quartz up to 6 mm, silty matrix; interbedded siltstone, olive-green, weathers brown, sandy, slightly calcareous (base: sandy, granule, conglomerate; quartz-overgrowth-cemented, clay-bonded, immature orthoquartzite; no feldspar)	3
55	Shale, dark-gray, calcareous, platy, sparsely fossiliferous	16
54	Limestone, dark-gray, weathers buff, fine-grained, slightly silty	2
53	Shale, dark-gray, very calcareous, platy, upper 6 ft partly covered	29
52	Limestone and shale: limestone, medium-dark-gray, fine-grained, silty, even beds up to 1 ft thick; interbedded with shale, dark-gray, partly silty, very calcareous, hard, micaceous, platy; unit forms cliff (10 ft above base: very slightly silty, spicular biomicrite)	31
51	Covered, probably shale and siltstone	16
50	Siltstone, medium- to dark-gray, very calcareous, partly sandy	5
49	Covered, probably shale	23
48	Shale, medium-dark-gray, weathers gray, very calcareous, platy; thin, sandy, micaceous siltstone at top	10
47	Covered, possibly shale	8
46	Siltstone and limestone: siltstone, pale-yellowish-brown, calcareous, cherty, slightly micaceous; wavy banding, pitted; interbedded with limestone, dark-gray, weathers brown, fine-grained, nodular (10 ft above base: silty biolithite)	24
45	Limestone, light-brown, weathers buff, coarse-grained, crinoidal, silty, some angular quartz grains (basal 1 ft: sandy pelmatozoan-brachiopodal biomicrudite)	2
44	Covered	67
43	Sandstone, buff-brown, weathers purple, poorly sorted, rounded quartz up to 2 mm, argillaceous matrix	2
42	Siltstone, medium-light-gray to olive; some thin, platy shale layers; upper contact very irregular	1-2
41	Sandstone and limestone: sandstone, yellowish-gray, weathers buff, subrounded quartz, poorly	

Unit	Lithology	Thickness (ft)
	sorted, calcareous cement, fossiliferous; interbedded with lenses of limestone, gray, weathering buff, fine-grained, sandy; *"Orbiculoidea"* sp., *Schizophoria oklahomae, Desmoinesia* cf. *D. nambeensis, Linoproductus pumilus, Rhyncopora magnicosta, Composita "ovata," Anthracospirifer newberryi*	
	(5 ft above base: very slightly sandy, pelmatozoan-algal biomicrudite)	8
40	Siltstone, light-yellowish-gray, poorly sorted, sandy, partly covered	6
39	Covered	3
38	Limestone, dark-gray, weathers light gray, fine-grained, silty; brecciated	1
37	Siltstone, light-olive-gray, weathers buff, sandy, calcareous cement; wood fragments at base, scattered brachiopods at top	
	(top: fossiliferous, fine-grained, sandstone; calcite-cemented, mature orthoquartzite; fossils 5% of rock; no feldspar)	3
36	Siltstone and shale: siltstone, olive-gray, weathers light-reddish-brown, slightly calcareous, thin-bedded, hard; interbedded with shale, silty, reddish-brown	4
35	Sandstone, dusky-yellow, weathers buff, coarse-grained, subangular to rounded quartz, poorly sorted, partly conglomeratic; scattered pebbles to 6 mm	
	(10 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	17
34	Siltstone, light-yellowish-brown, weathers buff, arenaceous, poorly sorted; nodular	2
33	Sandstone, light-yellowish-brown, weathers buff, fine- to medium-grained quartz, poorly sorted; cross-bedded	
	(base: medium sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	6
32	Covered	81
31	Sandstone, light-olive-gray, weathers light reddish brown, coarse-grained, poorly sorted; occurring in hard layers up to 1 ft thick; could be partly slumped	7
30	Covered	11
29	Shale and sandstone: light-yellowish-gray, weathers light reddish brown; shale, highly micaceous, silty, arenaceous, interbedded with thin, sandstone, fine-grained, platy, micaceous	11
28	Covered, probably siltstone	6
	Units 20 to 27 were measured on the bluff west of the Pecos River at a point 1,600 ft north of the mouth of Holy Ghost Creek. The section was shifted from that point northward on top of the underlying Tererro Formation (Mississippian), for a distance of 2,600 ft, to a major draw on the bluff on the west side of the valley, opposite a point on the road 0.5 mile south of the Willow Creek road junction. At this northerly locality the La Pasada Formation is mostly covered from the top of the Mississippian limestone to the base of unit 29. The difference in the thickness of this covered interval and that of units 20 to 27, measured farther south, provided the thickness of unit 28.	
27	Sandstone, light-gray to buff, medium- to coarse-grained, containing thin conglomeratic layers with pebbles up to 10 mm; plant remains, forms cliff	
	(5 ft above base: sandy, granule conglomerate, quartz-overgrowth-cemented, submature orthoquartzite; no feldspar; top 1 ft: fine sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	13
26	Sandstone, buff to greenish-tan, coarse-grained, poorly sorted, argillaceous, partly calcareous, conglomeratic at base, even-bedded	
	(base: sandy granule conglomerate; quartz-overgrowth-cemented, clay-bonded, immature orthoquartzite; 5% clay, no feldspar; 5 ft above base: granular coarse sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	10
25	Shale, weathers rust brown, platy, containing siltstone lenses in upper part	
	(top: medium siltstone; quartz-overgrowth-cemented, immature orthoquartzite; 5% clay)	2.5
24	Covered	2
23	Siltstone, greenish-purple, weathers maroon, thick-bedded	2
22	Covered, probably siltstone	3
21	Siltstone, greenish-purple, weathers dark maroon, thick-bedded	
	(top: siderite-nodule bearing, green mudstone)	2
20	Covered	2
	Unconformity	
	Tererro Formation (Mississippian)	

SECTION 25
SANTA BARBARA VALLEY

Base of section begins at bottom of small cliff on east side of Santa Barbara Camp Ground road just north of bridge over Rio Santa Barbara, 6.5 miles southeast of road junction with State Highway 75 at Penasco. Section continues due east up partly covered ridge to unit 53, shifts southeast 800 ft to base of high cliff visible from road, measured up cliff (unit 55 forms top), then continues east-northeast 0.5 mile along series of partly covered ridges to top of Bear Mountain (not visible from valley), which is mostly timbered.

Section 25 exposes the upper part of the Alamitos Formation including the upper contact with the overlying Sangre de Cristo Formation. The section is important in the regional interpretation of the stratigraphy. It was depicted graphically by Sutherland (1963, fig. 10). The entire exposure is upper Desmoinesian (Marmaton), as indicated by abundant fusulinids in several horizons, particularly unit 25-54 (Fusulinid zone V). The section was measured by P. K. Sutherland and Dean Gerber in August, 1957.

Unit	Lithology	Thickness (ft)
	Sangre de Cristo Formation—partial thickness	198
91	Covered; much thin-bedded talus of medium-grained sandstone, micaceous, and shale, sandy, micaceous; forms crest of timber-covered hill, thickness approximate	45
90	Conglomerate, weathers light yellowish gray, granular, quartz, feldspar, poorly sorted, scattered subrounded quartz pebbles up to 8 mm, thick bedding	
	(top: granular, coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 45% feldspar)	6
89	Covered, conglomerate and coarse-grained, arkosic sandstone talus, partly from above	40
88	Sandstone and conglomerate: sandstone, light-olive-gray, weathers light yellowish gray, medium- to coarse-grained quartz and feldspar, moderately sorted, partly conglomeratic; interbedded irregularly with conglomerate, poorly sorted, scattered, subrounded quartz pebbles to 10 mm	

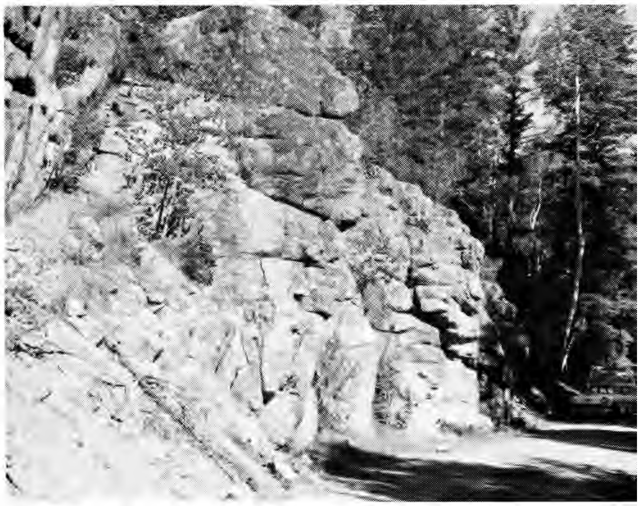

PHOTO 11–Basal unit of measured section 25, Santa Barbara valley. Arkosic conglomerates of Alamitos Formation.

Unit	Lithology	Thickness (ft)
	(2 ft above base: medium sandstone; quartz-overgrowth- and calcite-cement, submature arkose; 40% feldspar; 15 feet above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 40% feldspar)	21
87	Covered, sandstone and conglomerate talus from above	86
	Alamitos Formation–partial thickness	1,843
86	Limestone, dark-gray to black, weathers light gray, very fine grained, conchoidal fracture, hard, mainly seen as talus	
	(top: slightly silty, spicular biopelmicrosparite)	4
85	Conglomerate, weathers light yellowish gray, poorly sorted quartz pebbles up to 10 mm, arkosic	3
84	Covered	5
83	Sandstone and conglomerate: sandstone, yellowish-gray, weathers light yellowish gray, coarse-grained quartz, plagioclase and microcline feldspar, poorly sorted, slightly glauconitic, interbedded irregularly with poorly sorted, arkosic conglomerate, pebbles up to 10 mm	
	(1 ft below top: coarse sandstone; quartz-overgrowth- and calcite-cemented, mature arkose; 40% feldspar)	16
82	Covered	20
81	Sandstone and conglomerate: sandstone, weathers light yellowish gray, coarse-grained, poorly sorted; interbedded irregularly with poorly sorted, arkosic conglomerate, pebbles up to 10 mm	19
80	Covered	42
79	Sandstone, weathers light yellowish gray, medium-grained, micaceous matrix, thin-bedded, partly covered	10
78	Covered	22
77	Limestone, medium-dark-gray, weathers light yellowish gray, fine-grained, irregularly nodular, micaceous	
	(top: slightly silty, spicular biopelmicrite)	8
76	Covered; probably fine-grained, limestone	2
75	Limestone, dark-gray to black, weathers dark yellowish gray, very fine grained, conchoidal fracture, hard	
	(top: slightly silty, spicular, foraminiferal biomicrosparite)	1
74	Covered	27
73	Conglomerate, weathers light yellowish gray, granular, quartz and feldspar, cross-bedded	4
72	Covered; probably thin bedded	8
71	Conglomerate, weathers light yellowish gray, granular quartz and feldspar, poorly sorted, scattered subrounded pebbles up to 15 mm, arkosic, cross-bedded	5
70	Covered; probably thin bedded	10
69	Conglomerate, dusky-yellow, weathers light yellowish gray, granular, angular quartz and feldspar, poorly sorted, scattered, subrounded pebbles up to 15 mm, arkosic; limonitic matrix; calcareous cement, cross-bedded	
	(top: granular, coarse sandstone; quartz-overgrowth-cemented, clay-bonded, immature arkose; 50% feldspar)	5
68	Covered; some sandstone and conglomerate talus	55
67	Conglomerate, weathers light yellowish gray, granular to pebbly quartz and white feldspar, arenaceous matrix; badly slumped, forming slight terrace on ridge	10
66	Covered, sandstone, fine-grained and shale, arenaceous forming talus in lower 15 ft with conglomeratic sandstone talus above	70
65	Sandstone, weathers light yellowish gray, coarse-grained quartz, poorly sorted, conglomeratic with scattered subrounded quartz pebbles up to 10 mm, arkosic; unit slumped, forming highest beds at west end of east-west-trending ridge immediately above cliff of unit 62	6
64	Conglomerate, dusky-yellow, weathers light yellowish gray, granular to pebbly, angular quartz, microcline feldspar, rounded magnetite; arkosic	
	(top: very coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 70% feldspar)	5
63	Covered; sandstone, sandy shale, and conglomerate talus	12
62	Conglomerate, medium-light-gray, weathers light yellowish gray; granular to pebbly, angular quartz and microcline feldspar, poorly sorted, scattered pebbles to 30 mm, arkosic; arenaceous matrix; cross-bedded; forms massive cliff	
	(12 ft above base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature arkose; 50% feldspar; 23 ft above base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature arkose; 40% feldspar)	27
61	Covered; massive talus from above, some of which may be in place	85
60	Conglomerate, medium-light-gray, weathers light yellowish gray; granular to pebbly; quartz and microcline feldspar, poorly sorted, scattered pebbles to 10 mm; arkosic; arenaceous matrix, thick bedding	
	(top: granular, very coarse sandstone; quartz-overgrowth-cemented submature arkose; 60% feldspar)	4
59	Covered; thin-bedded siltstone talus in lower 20 ft	53
58	Sandstone, dark-gray, weathers dark yellowish gray, fine-grained, quartz; silty matrix, hard, irregularly bedded, partly covered	10
57	Limestone, medium-gray, weathers light gray, medium- to coarse-grained, fragmental, micaceous	
	(top: sandy biomicrosparrudite)	1
56	Limestone, medium-gray to black, weathers dark yellowish gray, fine-grained, silty; occurring in thin, hard layers 2 to 6 inches thick	
	(5 ft above base: very fine sandstone; calcite-cemented, submature arkose; 40% feldspar; 45 ft above base: very fine sandstone; calcite-cemented, submature, fossiliferous arkose; 45% feldspar)	51

Unit	Lithology	Thickness (ft)
55	Limestone, medium-gray, weathers light yellowish gray, coarse-grained, fragmental, crinoidal; thick-bedded, weathered surface pitted; forms top of high cliff (top: very sandy, brachiopod, pelmatozoan biomicrosparite); contains rare fusulinids	6
54	Limestone, medium-dark-gray, weathers dark yellowish gray, fine-grained to fragmental, crinoidal; hard, dense, nodular and irregular layers 0.5 to 1 ft thick; interbedded with thin calcareous siltstone layers; Fusulinid zone V; *Fusulina* aff. *F. cappensis; Anthracospirifer* cf. *A. curvilateralis chavezae, Echinaria* cf. *E. knighti?, Antiquatonia portlockiana, Buxtonia* sp. (5 ft above base: sandy, algal, spicular, pelmatozoan biomicrosparrudite)	78
53	Siltstone and limestone: medium-gray, weathers dark yellowish gray; siltstone, feldspathic, micaceous; calcareous cement, interbedded irregularly with thin nodular layers of limestone, fine-grained, silty, very hard (90 ft above base: sandy, spicular, pelmatozoan biomicrosparrudite)	120
	Lower 55 ft of unit 53 measured at northernmost exposure on ridge then section shifts eastward about ¼ mile to base of high cliff visible from valley bottom	
52	Covered; some shale talus in lower 15 ft	38
51	Sandstone, weathers olive brown, fine-grained quartz	2
50	Covered; shale and siltstone talus	5
49	Conglomerate, light-olive-gray, weathers light yellowish gray, granular quartz and microcline feldspar; arkosic; poorly sorted, scattered pebbles up to 10 mm, crossbedding (top: sandy granule conglomerate; quartz-overgrowth-cemented, submature, muscovite- and biotite-bearing arkose; 50% feldspar)	12
48	Covered	16
47	Sandstone, light-olive-gray, weathers light yellowish gray, medium- to coarse-grained quartz and feldspar, poorly sorted, partly conglomeratic in lower part, partly covered (12 ft above base: medium sandstone: quartz-overgrowth-cemented, submature, muscovite- and biotite-bearing arkose; 40% feldspar)	18
46	Covered	45
45	Conglomerate and sandstone: medium-light- to yellowish-gray, weathers light yellowish gray, pebbly, subrounded quartz and microcline feldspar to 20 mm; arkosic; poorly sorted, limonitic matrix; interbedded in upper part with irregular layers coarse-grained quartz sandstone, poorly sorted; forms discontinous cliff (10 ft above base: sandy, granule conglomerate; quartz-overgrowth-cemented, submature arkose; 60% feldspar)	21
44	Covered	82
43	Limestone, medium-dark-gray, weathers light gray, fine-grained, partly crinoidal, argillaceous; thin-bedded, poorly exposed (top: sandy, algal disbiopelmicrite)	4
42	Covered	13
41	Conglomerate, weathers light yellowish gray, poorly sorted, arenaceous matrix	7
40	Covered	5
39	Sandstone, weathers light yellowish gray, medium-grained, quartz, layers hard and even-bedded up to 1 ft, partly covered	5
38	Covered; some micaceous shale	30
37	Conglomerate, light-olive-gray, weathers light yellowish gray, granular, quartz and microcline feldspar, poorly sorted, scattered pebbles up to 30 mm; arkosic; massive, irregularly cross-bedded; forms cliff (top: granular, very coarse sandstone; quartz-overgrowth-cemented, submature arkose; 50% feldspar	16
36	Covered; shale talus, silty, micaceous in lower half (top: very fine sandstone; calcite-cemented, submature, muscovite- and biotite-bearing arkose: 40% feldspar)	50
35	Sandstone, yellowish-gray, weathers same, coarse-grained, quartz and feldspar, poorly sorted, feldspathic, micaceous matrix, calcareous cement; becomes conglomeratic in upper part (2 ft above base: medium sandstone; quartz-overgrowth- and calcite-cemented, mature arkose; 50% feldspar)	7
34	Covered; possibly shale	25
33	Shale, siltstone and limestone: medium-dark-gray, weathers light yellowish brown; shale, well-sorted quartz and feldspar, calcareous matrix, interbedded in lower half with siltstone in thin, nodular, hard layers and silty limestone (7 ft above base: fine sandstone; calcite-cemented, submature, muscovite-bearing arkose; 40% feldspar)	44
32	Siltstone, limestone and shale: medium-light-gray, weathers light yellowish gray; siltstone, subrounded quartz, well-sorted, calcareous cement, thin-bedded, hard; interbedded with thin, nodular, hard layers silty limestone and silty shale (7 ft above base: coarse siltstone; calcite-cemented, submature, muscovite- and biotite-bearing arkose; 40% feldspar: 22 ft above base: coarse siltstone; calcite-cemented, submature, muscovite- and biotite-bearing arkose; 40% feldspar)	23
31	Conglomerate, weathers light yellowish gray, granular quartz and feldspar, poorly sorted, scattered angular pebbles to 10 mm, massive, forms cliff	20
30	Covered; talus from above	6
29	Shale, dark-gray to black, friable	15
28	Siltstone, limestone and shale: medium-gray, weathers brownish gray; siltstone, subrounded quartz, well-sorted, pyritic, calcareous cement; thin-bedded, nodular; interbedded with smaller percentage of silty limestone and silty shale (top: silty, arkosic, brachiopod-ostracod, spicular biosparrudite)	20
27	Limestone and shale: limestone, dark-gray, weathers light yellowish gray, thin-bedded, nodular; interbedded with black, thin-bedded shale; unit becomes silty in upper part; unit poorly exposed; lower 10 ft contains *"Orbiculoidea"* sp., *Antiquatonia portlockiana, Anthracospirifer* cf. *A. curvilateralis chavezae*	27
26	Limestone and shale: limestone, medium-dark-gray, weathers light yellowish gray, fine-grained, partly silty, mainly thin-bedded but rare hard layers, up to 1 ft thick; interbedded with thin-bedded, shale, dark-gray, feldspathic; calcareous cement, poorly exposed (10 ft above base: fine sandstone; calcite-cemented, mature, biotite-bearing arkose; 40% feldspar)	28
25	Covered	28
24	Limestone and shale: limestone, medium-dark-gray, weathers light yellowish gray, fine-grained, slightly arenaceous, hard; interbedded with thin layers shale, black, very calcareous; poorly exposed; *Antiquatonia portlockiana, Echinaria* cf. *E. knighti?* (base: sandy, pelmatozoan-spicular biomicro-	

Unit	Lithology	Thickness (ft)
	sparrudite); brachiopods appear to be similar to those in 60-252	20
23	Siltstone, shale and limestone: dark-gray, weathers light yellowish gray; siltstone, well-sorted quartz, calcareous matrix, nodular, thin-bedded; interbedded with thin-bedded silty shale and silty limestone	11
22	Limestone, medium-gray, weathers light yellowish gray, fine-grained, very silty, hard layers up to 8 inches thick; interbedded with siltstone and shale layers, feldspathic, pyritic, very calcareous (top: fine sandstone; calcite-cemented, mature, fossiliferous arkose; 40% feldspar)	11
21	Covered; thin-bedded shale, siltstone and limestone talus	21
20	Siltstone, limestone and shale: dark-gray, weathers brownish gray; siltstone, feldspathic, micaceous, hard, calcareous cement; interbedded with occasional thin layers and nodules fine-grained limestone; forms cliff (4 ft above base: very fine sandstone; calcite-cemented, mature, fossiliferous arkose; 40% feldspar; 25 ft above base: very fine sandstone; calcite-cemented, mature, fossiliferous arkose; 40% feldspar)	35
19	Covered; talus of calcareous siltstone (5 ft above base, talus: fine sandstone; calcite-cemented, mature, biotite-bearing arkose; 50% feldspar)	14
18	Siltstone, limestone and shale: siltstone, dark-gray, weathers light brownish gray, calcareous cement, thin-bedded, nodular; interbedded with thin layers dark-gray limestone, silty, nodular; shale, calcareous	27
17	Covered	5
16	Siltstone, limestone and shale: siltstone, medium-dark-gray, weathers brownish gray, calcareous cement, thin-bedded, nodular; interbedded with thin layers dark-gray limestone, fragmental, feldspathic; shale, calcareous, hard (5 ft above base: coarse siltstone; calcite-cemented, mature, fossiliferous arkose; 13 ft above base: sandy, arkosic, algal biosparrudite; 35% feldspar)	27
15	Covered; thin-bedded siltstone and shale talus	27
14	Limestone, medium-light-gray, weathers light yellowish gray, medium-grained, fragmental, partly feldspathic, grains concentrated in irregular streaks, partly crinoidal, poorly exposed (top: sandy, arkosic, algal-brachiopodal, fusulinid-bearing, biomicrosparrudite; 40% feldspar)	15
13	Covered	5
12	Siltstone, shale and limestone: dark-gray, weathers light yellowish gray, nodular, platy, thin-bedded; siltstone, calcareous; interbedded with limestone and calcareous shale	54
11	Sandstone and siltstone: sandstone, light-gray, weathers light yellowish gray, calcareous, interbedded with thin layers siltstone, dark-gray, calcareous, partly arenaceous	9
10	Sandstone, light-olive-gray, weathers light yellowish gray, coarse-grained, quartz, moderately sorted, calcareous cement, highly cross-bedded, basal layers carbonaceous (1 ft above base: fine sandstone, calcite-cemented, mature, fossiliferous arkose; 40% feldspar)	7
9	Limestone, siltstone, and shale: medium-dark-gray, weathers light yellowish gray; limestone, fine-grained, silty, interbedded in thin, nodular layers with siltstone, feldspathic, argillaceous, calcareous cement, platy; and shale, silty, micaceous, calcareous cement (5 ft above base: sandy, arkosic, spicular biomicrosparite; 10% feldspar; 14 ft above base: sandy, arkosic, spicular biomicrosparite; 20% feldspar)	31
8	Covered	18
7	Sandstone, weathers light yellowish gray, coarse-grained quartz, poorly sorted, rare, subrounded quartz pebbles to 8 mm	2
6	Covered	4
5	Sandstone, weathers light yellowish gray, coarse-grained quartz, poorly sorted, rare subrounded quartz pebbles to 8 mm	4
4	Covered	10
3	Conglomerate and sandstone: conglomerate, weathers lightly yellowish gray, pebbly, poorly sorted, quartz, chert, quartzite and feldspar; lithic grains grade from coarse at bottom to finer in upper part; massive cross-bedded (4 ft above base: sandy, granule conglomerate; quartz-overgrowth-cemented, submature, muscovite-bearing arkose; 40% feldspar; 12 ft above base: medium sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 50% feldspar)	16
2	Covered	23
1	Conglomerate, light-olive-gray, weathers light yellowish gray, granular to pebbly, quartzite, quartz, feldspar, poorly sorted, lithic, rare cobbles to 80 mm, cross-bedded with occasional irregular streaks coarse sandstone, strike N. 20° E., dip 7° SE; forms cliff on road (4 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature arkose; 40% feldspar: 28 ft above base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature arkose; 60% feldspar)	31

SECTION 26
JICARITA PEAK

Section 26 was measured on the northwesten side of Jicarita Peak, beginning in the large cirque that faces northwest and can be seen from the Santa Barbara Campground. The section is reached by walking south from the Santa Barbara Campground, up the Rio Santa Barbara, for a distance of about 1,200 ft, to the mouth of Jicarita Creek. Walk southeastward up this creek for a distance of about 2. 5 miles to the floor of the cirque. There is no trail. The section was measured up the steep ridge on the south side of the cirque. The upper part was measured up the west side of the high nob forming the cap of the peak. It is the highest non-Precambrian peak in the southern Sangre de Cristo range.

This section appears from a distance to be well exposed but almost all rock layers are intensively slumped, possibly from Pleistocene frost action. The only rocks in place are those on the cirque face. Thicknesses throughout the measured section are approximate. Diagnostic fossils were not collected from this predominantly clastic section. The section has been correlated lithologically with measured section 40 to the south, and measured section 60 to the north, primarily on the basis of the change in feldspar percentages from the lower to the upper parts of the section. The section includes the upper part of the Flechado Formation and the lower part of the overlying Alamitos Formation. It was depicted graphically by Sutherland (1963, fig. 10). The section was measured by P. K. Sutherland and A. Lee McAlester in July, 1956.

Unit	Lithology	Thickness (ft)
	Alamitos Formation–partial thickness	1,098
19	Conglomerate and sandstone: medium-light-gray, weathers light yellowish gray, coarse-grained angular quartz, weathered feldspar (plagioclase), arkosic, poorly sorted, silty matrix; forms highest knob on peak (35 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature arkose; 30% feldspar; 220 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature arkose; 30% feldspar)	460
18	Sandstone and conglomerate: light-yellowish-gray, weathers same, coarse-grained quartz and feldspar, poorly sorted, feldspathic; top of unit forms broad bench below highest knob of peak; mostly slumped (120 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature arkose; 30% feldspar)	304
17	Sandstone and conglomerate: light-gray, weathers light yellowish gray, coarse-grained, subangular quartz and feldspar, poorly sorted, large-scale cross-bedding, includes some thin layers of shale and siltstone; forms highest portion of steep cliff at head of cirque; partly slumped and covered (10 ft above base: medium sandstone; quartz-overgrowth-cemented, submature arkose; 30% feldspar)	207
16	Sandstone and conglomerate: light-brownish-gray, weathers light yellowish gray, coarse-grained, angular quartz and weathered microcline feldspar, poorly sorted, arkosic; conglomerate layer contains angular pebbles up to 20 mm, limonitic matrix; unit includes a few beds of dark-gray siltstone, micaceous (5 ft above base: very coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 30% feldspar)	127
	Flechado Formation–partial thickness	645
15	Sandstone, light-olive-gray, weathers light gray, medium- to coarse-grained quartz and muscovite, moderately sorted, chloritic matrix, some carbonaceous material present, upper part conglomeratic, with pebbles up to 10 mm, beds 1 to 2 ft thick (20 ft above base: medium sandstone; quartz-overgrowth-cemented, submature, biotite-bearing subarkose; 5% feldspar)	75
14	Shale, micaceous; contains plant fragments (base: fine sandstone; quartz-overgrowth-cemented, immature, biotite-bearing subarkose; 5% feldspar)	10
13	Conglomerate, light-gray, very coarse grained, quartz and feldspar, poorly sorted with pebbles up to 10 mm, arkosic, arenaceous matrix	15
12	Sandstone, light-gray, very coarse grained, quartz and feldspar, poorly sorted, micaceous matrix, cross-bedded; upper portion poorly exposed (10 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing subarkose; 7% feldspar)	95
11	Covered; talus mostly shale with minor thin-bedded limestone, dark-gray, fine-grained (10 ft above base: talus, algal biomicrudite)	40

PHOTO *12—Jicarita Peak, on skyline; measured section 26 is on right side (southwest) of large cirque, then to top of peak; exposes upper part of Flechado Formation and lower part of Alamitos Formation. Limestone cliffs in foreground are units 25-53 to 55, and occur in upper part of Alamitos Formation, Santa Barbara valley.*

Unit	Lithology	Thickness (ft)
	Section shifted on top of unit 10 to bluff about 200 yards southeastward	
10	Sandstone, light-yellowish-gray, very coarse grained, subangular quartz and feldspar, pebbles to 40 mm, poorly sorted, matrix argillaceous and slightly calcareous (10 ft above base: medium sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing subarkose; 5% feldspar; top: medium sandstone; clay-bonded, immature, muscovite-bearing subarkose; 5% feldspar)	30
9	Sandstone, light-yellowish-gray, weathers same, medium- to coarse-grained, subrounded quartz, poorly sorted, chloritic matrix; cross-bedded layers 8 to 10 ft thick; some interbedded shale in lower part (base: medium sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing orthoquartzite; no feldspar)	114
8	Shale, dark-brown weathers dark reddish brown, very silty micaceous matrix; includes a few thin-bedded light-yellowish-gray layers of sandstone	6
7	Covered; probably shale	18
6	Sandstone, light-yellowish-gray, weathers light reddish brown, coarse-grained, quartz, orthoclase feldspar, quartzite pebbles up to 20 mm, lithic, matrix chloritic; in layers up to 2 ft thick; lower part mostly covered shale and siltstone, micaceous (top: granular, medium sandstone; quartz-overgrowth-cemented, clay-bonded, immature orthoquartzite; no feldspar)	53
5	Sandstone, light-yellowish gray, weathers light reddish gray, coarse-grained quartz, poorly sorted, subrounded quartz pebbles up to 20 mm, lithic; cross-bedded, layers up to 10 ft thick (5 ft above base: medium sandstone; quartz-overgrowth-cemented, mature, muscovite-bearing orthoquartzite; no feldspar)	22
4	Covered; talus of thin-bedded sandstone, micaceous	10
3	Sandstone, yellowish-gray, weathers light reddish gray, coarse-grained, subrounded quartz, poorly sorted, slightly conglomeratic; matrix chloritic; thick-bedded, upper part cross-bedded (base: medium sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing orthoquartzite; no feldspar)	50
2	Covered; sandstone talus	72
1	Sandstone, light-olive-gray, weathers light reddish gray, coarse-grained, rounded quartz, poorly sorted, scattered pebbles up to 10 mm, silty matrix, even-bedded, layers up to 2 ft thick; lowest exposed bed in cirque; strike N. 10° W., dip 6° E. (10 ft above base: medium sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	35

SECTION 29
DALTON CANYON

This section was measured on the north side of Dalton Canyon 2 miles west by road from the junction with State Highway 63 in the Pecos valley. The location of the section, on the north side of the road, is marked by a prominent overhanging cliff. The ledge of limestone that makes this cliff causes both Dalton Creek and the road to make a sharp bend southward about 100 yards east of a road junction. The section begins at the lowest exposure at the side of the road and continues northward for a distance of about 60 to 80 yards.

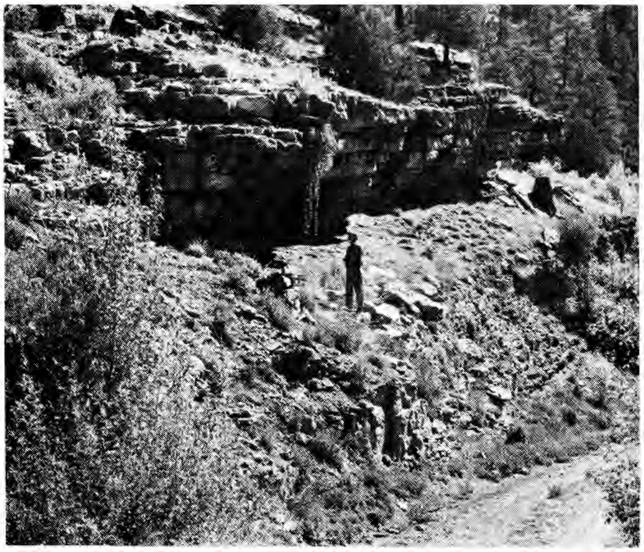

PHOTO *13 Dalton Canyon, lower half of measured section 29, highly fossiliferous middle part of La Pasada Formation. Unit 4 forms overhanging cliff.*

This is a fragmentary section which includes only the lower middle part of the La Pasada Formation. The sequence is approximately equivalent to units 36-122 to 36-133 at Dalton Bluff, located 1.5 miles southeast. The total section is early Desmoinesian. Fusulinid Zone III is represented in unit 29-4. This locality is one of the most fossiliferous lower Desmoinesian exposures in the southern Sangre de Cristo Mountains. We have obtained many more brachiopods from this section than from the equivalent units at Dalton Bluff because surfaces of bedding planes of fossiliferous layers are widely exposed. Section measured in July, 1956, by P. K. Sutherland and A. Lee McAlester.

Unit	Lithology	Thickness (ft)
	La Pasada Formation—partial thickness	129
10	Limestone and shale: medium-brownish-gray, weathers buff, fine-grained, silty, in nodular layers 2 to 6 inches; interbedded with thin, calcareous shale layers; *Rhipidomella* cf. *R. carbonaria, Mesolobus striatus, Kozlowskia haydenensis, Desmoinesia "missouriensis," Linoproductus planiventralis, Hustedia "mormoni," Composita "ovata," Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Phricodothyris perplexa, Beecheria daltonensis, "Bustonia"* sp. (base: algal, molluscan, bryozoan biomicrosparite; top: biomicrosparite)	18
9	Covered, probably shale and thin-bedded limestone	8
8	Limestone and shale: limestone, medium-gray, weathers buff gray, fine-grained, partly silty, in thin, nodular layers; alternating with thin, silty shale layers; top 2 ft of unit is sandy; *Chonetinella jeffordsi, Kozlowskia* cf. *K. haydenensis, Antiquatonia hermosana, Cleiothyridinia pecosii, Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Anthracospirifer rockymontanus, Beecheria daltonensis, "Buxtonia"* sp.	10
7	Covered, probably shale	6
6	Conglomerate and sandstone: conglomerate, yellowish-gray, weathers same, subangular grains to 44 mm, with scattered quartz pebbles to 50 mm,	

Unit	Lithology	Thickness (ft)
	becoming finer upward in unit, changing to coarse, poorly sorted, micaceous sandstone at top	
	(5 ft above base: granular, very coarse sandstone; calcite-cemented, submature, biotite-bearing subarkose; 20% feldspar)	9
5	Limestone, shale and siltstone: limestone, medium-gray, weathers buff, medium-grained, silty and shaly, partly nodular; interbedded with irregular layers of brown-weathering, calcareous siltstone and calcareous, silty shale; most of unit weathers with irregular pitted surface; highly fossiliferous; *"Orbiculoidea"* sp., *Derbyia crassa, Mesolobus striatus, Kozlowskia* cf. *K. montgomeryi, Desmoinesia "missouriensis," Sandia brevis?, Echinaria* cf. *E. knighti, Antiquatonia hermosana, Linoproductus planiventralis, Composita "ovata," Cleiothyridina pecosii, Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Punctospirifer* cf. *P. kentuckyensis, Phricodothyris perplexa, "Buxtonia"* sp.	
	(4 ft above base: slightly dolomitic biosparrudite)	10
4	Limestone and shale: limestone, medium-gray, weathers buff, medium-grained, shaly, occurring in thin, nodular to thick-bedded layers; alternating in lower part with much calcareous shale; unit forms prominent, overhanging cliff; highly fossiliferous; Fusulinid Zone III, *Fusulina* cf. *novamexicana; "Orbiculoidea"* sp., *Mesolobus striatus, Kozlowskia montgomeryi, Antiquatonia hermosana, Linoproductus planiventralis, Cleiothyridina pecosii, Neospirifer cameratus, Anthracospirifer curvilateralis chavezae*	
	(6 ft above base: algal, pelecypodal biomicrosparrudite)	17
3	Shale and limestone: shale, dark-gray to black, calcareous; interbedded in middle and upper part with limestone, medium-gray, weathering buff, fine-grained, in nodular layers 2 to 6 inches thick; *Meekella* cf. *M. striatocostata, Chonetinella jeffordsi, Kozlowskia montgomeryi, Antiquatonia hermosana, Linoproductus planiventralis, Composita "ovata," Cleiothyridina pecosii, Neospirifer cameratus, Neospirifer tewaensis, Anthracospirifer curvilateralis chavezae, Spriferellina ceres, Phricodothyris perplexa, "Buxtonia"* sp.	
	(8 ft above base: partially recrystallized algal biomicrudite)	16
2	Sandstone, conglomerate and shale: sandstone, light-brownish-gray, weathers buff, coarse-grained, poorly sorted; alternating with buff-weathering, silty, carbonaceous shale and one 3-ft layer of conglomerate 3 ft above base, poorly sorted, with scattered quartz pebbles, subrounded, to 50 mm, calcareous cement	
	(2 ft above base: medium sandstone; microcrystalline silica-cemented mature, muscovite- and biotite-bearing subarkose; 15% feldspar)	9
1	Limestone and shale: limestone, medium-dark-gray, weathers buff, fine-grained, partly silty; in nodular layers 2 to 8 inches thick; alternating with gray, partly silty, partly micaceous, mostly covered shale layers; base covered	26

SECTION 36
DATTON BLUFF *(Frontispiece)*

Bluff is on west side of the Pecos River, 6.6 miles by road north of the highway junction in the town of Pecos. Sutherland (1963) described it in detail (p. 96), depicted it graphically (p. 34), and prepared a detailed section (p. 56). The lower part of the section is shown graphically in the present report in fig. 7.

Brachiopods occur commonly at many horizons and are particularly abundant in the lower Desmoinesian, and have been used as a primary basis for delineating the Morrowan-Atokan boundary. Conodonts were collected from the Morrowan, Atokan and basal Desmoinesian part of the section, with slight disagreement between brachiopods and conodonts as to where the Morrowan-Atokan boundary should be placed. Several typical Morrowan brachiopod species extend as high as unit 36-68 although a single specimen of an undetermined species of the genus *Neospirifer* has been collected from that unit. We tend to place the top of the Morrowan at the top of unit 36-68.

The conodont species *Gnathodus coloradoensis* has its lowest occurrence in unit 36-66. Hence, Lane (personal communication) would place the Atokan at the base of this unit (see discussion on conodont correlations).

Fusulinids occur abundantly in the entire section from the upper Atokan upward; four zones can be recognized in section 36. Fusulinids are the basis for the subdivision of the Desmoinesian.

Unit	Faunal occurrence
	Middle Desmoinesian (Fusulinid Zone IV)
	Alamitos Formation
185	*Fusulina* sp., *Composita "ovata"*
	La Pasada Formation
173	*Fusulina* cf. *F. haworthi, Fusulina* sp. A and sp. B (Waddell)
167	*Fusulina* cf. *F. haworthi, Wedekindellina* cf. sp. D (Waddell)
165	*Fusulina* cf. *F. haworthi, Wedekindellina* cf. sp. D (Waddell), *Anthracospirifer mcalesteri?*
159	*Fusulina* cf. *F. haworthi, Wedekindellina* cf. *W. henbesti*
150	*Calliprotonia* n. sp. A, *Echinaria* cf. *E. knighti, Buxtonia* n. sp. B, *Antiquatonia hermosana, Linoproductus planiventralis, Composita "ovata," Anthracospirifer curvilateralis chavezae, A. mcalesteri?, Beecheria daltonensis*
149	*Fusulina* sp.
	Lower Desmoinesian (Fusulinid Zone III)
139	*Fusulina* sp., *Wedekindellina* cf. *W. euthysepta*
137	*Fusulina* sp., *Wedekindellina excentricus*
133	*Derbyia crassa, Mesolobus striatus, Chonetinella jeffordsi, Kozlowskia haydenensis, Desmoinesia "missouriensis," Echinaria* cf. *E. knighti, Buxtonia* n. sp. B, *Antiquatonia hermosana, Reticulatia* sp. A, *Horridonia? daltonensis, Linoproductus planiventralis, Hustedia "mormoni," Composita "ovata," Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Anthracospirifer mcalesteri, Punctospirifer* cf. *P. kentuckyensis, Phricodothyris perplexa, Beecheria* cf. *B. millepunctata, Beecheria daltonensis*
128	*Mesolobus striatus, Desmoinesia "missouriensis," Antiquatonia hermosana, Composita "ovata," Cleiothyridina pecosii, Anthracospirifer curvilateralis chavezae, Anthracospirifer "opimus," Sandia brevis?*
127	*Fusulina* cf. *F. novamexicana, Fusulina* cf. *F. euryteines, Wedekindellina* cf. *W. minuta*
122	Mesolobus striatus, Kozlowskia haydenensis *Neospirifer cameratus, "Buxtonia"* sp., *Anthracospirifer curvilateralis chavezae*
	Lowermost lower Desmoinesian (Fusulinid Zone II)
109	*Kozlowskia* cf. *K. haydenensis, Desmoinesia "missouriensis," Linoproductus planiventralis, Com-*

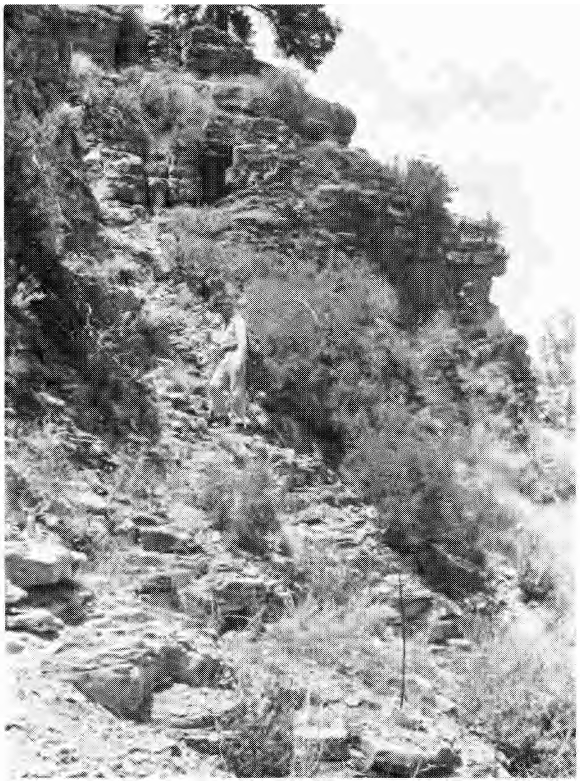

PHOTO 14–*Highly fossiliferous 4th Cliff at Dalton Bluff, formed by unit 36-133, middle part of La Pasada Formation.*

Unit	Faunal occurrence
	posita "ovata," Neospirifer cameratus, Anthracospirifer curvilateralis chavezae
105	*Fusulina* cf. *F. taosensis, Desmoinesia "missouriensis"?, Phricodothyris perplexa*
103	*Fusulina* cf. *F. taosensis, Antiquatonia hermosana, Composita "ovata," Phricodothyris perplexa, Gnathodus coloradoensis* n. subsp. A
97	*Isogramma* sp., Antiquatonia cf. *A. hermosana, Anthracospirifer curvilateralis chavezae, Neognathodus colombiensis, Gnathodus coloradoensis*

PHOTO 15—*Unique thick-bedded, algal limestone (unit 36-105) forming 3rd Cliff at Dalton Bluff; weathers with distinctive pitted surface.*

Unit	Faunal occurrence
	Atokan (Fusulinid Zone I)
94	*Fusulinella* cf. *F. famula, Neognathodus colombiensis, Composita "ovata," Gnathodus coloradonensis*
92	*Gnathodus coloradoensis*
89	*Fusulinella* cf. *F. devexa, Neognathodus colombiensis*
83	*Gnathodus coloradoensis, Neognathodus coloradoensis*
80	*Neognathodus colombiensis, Gnathodus coloradoensis*
79	Fusulinid molds, *Sandia brevis, Linoproductus planiventralis, Composita "ovata," Neospirifer tewaensis* (talus), *Neognathodus colombiensis*
71	*Sandia brevis, Antiquatonia* cf. *A. coloradoensis, Composita "ovata," Anthracospirifer newberryi, Idiognathoides* cf. *I. fossatus, Neognathodus colombiensis*
69	*Gnathodus coloradoensis, Idiognathoides fossatus*
	Morrowan or Atokan
68	*Rhipidomella trapezoida, Derbyia bonita?, Sandia* cf. *S. welleri, Antiquatonia coloradoensis, Neospirifer* sp., *Anthracospirifer newberryi, Gnathodus coloradoensis, Neognathodus colombiensis*
67	*Anthracospirifer curvilateralis tanoensis*
66	*Sandia welleri, Gnathodus coloradoensis*
	Morrowan
63	*Plicochonetes arkansanus, Desmoinesia nambeensis, Antiquatonia coloradoensis, Anthracospirifer newberryi?, Idiognathodus* n. sp. A
56	*Sandia welleri?, Zia novamexicana*
48	*Buxtonia grandis, Anthracospirifer curvilateralis tanoensis*
46	*Idiognathodus* sp. A, *Spirifer goreii*
41	*Neochonetes* n. sp. A
38	*Schizophoria altirostris?, Derbyia bonita?, Plicochonetes? arkansanus Neochonetes* n. sp. A?, *Sandia welleri?, Pulchratia? picuris, Antiquatonia coloradoensis, Linoproductus nodosus, Composita deflecta, Spiriferellina campestris, Anthracospirifer newberryi, Idiognathoides corrugatus*

SECTION 40
RIDGE EAST OF JICARILLA PEAK

This section describes the upper half of the La Pasada Formation and the lower part of the overlying Alamitos Formation. The lower Desmoinesian interval (Fusulinid Zone III) is faulted against the Precambrian quartzite (Jicarilla fault), with the Morrowan, Atokan and part of the lower Desmoinesian eliminated. This is the most northerly exposure where the La Pasada Formation has been recognized. It has a higher percentage of sandstone than found in the formation at measured section 10, Pecos Baldy ridge, located 4 miles southwest.

This section begins on the east slope of Jicarilla Peak about 350 ft below the summit. On the $7^1/2$ minute topographic map this mountain is named Chimayosos Peak but is not known by this name among the people in the region. The section was measured along the high ridge crest, called the Santa Barbara Divide, for a distance of about 3 miles eastward from Jicarilla Peak, to the summit of Santa Barbara Peak. This ridge forms the drainage divide between the Pecos and Santa Barbara rivers and the county line between Rio Arriba and Mora counties. The base of the section is the lowest exposed limestone east of the Jicarilla fault, located about 1,100 ft east of the summit of Jicarilla Peak.

PHOTO 16–*Measured section 40 begins at Jicarilla fault, high on east ridge of Jicarilla Peak, measured in sharply folded strata of La Pasada Formation.*

These lowest beds are overturned and dip at 85° west. The lower 400 ft of the section, up through unit 38, are folded into chevron folds. These units were measured mostly on the very steep north slope of the divide. Unit 53, at the top of the La Pasada Formation, is a shale which forms the lowest point on the first saddle about 3,500 ft east of the summit of Jicarilla Peak. East of this point the dips decrease progressively; measurements were achieved by a series of eastward offsets. These higher units are partly slumped and thicknesses are approximate.

For a photograph of Jicarilla Peak, the trace of the Jicarilla fault and the lower half of measured section 40, from the north, see Miller and others, (1963, pl. 12, fig. C). Section 40 is graphically depicted by Sutherland (1963, fig. 10). This section is remote and difficult to reach. It is located about 8 miles due south of the Santa Barbara Campground and can be reached by going south on the trail up the West Fork of the Santa Barbara River. The main trail climbs the divide to the saddle west of Jicarilla Peak. From that point walk eastward to the summit of the peak and continue eastward to the base of the section. This sequence was measured in August, 1956 by P. K. Sutherland and A. Lee McAlester.

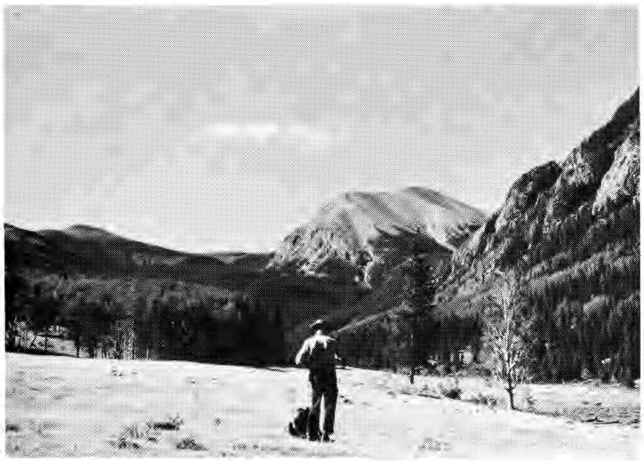

PHOTO 17—*Santa Barbara valley, looking south to Jicarilla Peak. Measured section 40 is on east slope of peak and on Santa Barbara Divide to left of peak (east).*

Unit	Lithology	Thickness (ft)
	Alamitos Formation–partial thickness	529
72	Sandstone, siltstone and shale: sandstone, very coarse grained, subangular quartz, arkosic; interbedded with light-yellowish-gray siltstone, micaceous, and shale containing plant fragment	6
71	Sandstone, light-olive-gray, very coarse-grained quartz and microcline feldspar, poorly sorted, partly conglomeratic, arkosic, slightly calcareous, micaceous matrix	
	(top: medium sandstone; quartz-overgrowth-cemented, mature, biotite-bearing arkose; 35% feldspar)	5
70	Covered; talus of sandstone and thin-bedded siltstone	22
69	Sandstone, medium-light-gray to yellowish-gray, weathers same, very coarse grained, quartz and microcline feldspar, poorly sorted, partly conglomeratic, arkosic, cross-bedded, very hard	
	(base: very coarse sandstone; quartz-overgrowth-cemented, mature arkose; 30% feldspar)	6
68	Covered; predominantly sandstone, minor limestone talus	
	(10 ft above base, talus: sandy, pelmatozoan, brachiopodal intrasparrudite; intraclasts of dismicrite)	45
67	Limestone and shale: limestone, medium-gray, weathers light yellowish gray, medium-grained, argillaceous, nodular, platy algae in some beds, contains siltstone lenses; interbedded with thin layers of partly covered shale	
	(base: pelmatozoan, foraminiferal biosparrudite)	6
66	Shale, dark-gray, very calcareous; 4-inch layer of calcareous siltstone at top	2
65	Siltstone, medium-gray, weathers light yellowish gray; lower 4 ft thin bedded, interbedded with silty, very calcareous shale, feldspathic, micaceous; upper 2 ft siliceous	
	(4 ft above base: sandy, spicular biomicrosparite)	6
64	Covered; probably mostly shale and thin-bedded sandstone, some limestone talus	110
63	Sandstone, light-olive-gray, weathers light yellowish gray, fine-grained quartz, poorly sorted, micaceous, slightly calcareous	
	(base: fine sandstone; calcite-cemented, mature, biotite-bearing, arkose; 40% feldspar)	4
62	Covered; probably shale, siltstone and thin-bedded sandstone	38
61	Sandstone, yellowish-gray, weathers light yellowish gray, very coarse-grained quartz and microcline feldspar, poorly sorted, partly conglomeratic, arkosic, hematitic matrix; unit badly slumped, thickness approximate	
	(15 ft above base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 40% feldspar)	80
60	Conglomerate, medium-light-gray, weathers light yellowish gray, granular, subrounded quartz and microcline feldspar grains and pebbles, slightly calcareous; contains thin layers of sandstone and shale; massive to slabby bedding; composition and thickness of all beds variable laterally; badly slumped, thickness approximate	
	(23 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, submature, biotite-bearing arkose; 40% feldspar)	40
59	Sandstone, medium-gray, weathers dark yellowish gray, very coarse-grained quartz, poorly sorted, slightly calcareous, weathers as slabs, plant fragments; contains a few thin layers of siltstone and shale, slightly micaceous; partly slumped, thickness approximate	
	(top: coarse sandstone; calcite-cemented, immature arkose; 40% feldspar)	35

Unit	Lithology	Thickness (ft)
58	Conglomerate, light-yellowish-gray, weathers same, granular to pebble quartz grains, poorly sorted, arkosic; some layers contain quartz pebbles up to 20 and 30 mm, weathers slabby and thick bedded (10 ft above base: coarse sandstone; calcite-cemented, submature arkose; 35% feldspar)	26
57	Sandstone and siltstone: sandstone, light-gray, weathers light yellowish gray, coarse-grained quartz and microcline feldspar, poorly sorted, slightly calcareous, arkosic; very thick bedded; interbedded in lower part with thin-bedded micaceous siltstone, plant fragments; gradational with unit 56 (22 ft above base: medium sandstone; calcite- and siderite-cemented, submature arkose; 35% feldspar)	57
56	Siltstone, shale and sandstone: siltstone, medium-gray, weathers brown, partly micaceous; interbedded with thin layers of shale, silty, micaceous and rare sandstone, fine-grained quartz, micaceous, plant fragments (5 ft above base: fine sandstone; calcite-cemented, submature, biotite-bearing arkose; 25% feldspar)	24
55	Shale and siltstone: shale, medium-gray, thin-bedded, silty, platy, partly micaceous; scattered, thin siltstone lenses	10
	Section offset eastward 600 ft on base of unit 54.	
54	Sandstone and siltstone: sandstone, medium-gray, fine- to medium-grained quartz and microcline feldspar, poorly sorted, slightly calcareous, chloritic cement, massive to thin-bedded; interbedded with rare, thin siltstones, medium-gray; plant fragments (base: fine sandstone; quartz-overgrowth-cemented, clay-bonded, immature, biotite-bearing arkose; 25% feldspar)	7
	La Pasada Formation—partial thickness	590.5
53	Shale, upper part dark gray, silty; interbedded with a few thin siltstone layers; lower part poorly exposed; unit forms lowest point on divide where trail crosses; thickness approximate	30
52	Limestone, medium-gray, weathers dark reddish brown with black wavy streaks, medium-grained, argillaceous; *Antiquatonia* cf. *A. hermosana, Linoproductus planiventralis, Composita "ovata", Phricodothyris perplexa* (top: slightly sandy, algal biomicrudite)	3
51	Covered; possibly shale	2
50	Limestone and shale: limestone, medium-dark-gray, weathers medium gray, fine-grained, silty, micaceous; interbedded with dark-gray to black, calcareous, platy shale (top: slightly sandy, spicular; foraminiferal biomicrosparrudite)	5
49	Covered; probably shale and siltstone	65
48	Sandstone, light-yellowish-gray, weathers same, very coarse grained quartz, poorly sorted with scattered quartz pebbles to 20 mm, micaceous; forms cliff and large rubble slide (top: medium sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	8
47	Covered; sandstone talus slide	15
46	Shale, black; containing numerous small limestone nodules; upper 8 ft partly covered by talus from above; thickness approximate (8 ft above base: partially recrystallized, algal biomicrudite)	20
45	Limestone and siltstone: limestone, dark-gray, weathers light yellowish gray, fine-grained, silty, platy algal in upper part; occurring as nodular layers interbedded with siltstone, light-yellowish-gray, weathers light yellowish brown, banded, very calcareous; *Mesolobus profundus?* (6 ft above base: recrystallized, dolomitic, brachiopodal, spicular biomicrosparrudite)	9
44	Shale; mostly covered	3
43	Sandstone, weathers light yellowish gray, medium- to coarse-grained quartz, very calcareous; scattered crinoid stem fragments (base: medium sandstone; calcite-cemented, mature, pelmatozoan orthoquartzite, no feldspar)	3
42	Covered; probably shale	7
41	Shale; black, friable	10
40	Limestone, dark-gray, weathers light yellowish gray, fine-grained, silty (base: recrystallized, algal biosparrudite)	3
39	Shale; mostly covered	2
	Section offset eastward over crest of anticlinal structure, on top of unit 38.	
38	Limestone and shale: limestone, dark-gray, weathers light yellowish gray, mottled, fine-grained; occurs as thin, partly brecciated, nodular layers interbedded with rare platy, nodular shale layers (5 ft above base: algal biomicrosparrudite)	12
37	Shale, dark-gray to black, calcareous, platy; contains a few thin beds of dark-gray fossiliferous limestone showing black streaks on weathered surface; partly covered	55
36	Limestone, dark-gray, weathers dark yellowish gray, fine-grained (base: algal biomicrudite)	1.5
35	Conglomerate, limestone boulders up to 200 mm, quartz pebbles in coarse-grained, poorly sorted, slightly calcareous matrix; conglomerate layers 2 inches to 1 ft thick, interbedded with thin sandstone layers (7 ft above base, matrix: coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	16
34	Sandstone, weathers light yellowish gray, very coarse grained quartz, subrounded, partly conglomeratic containing scattered limestone pebbles up to 50 mm, matrix slightly calcareous (4 ft above base: medium sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	8
33	Covered	4
32	Limestone; medium-gray, arenaceous	2
31	Covered; possibly shale	6
30	Limestone, light- to medium-gray, weathers light gray, black wavy streaks, fine-grained, thick bedding; fractured (base: partly recrystallized, algal biomicrudite)	2
29	Covered; probably shale	12
28	Limestone, dark-gray, weathers light yellowish gray, very fine grained; upper part slightly silty, irregularly bedded; Fusulinid Zone III; *Fusulina* cf. *F. novamexicana, Fusulina* cf. *F. euryteines, Wedekindellina* cf. *F. euthysepta; Antiquatonia hermosana* (base: partly silicified, algal biopelmicrosparite)	10
27	Shale, dark-gray, silty, calcareous, poorly exposed	3
26	Limestone, medium-dark-gray, weathers light yellowish gray, medium-grained, arenaceous, partly crinoidal; lower 2 ft irregularly bedded, upper part massive (5 ft above base: sandy, foraminiferal pelmatozoan biosparrudite)	17

Unit	Lithology	Thickness (ft)
25	Limestone, medium-dark-gray, weathers light yellowish gray, arenaceous	
	(base: slightly sandy biosparrudite)	3
24	Shale, dark-gray to black, very calcareous	4
23	Covered; apparently shale and siltstone	20
22	Sandstone, moderate-yellowish-brown, weathers light yellowish brown, fine- to medium-grained quartz, poorly sorted; argillaceous matrix; scattered subrounded quartzite grains up to 20 mm, slumped, thickness approximate	
	(8 ft above base: medium sandstone; clay-bonded, immature, muscovite-bearing orthoquartzite; no feldspar)	20
21	Sandstone, yellowish-gray, weathers light yellowish gray, coarse-grained quartz, poorly sorted; some thin conglomerate beds; slumped and partly covered; thickness approximate	
	(10 ft above base: granular, medium sandstone; quartz-overgrowth-cemented, clay-bonded, submature orthoquartzite; no feldspar)	25
20	Covered	22
19	Limestone and sandstone: limestone, medium-gray, fine-grained, arenaceous, fossiliferous; interbedded with sandstone, brownish-gray, coarse-grained quartz, very calcareous; unit has banded appearance	
	(base: coarse sandstone, calcite-cemented, mature, fossiliferous orthoquartzite; no feldspar: 5 ft above base: sandy, pelmatozoan, brachiopodal biomicrosparrudite)	8
18	Covered	7
17	Sandstone and shale: sandstone, medium-gray, weathers light yellowish gray, fine-grained quartz, calcareous; thin-bedded; interbedded with black calcareous shale, platy, arenaceous	4
16	Covered	2
15	Sandstone, dark-gray, weathers light yellowish gray, fine- to coarse-grained quartz, limestone and shale pebbles, poorly sorted, calcareous; thin shale layer near the base	
	(2 ft above base: medium sandstone; calcite-cemented, submature, fossiliferous orthoquartzite; trace feldspar)	18
14	Covered	47
13	Sandstone, light-yellowish-gray, coarse-grained quartz, poorly sorted, calcareous, conglomeratic at base	
	(basal 1 ft: very sandy, pelmatozoan biosparrudite; top: medium sandstone; calcite-cemented, submature, fossiliferous orthoquartzite; no feldspar)	2
12	Limestone and shale: limestone, medium-dark-gray, weathers light yellowish gray, fragmental, criniodal, silty and banded; 1 ft shale, dark-gray, platy in middle of unit	4
11	Covered	2
10	Sandstone, medium-gray, weathers light yellowish gray, coarse-grained quartz, poorly sorted, very calcareous	
	(5 ft above base: medium sandstone; quartz-overgrowth and calcite-cemented, submature, fossiliferous, intraclast-bearing orthoquartzite; no feldspar)	10
9	Covered, probably shale	1
8	Siltstone, dark-gray, weathers light yellowish gray, very calcareous, banded; contains nodular masses of limestone, dark-gray, fossiliferous; *Composita "ovata", Phricodothyris perplexa, Beecheria daltonensis*	
	(top 1 ft: partly silicified, algal, pelmatozoan biomicrosparrudite)	3
7	Sandstone, medium-gray, weathers light yellowish gray, coarse-grained quartz, very calcareous, partly conglomeratic at base with limestone pebbles up to 50 mm	
	(base: medium sandstone; calcite-cemented, mature, intraclast-bearing orthoquartzite; no feldspar)	3
6	Limestone, light-olive-gray, weathers light yellowish gray, fine- to coarse-grained, arenaceous; upper surface highly irregular; Fusulinid Zone II?, *Fusulina* sp.; *Kozlowskia montgomeryi, Desmoinesia "missouriensis", Sandia brevis?*	
	(top: slightly sandy, pelmatozoan, fusulinid biopelmicrudite)	5
5	Covered; partly siltstone and thin limestone layers	
	(base: slightly sandy, partially silicified, fusulinid biomicrosparrudite)	
4	Limestone conglomerate, medium-light-gray, cobbles to 100 mm, very fine grained limestone; matrix is arenaceous; calcareous cement, unit contains sandstone, fine-grained quartz, calcareous, in thin layers in upper part; basal contact irregular	
	(base: fossiliferous, medium sandstone; calcite-cemented, mature orthoquartzite; no feldspar)	2
3	Limestone, light-olive-gray, weathers light yellowish gray, fine-grained, partly fragmental, conchoidal fracture, argillaceous; occurs in thin to thick irregular nodular beds, weathered surface pitted; unit contains scattered irregular shale beds; upper 10 ft poorly exposed; *"Orbiculoidea"* sp., *Mesolobus striatus, Chonetinella jeffordsi?, Kozlowskia montgomeryi, Desmoinesia "missouriensis", Sandia brevis?, Hustedia "mormoni", Composita "ovata", Cleiothyridina pecosii, Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Punctospirifer* cf. *P. kentuckyensis, Phricodothyris perplexa*	
	(5 ft above base: partly silicified biointramicrudite)	24
2	Siltstone and limestone: siltstone, medium-dark-gray, weathers light reddish brown, calcareous, irregularly banded, thin-bedded; limestone, dark-gray, fine-grained, slightly silty, occurs as irregular, nodular masses; strike N. 25° E., overturned 85°W.; *Neospirifer cameratus, Neospirifer tewaensis, Phricodothyris perplexa*	
	(base: sandy spicular algal biosparite; top: algal biomicrosparrudite)	5
1	Shale, black, fractured with much slickensiding; mostly covered; exposed thickness	7
	Thrust fault, contact obscured by quartzite talus; fault dips steeply to the west	
	Ortega Formation (Precambrian)	
	Coarse-grained quartzite with thin beds of sillimanite-kyanite	

SECTION 41
NAMBE FALLS

This section exposes only the lower part of the La Pasada Formation but is probably the most important Morrowan sequence in the Sangre de Cristo Range. It is highly fossiliferous, particularly with brachiopods, and makes possible the correlation of several other more fragmentary sections (fig. 7). The highest Morrowan strata are truncated by a thrust fault. Massive limestones (Desmoinesian age) from higher in the La Pasada Formation have been thrust eastward against the Morrowan sequence

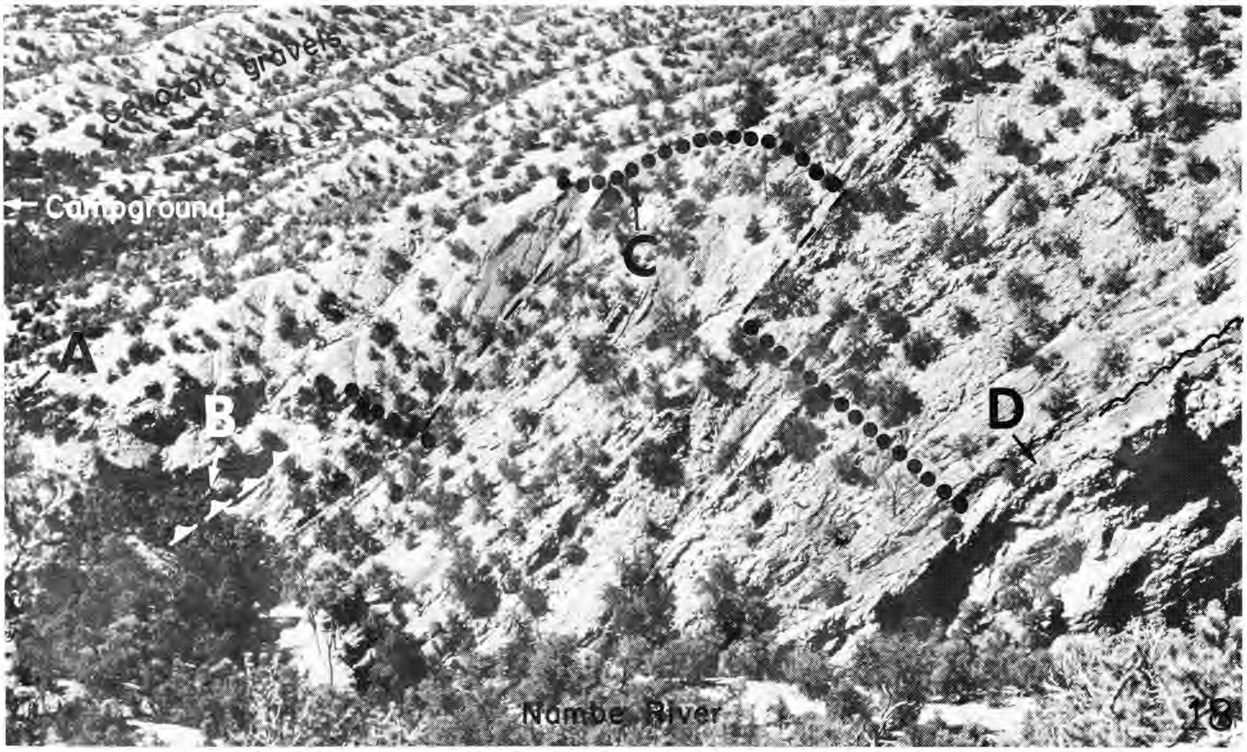

PHOTO *18—Entire exposure of measured section 41, lower part of La Pasada Formation, Morrowan age. "A" marks location of photo 19, locality 43. `B " marks fault contact at top of measured section 41 shown in photo 20. "C" marks location of photo 21. "D " marks basal unconformable contact with cliff-forming Mississippian limestones. Dotted line indicates route and offsets of measured section 41.*

PHOTO *19—Thick-bedded limestones, middle La Pasada Formation, Desmoinesian age, exposed north side Nambe River just east of campground, locality 43; see point "A" on photo 18.*

PHOTO *20—Thrust fault; middle La Pasada Formation at left, Desmoinesian age, faulted against lower part of same formation at right, Morrowan age; see point "B" on photo 18. Rock ledge at lower right, at river level, is unit 41-57.*

PHOTO *21—Limestones and shales in upper part of measured section 41, units 51 and 52, exposed high on ridge; see point "C" on photo 18.*

The section is exposed along bluffs on the northern side of the Nambe River between the campground at the end of the road, on the west, and Nambe Falls on the east, a distance of about 0.25 mile. It is located in NW$^1/_4$ SW$^1/_4$, sec. 29, T. 19 N., R. 10 E. The sequence dips steeply to the west. The falls flow over the Precambrian granites. The Mississippian and pre-Mississippian(?) sequence here form a vertical canyon on the river just west of the falls and is one of the most spectacular exposures of this rock sequence in the Sangre de Cristo Mountains. The section given herein begins with the unconformity at the base of the Pennsylvanian sequence exposed on the north side of the river 400 ft downstream from Nambe Falls and 800 ft upstream (east) of the eastern edge of the campground. The section was measured from the unconformity westward high on the steep hillside, well away from the river, 75 to 150 ft in elevation above river level through unit 41-51. The section was then offset downslope (south-southeast) toward the river on unit 41-49. Units 52 to 61 were measured in a small draw 30 to 40 ft above the river, just east of the thrust fault. The fault is exposed in the northern river bank about 300 ft east of the campground. The brecciated zone and the highly fractured black shale, marking the fault zone, below the Desmoinesian limestones, are not included in the measured section. Unit 41-57 is the highest Morrowan unit exposed at river level on the north side approximately 40 ft east of the fault. Higher units are exposed a short distance northward up the slope.

The massive limestones above the fault, exposed from the fault westward to the campground (locality 43), are highly fossiliferous and contain typical lower Desmoinesian fossils including fusulinids from Fusulinid Zone II. The entire Atokan part of the section has been cut out by faulting. If the thicknesses in the Nambe Falls area are the same as at Dalton Bluff (measured section 36) exposed 18 miles to the southeast in the Pecos valley, then the amount of section faulted out would be approximately 200 to 250 ft.

Nambe Falls is located on the Nambe Indian Reservation. It is reached by driving about 4 miles on an unpaved road leading southeastward from the Nambe Pueblo, up the Nambe River valley. The road ends at a campground on the northern bank of the river, just west of the measured section. Measured section 41 was described by P. K. Sutherland and A. Lee McAlester in August, 1956. Samples for conodonts were collected from the sequence in August, 1968, by Sutherland and Thomas W. Henry. At that time, yellow unit numbers were painted on the more resistant units.

The lower part of section 41, up through unit 27, contains nondiagnostic Morrowan conodonts. The occurrence of *Idiognathodus* n. sp. A in units 31, 34, 39 and 41 indicates an upper Morrowan age for this interval. *Neognathodus* n. sp., in unit 51, has not been found elsewhere in rocks of definite Morrowan age; Lane (personal communication) considers this unit and the overlying units to be Atokan. We disagree because brachiopod species we consider typically Morrowan are found in unit 58. The stratigraphic relations of these units are shown on fig. 7; the interval in dispute is marked.

The most important brachiopod horizon is the *Zia novamexicana* Zone, in unit 39, which provides a basis for correlation across the southern part of the Sangre de Cristo area (fig. 7).

Unit	Lithology	Thickness (ft)
	La Pasada Formation (Middle part, lower Desmoinesian)	
	Limestone, light to dark-gray, occurring in layers up to 2 ft in thickness, alternating with thin layers of calcareous shale, unit fossiliferous; Fusulinid Zone II: *Fusulina* aff. *F. taosensis; Mesolobus striatus, Kozlowskia haydenensis, Antiquatonia hermosana, Neospirifer cameratus;* thickness not measured (locality 43)	
	Thrust Fault	
	La Pasada Formation (Lower part, Morrowan)–partial thickness	196-216.5
61	Covered, probably shale, not included in total thickness, thickness estimated	(30)
60	Shale, dark-gray, weathers gray, friable, mostly covered	3
59	Shale and sandstone; shale, greenish-tan weathering with small rust-stained siltstone concretions; unit has 3-inch layer green-weathering, fine-grained, hard sandstone at top	1
58	Limestone, medium-gray, weathering light gray, coarse-grained, crinoidal, occurring in thin nodular layers, some argillaceous; *Antiquatonia coloradoensis, Cleiothyridina milleri, Spirifer goreii* (top: slightly silty, pelmatozoan-bryozoan biomicrosparite)	2
57	Sandstone, green, weathers greenish brown, fine-grained, micaceous, hard; thickness varies; highest Morrowan unit seen at river level	1.5-2
56	Shale, gray, weathers tan, micaceous; *Plicochonetes? arkansanus, Spirifer goreii*	3-4
55	Sandstone, weathers greenish brown, fine-grained, micaceous; alternating with thin micaceous shale layers; varies in thickness (top: fine sandstone; partly quartz-overgrowth-cemented, dominantly clay-bonded; immature orthoquartzite; no feldspar)	2-4
54	Shale, light-gray, weathers tan, micaceous, thin-bedded	2
53	Sandstone, weathers reddish brown, very coarse grained, poorly sorted, thick-bedded	4
52	Siltstone, shale and limestone: siltstone, dark-gray to black, calcareous; occurring in thin layers containing dark-gray fine-grained hard dense limestone nodules up to 6 inches long and interbedded with thin silty shale layers	7
51	Limestone, medium-gray, weathers light brown, fine-grained, fossiliferous, thick-bedded; *Neognathodus* n. sp. (top: biomicrite)	2
50	Shale, dark-gray to black, weathers light gray, friable	10
49	Limestone, weathers gray, argillaceous, thin-bedded; very fossiliferous; *Neochonetes? platynotus, Desmoinesia nambeensis, Cleiothyridina milleri, Anthracospirifer curvilateralis tanoensis?*	0.5
48	Shale, weathers gray to greenish tan, friable	7
47	Limestone, weathers pinkish brown, medium-grained, thin-bedded, crinoidal in upper part, fossiliferous; *Plicochonetes? arkansanus, Sandia welleri, Pulchratia? picuris, Linoproductus nodosus?, Hustedia gibbosa?, Spirifer goreii, Anthracospirifer newberryi, Anthracospirifer curvilateralis tanoensis, Punctospirifer morrowensis, Tesuquea formosa* (2 ft above base: pelmatozoan, bryozoan biomicrosparrudite)	4-5
46	Shale and limestone: shale, weathers greenish gray, fissile; contains numerous thin, medium-gray, fine-grained, limestone nodules in lower part;	

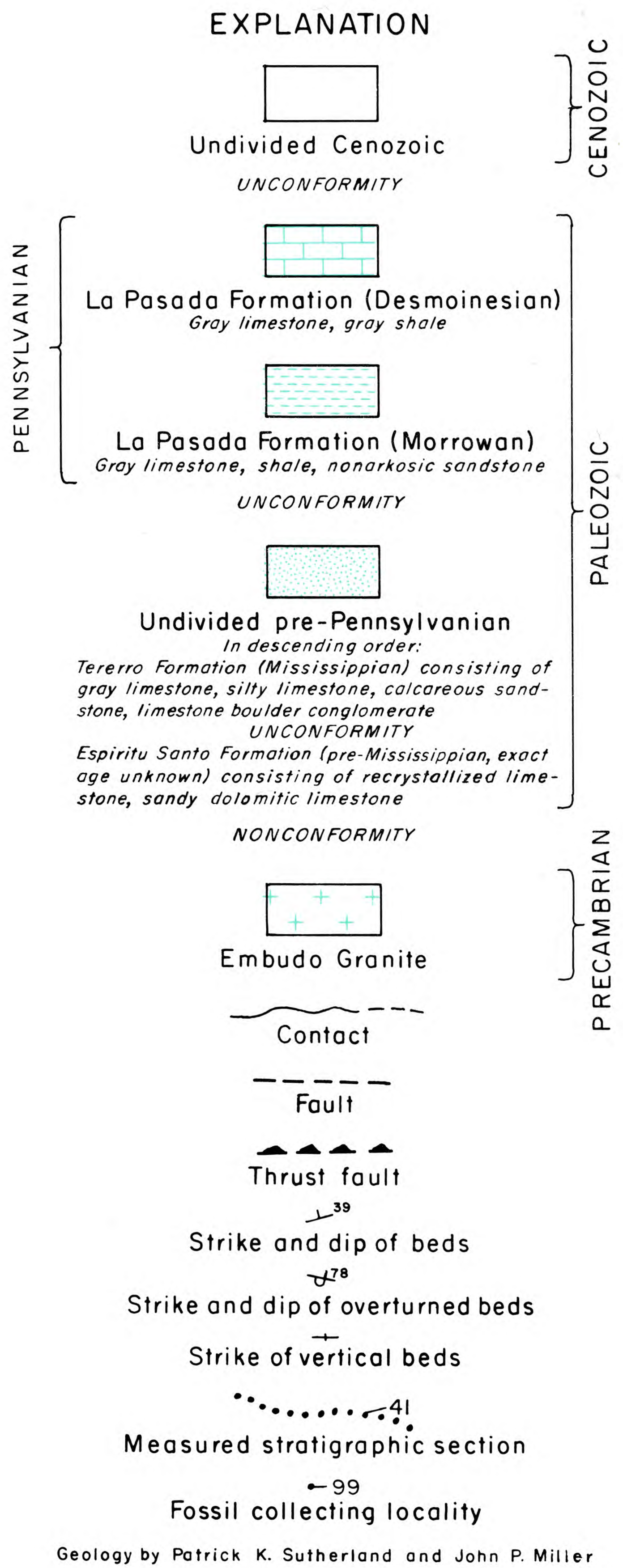

FIGURE 50—*Geologic and locality map of Nambe Falls area.*

Unit	Lithology	Thickness (ft)
	contains numerous small specimens of nodular algae	14
45	Limestone, weathers pinkish brown, medium-grained, crinoidal, fossiliferous	
	(top: brachiopod-molluscan-pelmatozoan-bryozoan biopelmicrudite)	2
44	Shale, dark-green, weathers maroon, partly covered	15
43	Sandstone, weathers reddish brown, very coarse grained, poorly sorted, conglomeratic, containing scattered quartz and limestone pebbles to 80 mm in diam., particularly in lower part; contains much fossil wood; *Dadoxylon* sp.	
	(2 ft above base: medium to coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	4
42	Shale, weathers ash gray, friable, with rare thin limestone layers; fossiliferous; *Schizophoria oklahomae, Meekella* n. sp. A, *Plicochonetes? arkansanus, Desmoinesia* cf. *D. nambeensis, Sandia welleri, Echinaria* n. sp. A, *Buxtonia* cf. *B. grandis, Antiquatonia coloradoensis, Hustedia gibbosa?, Composita gibbosa, Spirifer goreii, Anthracospirifer curvilateralis tanoensis*	1
41	Limestone, weathers pinkish brown, coarse-grained, crinoidal, upper 6 inches sandy, upper surface irregular; *Idiognathodus* n. sp. A	
	(2 ft above base: very slightly sandy biosparite)	3-4
40	Shale, weathers maroon to gray, friable	2-3
39	Limestone, buff-gray, weathers pinkish-buff, crinoidal, fossiliferous; *Zia novamexicana* Zone: *Schizophoria oklahomae, Meekella* n. sp. A, *Sandia welleri, Pulchratia? pustulosa, Pulchratia? picuris, Antiquatonia coloradoensis, Linoproductus nodosus, Linoproductus devargasi, Zia novamexicana, Anthracospirifer newberryi, Idiognathodus* n. sp. A	
	(1 ft above base: slightly silty, bryozoan, pelmatozoan biomicrosparrudite; 5 ft above base; very slightly sandy biomicrosparrudite)	10
38	Sandstone, greenish-brown, weathers maroon, coarse-grained, poorly sorted, small-scale cross-bedding, slightly calcareous, conglomeratic near base, lower surface highly irregular; fossiliferous at top; *Schizophoria oklahomae*	
	(1.5 ft above base: very coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; 1% feldspar)	2.5-3
37	Shale, gray, partly micaceous, friable, mostly covered	3
36	Sandstone, green, weathers reddish brown, coarse-grained, poorly sorted, partly conglomeratic, fragments angular	
	(top: very coarse sandstone; microcrystalline silica- and quartz-overgrowth-cemented, immature, fossiliferous orthoquartzite; no feldspar)	0.5-1
35	Shale, dark-green, weathers green to maroon, micaceous	1.5
34	Limestone, light-gray, weathers buff, coarse-grained, crinoidal, occurring in massive hard layers; rare, thin, hard, coarse sandstone lenses near top; *Idiognathodus* n. sp. A	
	(4 ft above base: very slightly sandy, bryozoan-pelmatozoan biosparite)	8
33	Limestone and shale: limestone, light-gray, weathers same, coarse-grained, highly crinoidal; occurring in layers 2 to 6 inches thick, interbedded with thin layers of crinoidal, calcareous, gray shale; unit highly fossiliferous; *Schizophoria oklahomae, Schizophoria altirostris?, Rhipidomella trapezoida, Meekella* n. sp. A, *Derbyia bonita, Pliocochonetes? arkansanus, Tesuquea formosa, Pulchratia? picuris, Buxtonia grandis, Antiquatonia coloradoensis, Linoproductus nodosus, Rhynchopora magnicosta, Composita gibbosa, Cleiothyridina milleri, Spirifer goreii, Anthracospirifer curvilateralis tanoensis?, Spiriferellina campestris, Beecheria stehlii*	2
32	Covered, probably shale; *Lingula* sp. A in top 1 ft	18
31	Limestone, medium-gray, weathers buff gray, crinoidal, fossiliferous; *Idiognathodus* n. sp. A	
	(top: extensively recrystallized, bryozoan-pelmatozoan biomicrosparrudite)	2
30	Siltstone, greenish-gray, weathers greenish brown, slightly calcareous, micaceous, cross-bedded, basal surface highly undulating	
	(top: fine sandstone; calcite- and quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	3-5
29	Shale and siltstone: greenish-gray, weathers same; shale, micaceous, silty, interbedded in thin layers with thin beds micaceous siltstone; *Sandia welleri, Linoproductus nodosus*	3
28	Shale and limestone: shale, dark-gray to black, weathers maroon, friable, with thin, medium-gray silty limestone layer at top	2.5
27	Limestone, buff-gray, weathers same, fine-grained, crinoidal, thin-bedded, very fossiliferous; *Schizophoria oklahomae, Tesuquea formosa, Linoproductus nodosus, Spirifer goreii, Phricodothyris perplexa*	
	(2 ft above base: slightly sandy biomicrite)	3
26	Limestone, buff-gray, weathers same, coarse-grained, crinoidal, massive, even-bedded layers, fossiliferous; *Schizophoria altirostris?*	
	(5 ft above base: slightly sandy, partially recrystallized, bryozoan, pelmatozoan biomicrudite)	11
25	Covered, poorly exposed gray shale in lower part	20
24	Limestone, buff-gray, weathers buff, with scattered, subangular quartz pebbles to 4 mm, thickness variable; *Anthracospirifer matheri, Beecheria stehlii*	
	(top: sandy, bryozoan-pelmatozoan biomicrudite)	2-3
23	Shale, weathers maroon to yellow, friable	5
22	Sandstone, brownish-gray, weathers reddish brown, coarse-grained, slightly calcareous; many wood fragments; upper surface irregular	
	(1 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; no feldspar)	1.5
21	Shale, dark-gray to black, fossiliferous	1.5
20	Limestone, medium-gray, weathers buff, coarse-grained, crinoidal, fossiliferous, basal surface highly irregular giving varying thickness; *"Orbiculoidea" youngi?*	
	(2 ft above base: slightly sandy, bryozoan, pelmatozoan biomicrosparrudite)	2-4
19	Shale, black, with rare, small limestone concretions, thickness irregular	1-2
18	Sandstone, dark-greenish-gray, weathers greenish black, disappears northward, rests on highly irregular Mississippian surface, fills cavities in upper surface of limestone, thickness variable	
	(1 ft above base: medium sandstone; quartz-overgrowth-cemented, clay-bonded, immature, chlorite- and metamorphic rock fragment-bearing orthoquartzite; top: extensively bimodal granular and fine sandstone; quartz-overgrowth-cemented and clay-bonded, chlorite- and metamorphic rock fragment-bearing orthoquartzite; no feldspar)	0-7
	Unconformity	
	Tererro Formation (Mississippian)	

SECTION 42
ELK MOUNTAIN

Elk Mountain is located about 7 miles east-northeast of Terrero, at the south end of the East Range. It is reached by driving 10.3 miles east on the Willow Creek jeep road from its junction with State Highway 63 at the Pecos River. Park at point where the jeep road crosses the East Divide, 1 mile due north of the summit of Elk Mountain.

Elk Mountain is a rounded, partly grass-covered nob rising only slightly above timber line. The peak itself (units 12 to 29) consists of lower Desmoinesian limestones (Fusulinid Zone III) within the La Pasada Formation. The fusulinids in unit 42-26 are very similar to those in unit 36-127.

The base of the section starts at the top of the Tererro Formation (Mississippian) at its westernmost outcrop in the bottom of Burro Canyon, about 1 mile due east of the top of Elk Mountain. This point is 1,200 ft below the top of Elk Mountain. Units 9 to 11, which are mostly covered, were measured west-northwest up the steep hillside at the head of Burro Canyon, to the lowest exposures in the saddle at the north edge of Elk Mountain (unit 12). The partly exposed lower part of the section is included to provide an approximate interval from the base of the Pennsylvanian section to the exposures on Elk Mountain. This mostly covered interval presumably includes rocks of Morrowan and Atokan age. Major faulting does not appear to be concealed in this covered interval. Units 13 to 27 were measured on the north slope of Elk Mountain. Elk Mountain is on the crest of a broad anticlinal fold extending north along the east divide. The section was measured in June, 1957 by P. K. Sutherland and Dean Gerber.

Unit	Lithology	Thickness (ft)
	Top of section is about 200 yards south of highest point on Elk Mountain.	
	La Pasada Formation—partial thickness	925
29	Limestone, medium-gray, weathering buff gray, fine-grained, thin-bedded; strike N. 20° W., dip 10° SW; poorly exposed, thickness approximate	2
28	Siltstone, brownish-gray, weathering buff, slightly calcareous; thin-bedded (very fine sandstone; calcite-cemented, submature, muscovite- and feldspar-bearing orthoquartzite; trace feldspar)	1
27	Limestone, black to light-gray, fine-grained, thin- to thick-bedded, spicular; forms summit of Elk Mountain; *Antiquatonia hermosana, Reticulatia* sp. A, *Composita "ovata"*	12
26	Limestone, black to light-gray, weathers light gray, very fine grained, spicular; mostly thin-bedded; poorly exposed; Fusulinid zone III: *Fusulina* cf. *F. novamexicana, Wedekindellina* sp. (top: partly recrystallized biomicrudite)	12
25	Limestone, dark-gray, weathering light buff gray, very fine grained; conchoidal fracture, thin-bedded, includes some layers of calcareous silty shale; forms bench; *Fusulina* sp. (top: spicular pelmatozoan brachiopodal, molluscan biomicrudite)	15
24	Limestone, black, weathering light buff gray, very fine grained; conchoidal fracture; beds 3 to 4 inches thick; some thin calcareous shale layers	27
23	Covered, sandstone and shale talus	11
22	Sandstone, weathering buff, coarse-grained, poorly sorted, partly conglomeratic poorly exposed, probably includes some shale	12
21	Limestone, medium-gray, weathering light gray, fine-grained, arenaceous; forms top of bench	3
20	Limestone, black, weathering buff, fine-grained; fractured; *Mesolobus striatus, Kozlowskia montgomeryi, Phricodothyris perplexa* (5 ft above base: spicular biomicrite)	7
19	Limestone, medium- to dark-gray, weathering buff gray, fine-grained, thin-bedded	2
18	Sandstone and shale: sandstone, weathering buff, fine-grained, platy, wood fragments; partly covered, 3 ft or more arenaceous shale at base (8 ft above base: very fine sandstone; quartz-overgrowth- and calcite-cemented, submature, muscovite-, biotite-, and feldspar-bearing orthoquartzite; 1% feldspar)	16
17	Limestone, medium-gray to black, weathering buff, fine-grained, scattered crinoid stems; forms bench	13
16	Shale, black, silty, calcareous	3
15	Limestone, black, weathering buff, fine-grained, scattered crinoid stems; platy, partly covered; forms bench; *Chonetinella jeffordsi, Linoproductus planiventralis, Neospirifer cameratus* (top: very slightly silty pelmatozoan biomicrosparrudite)	5
14	Shale, dark-gray, silty, slightly calcareous, mostly covered	5
13	Limestone, light-gray, weathering buff gray, coarse-grained; a brachiopod biostrome of *Desmoinesia "missouriensis," Beecheria* cf. *B. millepunctata*	3
12	Limestone, dark-gray, weathering buff, fine-grained, silty, thin-bedded, flaggy, partly covered; forms lowest exposure on north slope of Elk Mountain (7 ft above base: sandy, micaceous, spicular biomicrosparite)	11
	Section turns southward in open saddle and continues up north slope of Elk Mountain	
11	Covered and sandstone: rare exposures, much coarse talus of sandstone, weathering buff, coarse-grained; 2-ft layer of fossiliferous limestone occurs 35 ft below top of unit; thickness approximate	165
10	Covered; no coarse talus, possibly shale and thin-bedded sandstone; thickness approximate	400
9	Covered and sandstone: coarse talus of sandstone, weathering buff, coarse-grained; thickness approximate	200
	Unconformity	
	Tererro Formation (Mississippian)	

LOCALITY 43
NAMBE FALLS-DESMOINESIAN

Near Nambe Falls the upper part of the La Pasada Formation, composed of Desmoinesian limestones, is thrust eastward against the lower part of the La Pasada Formation (measured section 41). For a detailed location see measured section 41 and fig. 50. The Desmoinesian limestones include both Fusulinid Zone II and III. Stratigraphic sections were not measured, but several hundreds of feet of strata are present on the high hill immediately south of Rio Nambe at the falls. These rocks include: *Fusulinia* cf. *F. taosensis; Mesolobus striatus, Kozlowskia haydenensis, Cleiothyridina pecosii, Anthracospirifer curvilateralis chavezae, Anthracospirifer "occiduus ", Antiquatonia hermosana.*

SECTION 47
DIVIDE AT HEAD OF RIO VALDEZ

This section begins on the East Divide on the steep east-facing cirque-like slope at the head of Santiago Creek. In this area the Del Padre Formation (pre-Mississippian) rests unconformably on the Precambrian and is, in turn, overlain unconformably by the Pennsylvanian. The Tererro Formation (Mississippian) is missing. Units 6 to 25 are exposed on the east side of the East Divide. From this point the section is offset 1.7 miles west-northwest across a broad, mostly open, covered ridge, to the distinct saddle or pass in the east-west divide at the head of Rio Valdez. Units 27 to 31 were examined in the most easterly draw of the headwaters of the Pecos River. Unit 32 is black shale exposed on the divide between the headwaters of the Valdez and the South Fork of Rio de la Casa to the north. The remainder of the section was measured on the narrow divide extending northwestward by a series of westward offsets. The top of the section is located about 1.1 miles northwest of the shale saddle of unit 32 and ends at a small saddle marked by a fault.

The lower part of the section, units 6 to 25, is Morrowan and is much more highly clastic than the sequence of the same age at Dalton Bluff, in the Pecos valley 24 miles southwest. Rocks of Atokan age are probably included in the covered interval of unit 26. The remainder of the section, units 27 and higher, are early and middle Desmoinesian and represent more shaly facies of the upper part of the La Pasada Formation in its northern development. In comparison with measured section 40, exposed on the Santa Barbara Divide 4 to 5 miles west, the Desmoinesian limestones here are less fossiliferous, more fine grained, darker, commonly spiculiferous and possibly represent deeper water deposition. The upper part of the section shows marked lateral facies changes. Also the sandstones throughout the section contain very small percentages of feldspar, the same as in the La Pasada Formation at measured section 40. The great mass of arkosic sandstones and conglomerates making up Santa Barbara Peak, to the west and stratigraphically higher than the top of the section, are part of the Alamitos Formation. The section was measured in June, 1957 by P. K. Sutherland.

Unit	Lithology	Thickness (ft)
	Top of section at end of cliff of unit 64, at fault marked by first small saddle southeast of Santa Barbara Peak on Pecos River-Rio de la Casa divide. Shale crops out immediately west of fault.	
	La Pasada Formation–partial thickness	2,548
64	Conglomerate and shale: conglomerate weathers buff, coarse-grained, poorly sorted, subangular grains, quartz pebbles up to 4 cm, thick-bedded, cross-bedded; interbedded with thin layers of black, carbonaceous shale and sandstone, plant fragments; unit forms cliff facing south toward Pecos Valley (10 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; trace feldspar; 18 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; trace feldspar; 32 ft above base: medium sandstone; quartz-overgrowth- and calcite-cemented, submature, orthoquartzite; trace feldspar)	40
	Section offset ¼ mile westward on divide. Unit 63 appears to underlie unit 64 but relationship is uncertain.	
63	Siltstone and shale: siltstone, weathers buff, micaceous, platy, beds up to 0.5 ft; interbedded with thin micaceous shale layers; scattered plant fragments; unit forms nob on ridge (top: fine sandstone; calcite-cemented, submature, fossiliferous orthoquartzite; feldspar 1%)	6
62	Shale, weathers brown, silty, micaceous	12
61	Covered, probably shale	12
60	Shale and limestone: shale, black, calcareous, fissile; interbedded with thin layers limestone, black, weathers light gray, very fine grained, micritic, conchoidal fracture	5
59	Sandstone, weathers reddish brown, fine-grained, silty, partly carbonaceous	1
58	Sandstone, weathers buff, medium- to coarse-grained, poorly sorted, scattered quartz grains up to 2 mm; seen as loose blocks on divide, thickness approximate (top: medium sandstone; quartz-overgrowth-cemented, immature, orthoquartzite; feldspar 4%)	5
57	Covered, probably shale and micaceous siltstone	11
56	Limestone, black, weathers buff red, very fine grained, micritic, conchoidal fracture	1
55	Shale, dark-gray, silty, calcareous	11
54	Covered, probably shale	15
53	Limestone, black, weathers brown; fine-grained, nodular to platy	0.5
52	Shale, dark-gray, fissile; partly covered	4.5
51	Limestone, black, weathers buff gray, fine-grained, silty, platy	4
50	Shale, dark-gray, fissile, mostly covered	7
49	Limestone, black, weathers reddish brown, very fine grained, micritic	0.5
48	Shale, dark-gray, partly silty, calcareous; *Desmoinesia "missouriensis"?*	10.5
47	Siltstone, weathers buff brown, sandy, partly carbonaceous	2
46	Covered, possibly shale; interval approximate	15
45	Sandstone, weathers buff, coarse-grained, poorly sorted, conglomeratic (top: coarse sandstone; quartz-overgrowth-cemented, mature, orthoquartzite; trace feldspar)	8
44	Covered; talus of micaceous shale and siltstone, contains plant fragments; section offset 80 yards westward on ridge; thickness approximate	17
43	Shale and limestone: shale, black; interbedded with thin layers up to 0.5 ft thick of limestone, black weathering rust brown, nodular, micritic, algal and limestone nodules	8
	West of small saddle on ridge unit 42 apparently changes character westward by rapid facies change to fine-grained sandstone with plant fragments. Section offset westward on unit 42 approximately 100 yds	
42	Sandstone, conglomerate and siltstone: weathers buff; sandstone, coarse-grained, poorly sorted, interbedded with conglomerate layers (4 ft above base: medium sandstone; quartz-overgrowth-cemented, submature orthoquartzite; feldspar 2%)	10
41	Shale, black, fissile	15.5
40	Limestone, black, weathers buff, fine-grained, micritic	0.5
39	Shale, black, fissile	3
38	Covered; forms saddle, interval approximate	3
37	Shale, siltstone, and limestone: shale, dark-gray, grading upward into calcareous, platy siltstone; interbedded with thin, nodular layers of black, fine-grained, sparsely fossiliferous limestone near	

Unit	Lithology	Thickness (ft)
	base; *Lingula* cf. *L. carbonaria, Sandia brevis?, Anthracospirifer curvilateralis chavezae, "Buxtonia"* sp.	
	(base: spicular biomicrite; top: fine sandstone; calcite-cemented, submature, fossiliferous, orthoquartzite; feldspar 1%)	18
36	Shale and siltstone: shale, dark-gray, sparsely fossiliferous; interbedded with thin layers of calcareous, partly micaceous, siltstone	25
	Possible fault in saddle on divide separating units 35 and 36.	
35	Sandstone, weathers brown, poorly sorted, micaceous; plant fragments	
	(top: medium sandstone; quartz-overgrowth-cemented, immature, orthoquartzite; feldspar 2%)	5
34	Shale, dark-gray	8
33	Limestone, dark-gray, weathers buff, silty, thin-bedded, sparsely fossiliferous	2
32	Shale, dark-gray, platy; exposed in saddle on divide	45
31	Shale and limestone: shale, dark-gray, containing at base and at top ½ ft layers of limestone, black, weathers reddish brown, very fine grained, conchoidal fracture, nodular; strike N-S, dip 9° W.	6
30	Shale and limestone: shale, black, nodular, sparsely fossiliferous; layers of dark-gray fossiliferous limestone 2 to 4 inches thick 2 ft above base	7
29	Siltstone and shale: siltstone, brownish-gray, weathers brown, highly micaceous; thin cross-bedded layers; interbedded with silty, micaceous, partly covered shale	
	(8 ft above base: fine sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; feldspar 2%)	20
28	Limestone, medium-gray, weathers buff, silty, crinoidal; thickness variable; *Mesolobus striatus*	1
27	Shale and siltstone: shale, dark-gray, partly micaceous; includes a few thin micaceous siltstone layers containing plant fragments partly slumped, thickness approximate	65
26	Covered; lower 800 ft has talus of sandstone, siltstone and shale; interval approximate (map computation, based on dip of 10 degrees west)	1,800
	Section moved at right angle to strike, from northwest rim or steep slope at head of Santiago Creek 2.1 miles west northwest across covered interval (unit 26) along broad ridge to lowest exposure on divide between Rio Valdez and Rio de la Casa. Units 27 to 31 observed in most easterly draw of headwaters of Pecos River just south of main divide. Higher units measured westward along crest of divide.	
25	Sandstone, conglomerate and shale: weathers buff; sandstone, medium- to coarse-grained, poorly sorted, in thick-bedded layers up to 2 ft; alternating with poorly sorted, thick-bedded conglomerate layers up to 5 ft and mostly covered beds of micaceous, silty shale containing plant remains; unit partly covered; forms highest beds on northwest rim of cirque; strike N. 20° E., dip 10° N.	
	(12 ft above base: granular, coarse sandstone; quartz-overgrowth-cemented, immature orthoquartzite; no feldspar; 30 ft above base: fine sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; feldspar 2%; 45 ft above base: medium sandstone; quartz-overgrowth-cemented, submature, orthoquartzite; no feldspar)	65
24	Sandstone, medium-gray, weathers buff, poorly sorted, partly conglomeratic, irregular calcareous lenses, thick-bedded, forms cliff	
	(top: coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	9
23	Sandstone, medium-gray, weathers buff, poorly sorted, conglomeratic, quartz pebbles up to 5 mm; irregular fossiliferous limestone lenses	3
22	Shale, friable, partly covered	11
21	Sandstone and limestone: sandstone, greenish-gray, poorly sorted, calcareous; interbedded with sandy, crinoidal, fossiliferous limestone; *Desmoinesia nambeensis, Anthracospirifer curvilateralis tanoensis, Spiriferellina campestris*	5
20	Sandstone, weathers buff, poorly sorted, partly conglomeratic, scattered pebbles up to 5 mm; mostly slumped, probably some shale in lower part; thickness approximate	
	(30 ft above base: sandy, bryozoan, pelmatozoan biosparrudite; top: coarse sandstone; quartz-overgrowth-cemented, clay-bonded, immature orthoquartzite; no feldspar)	50
19	Shale and limestone: shale, black; interbedded in lower part with thin layers dark-gray, crinoidal limestone; *Schizophoria oklahomae, Schizophoria altirostris?, Tesuquea formosa, Pulchratia? picuris, Buxtonia grandis, Linoproductus nodosus, Composita gibbosa, Spirifer goreii, Anthracospirifer curvilateralis tanoensis, Spiriferellina campestris*	15
18	Sandstone, siltstone, and shale: sandstone, weathers buff, fine-grained, poorly sorted, partly carbonaceous; medium-bedded, irregular layers up to 1 ft thick; interbedded with micaceous siltstone and shale, plant fragments; thickness approximate	
	(fine sandstone; quartz-overgrowth-cemented, immature, orthoquartzite; 26 ft above base: medium sandstone; calcite-cemented, submature orthoquartzite; no feldspar)	40
17	Covered; shale talus lower 10 ft, sandstone upper part; interval approximate	35
16	Limestone, medium-gray, weathers buff, coarse-grained, slightly sandy, highly crinoidal	
	(top: sandy, brachiopod-bryozoan, pelmatozoan biosparrudite)	3
15	Covered, probably shale	8
14	Shale and siltstone: shale, dark-gray, carbonaceous; interbedded with thin layers of micaceous siltstone; numerous plant fragments	
	(10 ft above base: fine sandstone; quartz-overgrowth-cemented; submature, orthoquartzite; no feldspar)	22
13	Shale and siltstone: shale, black, carbonaceous, micaceous, friable; thin, nodular siltstone layers near top; unit forms bench	5
12	Covered, probably black shale	16
11	Sandstone, medium-gray, weathers rust red, coarse-grained, poorly sorted, partly conglomeratic, partly carbonaceous; irregular bedding	
	(top: coarse sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	4
10	Covered, probably shale and sandstone	11
9	Sandstone, medium-gray, weathers buff red, medium-grained, thick-bedded; includes a few thin layers of carbonaceous shale	
	(3 ft above base: medium sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	5
8	Covered, probably shale	11
7	Sandstone and shale: sandstone, dark-gray, weathers rust brown, medium-grained, poorly sorted, carbonaceous; interbedded irregularly with black shale; numerous plant fragments	

Unit	Lithology	Thickness (ft)
	(4 ft above base: medium sandstone; quartz-overgrowth-cemented, mature orthoquartzite; no feldspar)	6
6	Sandstone, brown to black, weathering buff, fine-grained, shaly, micaceous, carbonaceous, and containing numerous plant fragments in upper 3 ft; highly variable in thickness	
	(base: interlaminated, medium and fine sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing orthoquartzite; no feldspar)	4
	Unconformity	
	Del Padre Formation (pre-Mississippian)	

LOCALITY 51
HYDE PARK ROAD

The lower part of the La Pasada Formation consisting of Morrowan rocks, outcrops on the Hyde Park Road (State Highway 475) 0.1 to 0.2 mile south of the sharp bend in the road located on the bluff immediately south of Little Tesuque Creek. Fossils were collected in a road cut on the east side of the road, in interbedded limestones and shales. This locality is 4.6 miles by road from the Plaza in Santa Fe. The horizon is low in the Morrowan sequence. For a road log see Baldwin and Kottlowski (1968, trip 2, stop E, p. 21). Fossils collected include: *Schizophoria oklahomae, Composita gibbosa, Cleiothyridina milleri.*

LOCALITY 56
RIO PUEBLO—WEST

This is an isolated locality at the north edge of State Highway 3 in the Rio Pueblo valley about 500 ft east of the junction with State Highway 75 to Penasco. This locality is in the Alamitos Formation and contains brachiopods of late middle Desmoinesian age and correlates approximately with unit 230 in measured section 60. It is interesting because diagnostic fossils are rare in the predominantly clastic Alamitos Formation. Included are: *Antiquatonia portlockiana, Composita "ovata, " "Buxtonia"* sp., *Anthracospirifer* cf. *A. curvilateralis chavezae.*

SECTION 60
RIO PUEBLO VALLEY

Section 60 is located on the north side of the Rio Pueblo valley. Sutherland (1963) described it in detail (p. 66), depicted the lower half graphically and prepared a detailed section (p. 35). Since the section was measured in July, 1957, State Highway 3 has been rerouted slightly and the new road covers units 16 to 18.

The predominantly clastic sequences of the Rio Pueblo valley are very poorly fossiliferous compared to the predominantly carbonate sequences of the Pecos valley to the south.

Section 60, about 5,700 ft thick, exposes strata ranging in age from Morrowan to upper middle Desmoinesian. Fusulinids were found at only a single horizon near the top of the sequence. Important brachiopod faunas occur in the lower Desmoinesian and Morrowan.

Unit	Faunal occurrence
	Middle Desmoinesian
	Alamitos Formation
255	*Antiquatonia portlockiana*
252	*Echinaria* cf. *E. knighti?, Antiquatonia portlockiana, "Buxtonia"* sp., *Anthracospirifer* cf. *A. curvilateralis chavezae*
232	*Mesolobus euampygus?, Desmoinesia muricatina, Antiquatonia portlockiana*
230	High in Fusulinid Zone IV: *Fusulina* sp., *Wedekindellina* sp.
228	*"Buxtonia"* sp.
	Lower Desmoinesian
	Flechado Formation
124	*Kozlowskia montgomeryi, Desmoinesia "missouriensis," Linoproductus planiventralis?, Composita "ovata," Neospirifer cameratus, Anthracospirifer curvilateralis chavezae?, Phricodothyris perplexa, Beecheria daltonensis*
90	*Anthracospirifer* sp.
	Morrowan or Atokan
52	*Sandia* cf. *welleri, Neospirifer?* sp.
	Morrowan
38	*Buxtonia grandis, Antiquatonia coloradoensis, Linoproductus nodosus?, Anthracospirifer curvilateralis tanoensis*
33	*Linoproductus nodosus?*
26	*Schizophoria oklahomae?, Schizophoria altirostris?, Sandia welleri, Tesuquea formosa*
18	*Derbyia bonita, Tesuquea formosa, Pulchratia? picuris, Buxtonia grandis, Anthracospirifer newberryi*

SECTION 61
SANTA FE QUARRIES
(See also Section 62)

The nearest exposure of Pennsylvanian rocks to Santa Fe is at the long-abandoned, small, shallow quarries at the east edge of the city. This outcrop belt is no more than half a mile in diameter, and mostly an erosional feature surrounded by unconsolidated sands and gravels of the Tesuque Formation (Cenozoic). This outcrop area probably is the location of Newberry's (1876, p. 43) Carboniferous " Section No. 1-Section of strata at Santa Fe." We have been unable to recognize any of his individual units, but his general lithologic types, particularly the red and buff shales, are similar to those exposed in the quarries. Possibly the quarries were in existence during Newberry's time although he does not mention them.

Only the lower part of the La Pasada Formation is exposed in the quarries; the area is structurally disturbed by at least one major and several minor faults. Only fragmentary sections can be measured; but are given here because the quarries include several of the most highly fossiliferous Pennsylvanian localities in the Sangre de Cristo region. Included are 2 measured sections, 61 (Morrowan) and 62 (Atokan), both shown graphically on fig. 3, and 2 isolated fossil localities, 68 (Morrowan) and 64 (Atokan). The exact locations of these sections and localities within the quarries are given on fig. 51.

The quarries are located about 1 mile southeast of the Santa Fe Plaza, adjacent to Gonzales Road. They are reached by going northeast on Gonzales Road from its junction with Cerro Gordo Road for a distance of 0.15 mile. This point on the road is opposite the lower part of measured section 61, about 50 ft northwest of the road (see map). A car can be parked on a short dirt track northwest of the road.

A major fault roughly parallels Gonzales Road, lying about 200 ft northwest of the road at the carpark. This fault separates Morrowan rocks to the southeast and Atokan rocks to the northwest, and is marked at one spot by a fault breccia of large, well-cemented sandstone blocks. The locations of sections 61 and 62, including offsets in measurements, are indicated by dotted lines. These sections were measured in August, 1957, by P. K. Sutherland and Dean Gerber. In August, 1968, Sutherland and Thomas W. Henry collected conodont samples from these sections.

Section 61 is covered at the base; a minor fault occurs between units 9 and 10; the top of the section is covered.

Section 62 is entirely Atokan as indicated by brachiopod correlations with measured section 36 (see fig. 3). Identifiable fusulinids have not been recovered, but silicified fusiform fusulinid molds were recovered from units 62-29 and 62-33. Several units contain the conodonts *Gnathodus coloradoensis, Idiognathoides fossatus* and *Neognathodus colombiensis* indicating (according to Lane, personal communication) an Atokan age.

Unit	Lithology	Thickness (ft)
	La Pasada Formation (Morrowan)—partial thickness	62.5
11	Limestone and shale: limestone, medium-gray, weathers gray to maroon, thin-bedded, nodular calcilutite; interbedded with gray to maroon shale; highly fossiliferous; *Zia novamexicana* Zone: *"Orbiculoidea" youngi?, Leptalosia* sp., *Pulchratia? pustulosa, Antiquatonia coloradoensis, Linoproductus devargasi, Zia novamexicana, Composita gibbosa, Composita deflecta, Anthracospirifer newberryi, Punctospirifer morrowensis, Idiognathodus* n. sp. A (6 ft above base: bryozoan, pelmatozoan, brachiopodal, micritic calcarenite)	15+
	Section offset northeastward 50 ft on top of unit 10.	
10	Limestone, medium-gray, weathers gray to maroon, thin- to thick-bedded, nodular calcilutite; unit partly disturbed by faulting	7
	Fault: units 7 to 9 truncated by fault at northwest end of exposure, marked by brecciated zone in limestone	
9	Limestone, maroon, weathers buff, coarse-grained	

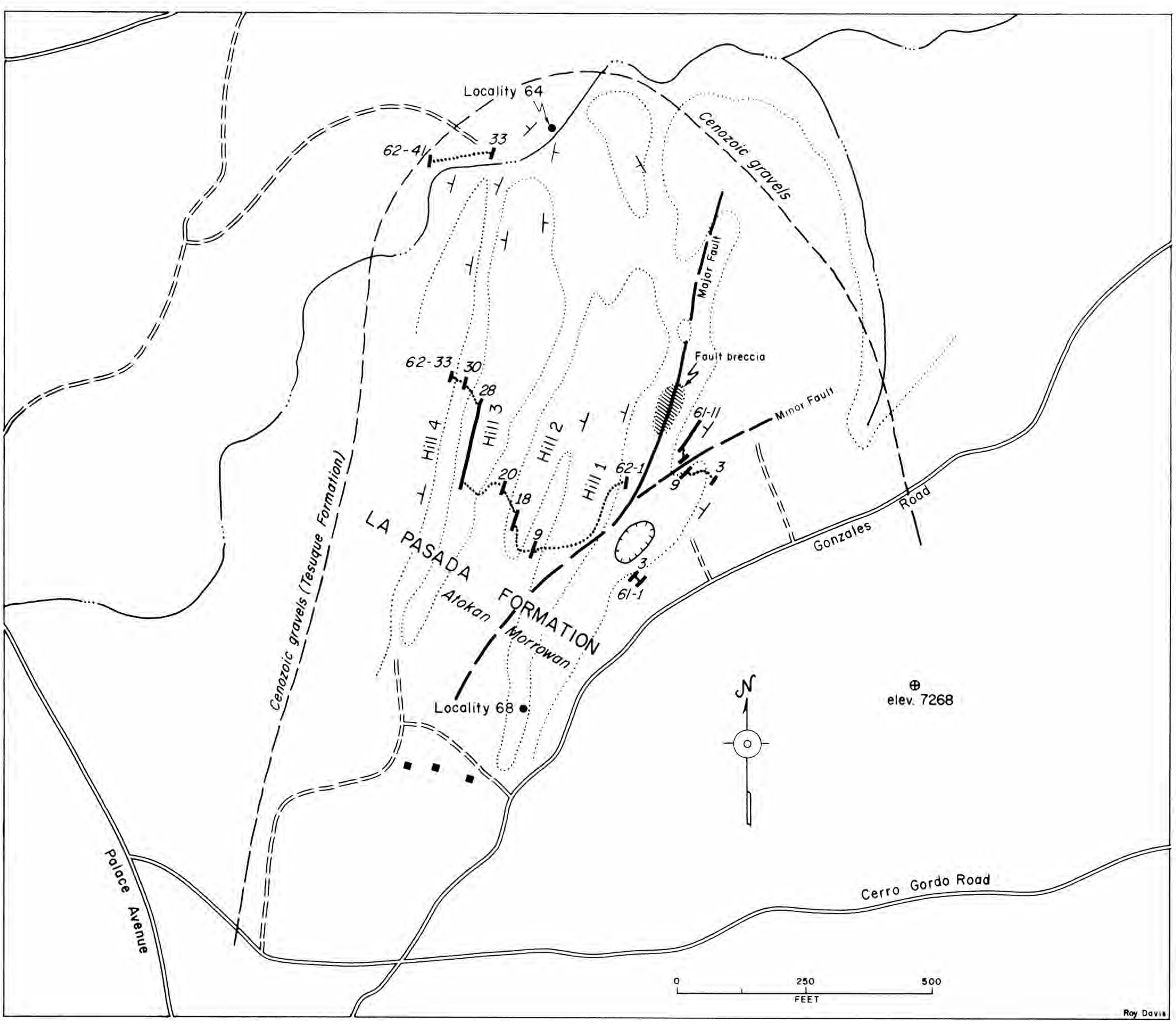

FIGURE 51—Geologic and locality map of Santa Fe Quarries

PHOTO 22- *Measured section 61, unit 11, looking east. Shales are highly fossiliferous.*

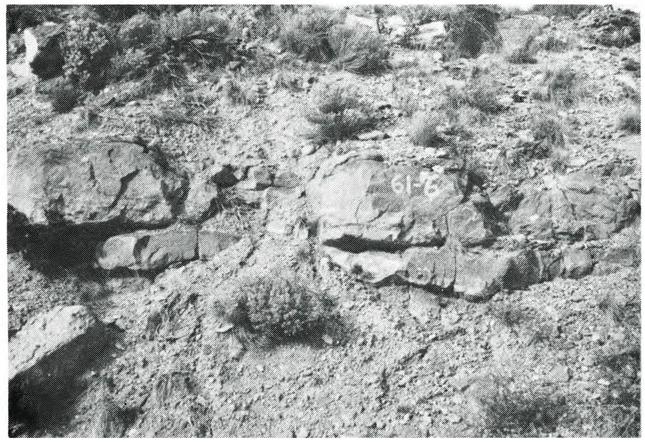

PHOTO 24- *Measured section 61, unit 6A, looking north.*

Unit	Lithology	Thickness (ft)
	pelmatozoan calcarenite, interbedded with irregular patches micrite; scattered quartz pebbles. Unit truncated by fault at northwest end of exposure	2.5
8	Sandstone, medium-gray, weathers maroon, argillaceous, partly conglomeratic, coarse-grained, fossil molds; basal contact gradational; upper contact sharp and undulating (base: coarse sandstone; skeletal, calcite-cemented orthoquartzite; trace feldspar)	1.5
7	Shale, weathers maroon and brown, banded; partly covered	3.5
	Unit offset 30 feet northwestward on top of unit 6B to base of hill.	
6B	Limestone and conglomerate: upper 3 ft echinoderm calcarenite with irregular micritic patches; basal 1 ft sandy, conglomeratic calcarenite with scattered quartz pebbles, thick-bedded, minor interbedded shale; unit lenses laterally and may be truncated by overlying unit; *Idiognathoides convexus* (base: granular coarse sandstone; skeletal, calcite-cemented orthoquartzite; no feldspar; 1 ft above base: bryozoan, pelmatozoan, calcarenite)	4
6A	Limestone and shale: limestone, weathers dark red to brown, argillaceous, skeletal calcarenites; interbedded with calcareous shale; *Rhipidomella trapezoida, Derbyia bonita, Pliocochonetes? arkansanus, Neochonetes* n. sp. A, *Tesuquea formosa, Pulchratia? picuris, Linoproductus nodosus, Composita gibbosa?, Spirifer goreii, Anthracospirifer newberryi, Spriferellina campestris, Punctospirifer morrowensis, Beecheria stehlii, Beecheria gerberi*	4
5	Shale, weathers dark maroon to red, friable and blocky; includes 0.5 ft conglomerate 7 ft above base; strike, N. 40° E., dip, 28° SE; thickness estimated	9
4	Limestone, weathers maroon, sandy, skeletal, conglomeratic; quartz pebbles up to 1.5 inches in diam., occurs as single nodular layer; more sandy at base, grading upward into limestone; gradational with underlying unit; section offset northeast approximately 225 feet on top of unit 3	1
3	Sandstone and shale: sandstone, weathers greenish brown to maroon, coarse grained and thick bedded in basal 2 ft, well-indurated, becoming finer grained, thin bedded upward; interbedded in upper part with thin maroon weathering shale layers	6
2	Limestone and shale: limestone, weathers red to reddish brown; at gully, unit is mostly thin nodular limestone layers interbedded with thin shale, but limestones thin northward and the shales become dominant; thickness measured at most southerly exposure in small gully; highly fossiliferous; *Schizophoria altirostris?, Derbyia bonita, Plicochonetes? arkansanus, Neochonetes* n. sp. A, *Tesuquea formosa, Pulchratia? picuris, Linoproductus nodosus, Hustedia gibbosa?,*	

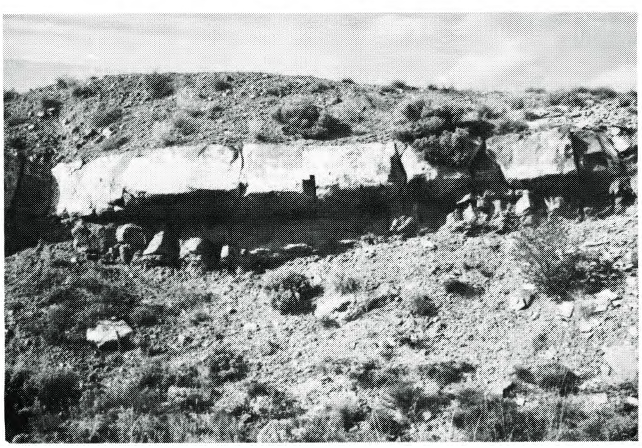

PHOTO 23-*Measured section 61, units 7 to 9, looking northwest.*

PHOTO 25- *Measured section 61, units 6A at left and unit 5 (maroon shale) at right, looking northeast.*

Unit	Lithology	Thickness (ft)
	Composita gibbosa, Spirifer goreii, Anthracospirifer curvilateralis tanoensis, Anthracospirifer matheri, Spiriferellina campestris, Punctospirifer morrowensis, Phricodothyris perplexa, Beecheria stehlii	
	(base: sandy biomicrudite; top: sandy bryozoan, pelmatozoan biomicrudite)	6
1	Sandstone, weathers reddish buff, coarse-grained, badly slumped, mostly seen as loose blocks	
	(talus: coarse sandstone; quartz-overgrowth-cemented, clay-bonded, submature orthoquartzite; trace feldspar)	3
	Units 1 to 3 measured in small draw 50 ft from road and 100 ft southwest from carpark; base of unit covered.	

SECTION 62
SANTA FE QUARRIES
(See also Section 61)

Unit	Lithology	Thickness (ft)
	Tesuque Formation	
	Unconformity	
	La Pasada Formation (Atokan)–partial thickness	154-192
41	Siltstone, medium-gray, weathers tan	1-5
40	Limestone and shale: similar to unit 38 but limestone medium bedded; *Neognathodus colombiensis*	
	(base: highly sandy biomicrudite)	1.5
39	Shale, weathers olive tan, friable	8
38	Limestone and shale: limestone weathers tan, occurs in very thin nodular layers interbedded with thin shales, fossiliferous	
	(top: sandy biomicrite)	2
37	Shale, weathers olive tan, friable	6
36	Limestone, buff-gray, weathers tan, fine-grained, partly crinoidal, medium-bedded; *Neognathodus colombiensis*	
	(top: highly sandy, brachiopod biomicrudite; 1% feldspar)	1.5
35	Covered, probably shale	3
34	Shale and sandstone: shale light gray, weathers gray and maroon; sandstone weathers tan, medium-grained, micaceous, occurs as irregular lens up to 2 ft thick in shale	
	(medium sandstone; quartz-overgrowth-cemented, mature, muscovite-bearing subarkose; 12% feldspar)	9
33	Limestone, medium-gray, weathers buff, coarse-grained, crinoidal, fossiliferous, partly nodular, thick-bedded; forms fourth Atokan ridge; *Neognathodus colombiensis*	
	(base: slightly sandy, brachiopod-pelmatozoan biomicrosparrudite; top: sandy, brachiopod-pelmatozoan biomicrudite)	6
32	Sandstone, weathers dark brown, fine- to coarse-grained, poorly sorted, micaceous	0.5
31	Shale, light-gray, weathers maroon, friable, usually covered	5
30	Covered, may conceal fault, forms draw between third and fourth Atokan ridges	12
29	Limestone and shale: limestone, buff-gray, weathers tan, coarse-grained, crinoidal, occurs in thin nodular layers interbedded with thin shale; highly fossiliferous	1.5
28	Shale, weathers olive brown and tan, friable, upper 2 ft calcareous and very fossiliferous; units 28 and 29 contain *Lingula* cf. *L. carbonaria, "Orbiculoidea" youngi?, "Orbiculoidea"* sp., *Derbyia bonita, Neochonetes henryi, Sandia brevis, Buxtonia* n. sp. A, *Anthracospirifer* cf. *A. curvilateralis chavezae, Punctospirifer* cf. *P. kentuckyensis*	6
27	Siltstone, light-gray, weathers buff gray, calcareous, upper few inches fossiliferous	4
26	Shale, limestone, and siltstone: shale, maroon-weathering, interbedded with thin layers calcareous siltstone, and nodular fossiliferous calcilutite; *Lingula* cf. *L. carbonaria, Neognathodus colombiensis*	
	(3 ft above base: slightly silty, spicular biomicrite)	4
25	Limestone, similar to unit 23 but somewhat argillaceous; *Neognathodus colombiensis, Neognathodus* n. sp. A	
	(2 ft above base: sandy, pelmatozoan-bryozoan biosparrudite)	3.5
24	Shale, weathers olive green, friable	1
23	Limestone, medium-gray, weathers buff gray, coarse-grained, crinoidal, thick-bedded; *Gnathodus coloradoensis, Neognathodus colombiensis*	
	(1 ft above base: sandy, brachiopod, bryozoan-pelmatozoan intrabiosparrudite)	3
22	Sandstone, weathers tan, coarse-grained, poorly sorted, angular to subangular grains, calcareous	0.5-1
21	Shale, weathers maroon to tan, friable	4
20	Covered, probably shale, forms draw between second and third Atokan ridges	9
19	Shale, siltstone, and covered: shale, weathers buff, contains occasional calcareous siltstone and limestone layers: basal 5 ft covered	15
18	Shale and limestone: shale, weathers tan, very fossiliferous, includes thin, hard, nodular fossiliferous calcilutite layers in upper part; units 17 and 18 contain *"Orbiculoidea"* sp., *Derbyia bonita?, Neochonetes whitei, Kozlowskia montgomeryi, Desmoinesia ingrata, Sandia brevis, Buxtonia* n. sp. A, *Linoproductus planiventralis, Composita "ovata", Cleiothyridina milleri, Neospirifer cameratus, Anthracospirifer* cf. *A. curvilateralis tanoensis, Gnathodus coloradoensis, Idiognathoides fossatus, Neognathodus colombiensis*	
	(top: slightly silty, spicular biomicrite)	7
17	Limestone, medium-gray, weathers tan, fine-grained, partly crinoidal, occurs in nodular layers, highly fossiliferous	
	(base: very sandy biomicrudite)	2
16	Sandstone, similar to unit 12	2
15	Limestone and shale: limestone, weathers buff, crinoidal, irregular nodular layers interbedded with tan weathering, friable, thin shale layers; *Idiognathoides fossatus, Neognathodus colombiensis*	
	(1 ft above base: very sandy biomicrosparrudite)	1-2
14	Sandstone, similar to unit 12	0-2
13	Shale, weathers tan, micaceous	0.5
12	Sandstone, medium- to dark-gray, weathers buff, very coarse grained, partly conglomeratic, poorly sorted, highly calcareous, weathers with pitted surfaces	0-7
11	Limestone, medium-gray, weathers buff, very coarse grained, crinoidal, thick-bedded; *Neognathodus colombiensis, Idiognathoides fossatus, Gnathodus coloradoensis*	
	(base: sandy, pelmatozoan biosparrudite)	0-3
10	Sandstone, weathers buff brown, very coarse grained, partly conglomeratic, channeloid	
	(5 ft below top: coarse sandstone; quartz-over-	

PHOTO 26- *Measured section 62, unit 10, looking west. Forms part of A to kan "Hill 2" (see fig. 51).*

Unit	Lithology	Thickness (ft)
	growth-cemented, submature orthoquartzite; 5% feldspar)	0-8
	Units 10 to 12 wedge out in thickness in a lateral distance of 40 to 50 ft north. These units form highest part of second Atokan ridge	
9	Shale, light-greenish-gray, weathers olive brown to red, friable, fractured, forms draw between first and second Atokan ridges	6
8	Sandstone, weathers maroon, very coarse grained, partly conglomeratic, poorly sorted, subangular to angular, scattered pebbles up to 8 mm in diam., micaceous, thick bedding (3 ft above base: very sandy pelmatozoan, bryozoan, algal biosparrudite; top: coarse sandstone; quartz-overgrowth-cemented, clay-bonded, immature, muscovite-bearing subarkose; 15% feldspar)	6
7	Shale, weathers in streaks of light gray and maroon, highly fractured, thickness varies from 1.5 to 4 ft in a distance of 10 ft, may represent small fault zone subparallel to bedding	1.5-4
6	Sandstone, weathers brown, very coarse grained, poorly sorted, angular to subangular grains, with scattered pebbles up to 1 cm in diam., fossiliferous in upper 2 ft, unit highly variable in thickness, wedging from 0 to 10 ft in a distance of 20 ft, part of thinning may be due to faulting, forms highest part of first Atokan ridge (top: very sandy, brachiopod-pelmatozoan, pelecypod biomicrudite; 5% feldspar)	0-10

PHOTO 27- *Measured section 62, units 6 to 8, looking north. Forms part of Atokan "Hill 1."Dip to west.*

Unit	Lithology	Thickness (ft)
5	Siltstone and shale: weathers in alternating maroon and light-gray bands in layers 0.5 to 1.0 inch in thickness, evenly bedded, top 2 ft more thinly bedded (top: sandy echinoderm, bryozoan biosparrudite)	9
4	Sandstone, light-gray, weathers maroon, very fine-grained, contains thin silty streaks, alternating 0.5-inch gray and maroon streaks give unit banded appearance, thickness variable, thinning to 0 ft laterally in 30 ft (top: fine sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing orthoquartzite: trace feldspar)	3
3	Siltstone and shale: siltstone, weathers white to light gray, argillaceous, micaceous, interbedded in lower part with micaceous silty shale, evenly bedded, banded	3
2	Shale, light-olive-green, weathers rust brown, friable	2
1	Sandstone, weathers dark maroon to brown, very poorly sorted, fine- to coarse-grained, angular to subangular (top: coarse sandstone; quartz-overgrowth- and calcite-cemented, mature orthoquartzite: trace feldspar)	4

LOCALITY 64
SANTA FE QUARRIES-NORTH

An exceptionally fossiliferous isolated exposure in the northern part of the Santa Fe Quarries contains Atokan brachiopods. This locality correlates stratigraphically with the upper part of measured section 62, possibly with unit 30, the covered interval between the third and fourth Atokan ridges. For a detailed location see the introductory discussion to sections 61 and 62 and fig. 51. Included are *Sandia santafeensis, Buxtonia* n. sp. A, *Anthracospirifer newberryi, Neognathodus colombiensis.*

SECTION 65
SOUTH OF TALPA

South of Talpa is a sharp north-trending ridge between Arroyo Miranda on the west and Rio Grande del Rancho on the east. The crest of this ridge is formed mostly by the well-indurated Del Padre Sandstone (pre-Mississippian) which stands vertically. Pre-Cambrian granites outcrop on the west slope and Mississippian and Pennsylvanian sedimentary rocks on the east slope. Section 65 is located in one of the many small subparallel valleys that flow east from the crest of this ridge into Rio Grande del Rancho. To a greater or lesser extent these valleys expose the lower part of the Flechado Formation; layers covered in one valley may be exposed in the next valley 1,000 to 1,500 ft north or south.

The section is reached by driving south on State Highway 3 from its junction with U.S. Highway 64 for a distance of 3.65 miles. From this point on the road, walk west, cross the Rio Grande del Rancho and proceed up the valley to the top of the Mississippian limestone, a short distance east of the ridge crest. The base of the Pennsylvanian is about 3,000 ft west of the river. Major faulting and major changes in dip disrupt the Pennsylvanian sequence and we could only measure 600 ft of strata above the base of the Pennsylvanian. Even within this interval dent in unit 55. The highest unit in our section is located about 1,500 ft east of the base of the section. In the same area Young (1945, p. 38) measured a section (2.5 miles south of Talpa) which he extended eastward to the Rio Grande del Rancho. He does not mention faulting and gives 1,200 ft for his section; *Fusulina needhami* is listed 1,020 ft above the base.

Section 65 is a partial section of only the lower Morrowan part of the Flechado Formation, but the strata are better and more continuously exposed than in section 60. Morrowan brachiopods occur at several horizons in the lower 500 ft. The top of section 65 may overlap slightly with the lower part of section 67, east of Taos, which contains Atokan fossils in its lower part; or, a limited interval of strata may be missing between the top of section 65 and the base of 67. Section 65 was measured in July, 1957, by P. K. Sutherland and Dean Gerber.

Unit	Lithology	Thickness (ft)
	Flechado Formation–partial thickness	586.5
72	Sandstone, weathers rust brown, medium- to coarse-grained, partly shaly, irregularly thick-bedded; some layers are conglomerate with subrounded quartz pebbles up to 10 mm; unit observed on hillside north of creek	
	(5 ft above base: medium sandstone; quartz-overgrowth-cemented and clay-bonded, immature orthoquartzite; no feldspar; 12 ft above base: biomodal, very coarse- and very fine sandstone; quartz-overgrowth-cemented, immature orthoquartzite; no feldspar)	18
71	Shale and siltstone: shale, weathers olive buff, partly silty, friable, interbedded with a few thin nodular buff-weathering micaceous siltstone layers; upper part of unit mostly covered	
70	Sandstone, weathers buff, coarse-grained, poorly sorted, unit irregular in thickness, appears to thin laterally in both directions	1
69	Shale, weathers buff, partly silty, friable, including a few thin micaceous siltstone layers	10.5
68	Sandstone, weathers buff, medium- to coarse-grained, poorly sorted, partly conglomeratic, particularly at base where gradational with underlying unit; forms a cliff with unit 67	
	(top: medium sandstone; quartz-overgrowth-cemented and clay-bonded, immature orthoquartzite: no feldspar)	8
67	Conglomerate, weathers buff, poorly sorted, sandy, grains average 2 mm in diam. but quartz pebbles, subrounded, range up to 10 mm; unit most coarse at base	
	(top: granular, very coarse sandstone; quartz-overgrowth-cemented, clay-bonded, immature, orthoquartzite: no feldspar)	
66	Covered, probably shale and thin-bedded, talus includes thin-bedded, nodular limestone	6
65	Shale, weathers olive buff, slightly micaceous, friable	5
64	Covered, probably shale and thin-bedded units	22
63	Limestone and siltstone: limestone, medium-gray, weathers light gray, fine-grained, nodular, thin-bedded; interbedded with siltstone, dark-gray, weathers brown, partly calcareous, unit poorly exposed; *Pulchratia? picuris?, Linoproductus nodosus, Anthracospirifer curvilateralis tanoensis*	2
62	Siltstone and shale: siltstone, weathers buff, slightly micaceous, partly shaly, thin-bedded; interbedded with buff weathering silty micaceous shale; unit slumped and poorly exposed	20
61	Sandstone, weathers buff, fine- to medium-grained, becomes finer and well sorted upward; unit overturned, dip 85° W.	
	(9 ft above base: medium sandstone; quartz-overgrowth- and calcite-cemented, mature, muscovite-bearing orthoquartzite; no feldspar)	11
60	Conglomerate, weathers buff, poorly sorted, with scattered quartz pebbles in lower 1 ft up to 10 mm	5
59	Shale, weathers brown, partly silty, friable	6
58	Siltstone and limestone: medium-gray, weathers brown, calcareous, banded, thin-bedded; interbedded with nodular layers, medium-gray, silty limestone; sparsely fossiliferous; unit overturned, dip 80 to 85° W.	4
57	Shale, weathers olive brown, friable, partly covered	45
56	Limestone and shale: limestone, medium-gray, weathers brown, fine-grained, nodular, thin-bedded; interbedded with calcareous shale; basal contact covered; unit overturned, dip 85°W.; *Desmoinesia nambeensis?, Hustedia gibbosa?*	
	(3 ft above base: sandy, brachiopod-pelmatozoan biosparrudite)	9
55	Siltstone, weathers buff, sandy, fractured, mainly slumped and appears to show change in strike north on hill which could reflect faulting	15
54	Sandstone, weathers buff, fine-grained, partly micaceous, banded	
	(5 ft above base: fine sandstone; quartz-overgrowth-cemented, submature, muscovite-bearing orthoquartzite; no feldspar)	12
53	Covered	2
52	Sandstone, medium-gray, weathers buff gray, medium-grained, poorly sorted, partly calcareous, irregularly thick-bedded; strike N. 10° W., dip 80° E.	
	(base: medium sandstone; quartz-overgrowth- and calcite-cemented, submature, fossiliferous orthoquartzite; no feldspar)	5
51	Covered	16
50	Sandstone, weathers rust brown, medium-grained, partly silty, thin-bedded	4
49	Covered	5
48	Limestone, medium gray, weathers light gray, coarse-grained, partly crinoidal, irregularly sandy, thick-bedded; sandy zones give streaked appearance on weathered surface, fossiliferous; *Anthracospirifer curvilateralis tanoensis*	
	(base: medium sandstone; calcite-cemented, submature, fossiliferous orthoquartzite; no feldspar)	5
47	Covered, appears to be thin bedded	11
46	Sandstone, weathers rust brown, coarse-grained, very poorly sorted, partly conglomeratic, with scattered quartz pebbles to 15 mm, in lower 5 ft, fractured, becomes finer grained in top 5 ft	
	(13 ft above base: medium sandstone; quartz-overgrowth-cemented, submature orthoquartzite; no feldspar)	14.5
45	Shale, weathers buff gray; contains small gray limestone nodules in lower 5 ft; alternating higher with thin sandy siltstone layers; upper 20 ft mainly covered; beds vertical to slightly overturned	45
44	Covered, probably thin-bedded shale and siltstone	28
43	Siltstone, weathers olive brown, partly argillaceous and shaly, thin-bedded	2
42	Sandstone, weathers buff, coarse-grained, poorly sorted, partly conglomeratic, with pebbles up to 3 mm, thick-bedded; basal contact irregular and possibly disconformable; forms waterfall on creek	
	(top: coarse sandstone; quartz-overgrowth- and calcite-cemented, submature orthoquartzite; no feldspar)	5

Unit	Lithology	Thickness (ft)
41	Limestone, medium-gray, weathers brown, partly crinoidal, hard, medium-bedded, irregular due to irregular upper surface	1
40	Limestone and shale: limestone, light-gray, weathers buff, fine-grained, highly fossiliferous, nodular, thin-bedded; interbedded with buff weathering calcareous shale; *Pulchratia? picuris, Tesuquea formosa, Linoproductus nodosus, Composita gibbosa, Spirifer goreii, Anthracospirifer newberryi, Anthracospirifer curvilateralis tanoensis, Spiriferellina campestris, Punctospirifer morrowensis*	9
39	Limestone, medium-gray, coarse-grained; thin-bedded, fossiliferous	4
38	Shale and sandstone: shale, weathers buff; interbedded in middle with 1-foot layer coarse-grained sandstone	6
37	Limestone, medium-gray, coarse-grained, crinoidal, sandy, fossiliferous	
	(base: sandy, brachiopodal, pelmatozoan, bryozoan biosparrudite)	3
36	Covered, probably shale	3
35	Sandstone, weathers buff gray, medium- to coarse-grained, poorly sorted, thick- and irregularly bedded, lower and upper surfaces irregular	
	(base: medium sandstone; quartz-overgrowth- and calcite-cemented, clay-bonded, immature orthoquartzite; no feldspar)	5
34	Covered, appears to be shale	2
33	Siltstone and shale: siltstone dark gray to black, banded, in thin, nodular layers, interbedded with thin silty shale	3
32	Limestone and siltstone: limestone, dark-gray, weathers light gray, fine-grained, silty, occurring in thin nodular beds, interbedded with thin irregular layers of calcareous siltstone	
	(top: slightly silty, spicular biomicrosparite)	2
31	Limestone, medium-gray, weathers buff gray, coarse-grained, crinoidal, sandy	
	(top: sandy, bryozoan, brachiopodal, pelmatozoan biomicrosparrudite)	2
30	Shale and siltstone: shale, dark-gray, weathers gray to brown, friable, interbedded with rare, banded siltstone layers	11
29	Covered, probably shale	28
28	Shale and siltstone: shale in lower 10 ft, olive-gray, friable, overlain by black, splintery shale; interbedded with thin, hard siltstone layers; upper part poorly exposed, vertical to slightly overturned	70
27	Siltstone, light-gray, weathers brown, siliceous cement, very hard, partly banded; forms smooth dip slope cliff in stream bed; strike N. 10° W., dip 59° E.	3
26	Covered	2
25	Shale and siltstone: shale, dark-gray, weathers buff, silty micaceous, platy; interbedded with thin layers siltstone, similar to unit 24 except some layers contain small siliceous black shale pellets	18
24	Siltstone, medium-gray, weathers rust brown, banded, siliceous, medium-bedded; forming cliff	
	(3 ft above base: very fine sandstone; quartz-overgrowth- and microcrystalline silica-cemented, mature muscovite- and biotite-bearing orthoquartzite; no feldspar)	12
23	Covered, possibly same as unit 22	3
22	Shale and siltstone: shale weathers olive buff, silty, interbedded with siltstone; weathers same, sandy, micaceous, thin-bedded, containing scattered wood fragments, unit poorly exposed	8
21	Siltstone, dark-gray, weathers buff gray, banded siliceous, conchoidal fracture	
	(3 ft above base: very fine sandstone; microcrystalline silica-cemented, submature, muscovite- and biotite-bearing orthoquartzite; no feldspar)	5
20	Sandstone, weathers olive brown to maroon, coarse-grained to very coarse grained, poorly sorted, basal 6 inches irregularly conglomeratic, and containing imprints of wood fragments	
	(7 ft above base: coarse sandstone; quartz-overgrowth-cemented, clay-bonded, immature, apatite-bearing orthoquartzite; no feldspar)	10
19	Shale, olive green, weathers buff green, unit thins to 4 ft laterally in 30 ft apparently due to irregularity of upper surface	8.5
18	Siltstone and chert: siltstone, olive-brown, weathers reddish brown, varying from very hard nodular layers to thin-bedded more platy layers, containing an irregular white to gray chert layer at base up to 6 inches thick, and higher in unit including scattered similar small chert nodules up to 5 inches in diam.; underlying contact with unit undulating; top 3 ft poorly exposed	11
	Unconformity	
	Tererro Formation (Mississippian)	

SECTION 67
TAOS CANYON

The section is located on the steep bluff on the north side of the Rio Fernando de Taos, 2.8 miles east of the junction of U. S. Highway 64 and State Highway 10 in the center of Taos. The section begins in a gully 20 yards north of State Highway 10 and approximately 20 yards east of a Carson National Forest sign. The section continues northward up the hillside to a point north of the crest of the highest cliff facing the Taos Canyon. Several lateral shifts are in section.

This section is incomplete, exposing neither the base nor the top of the Flechado Formation, but the section is much better exposed than the equivalent strata in section 60. The lowest units exposed are Atokan; two units, 12 and 23, are particularly fossiliferous. The lower part of the section may slightly overlap the upper part of section 65, located about 5 miles to the southwest; or there may be a slight gap between the top of section 65 and the base of section 67. The middle and upper parts of the measured section are early Desmoinesian as indicated by the brachiopod faunas at several horizons. The section was measured in July, 1957, by P. K. Sutherland and Dean Gerber. This section was also measured by Young (1945, p. 46).

The lower part of this section exposes a series of exceptionally well-developed depositional cycles, each beginning with a coarse sandstone or conglomerate which commonly show evidence of having channeled the underlying unit. Units which begin cycles are: 1, 8, 18(?), 24 and 35. The best exposed cycle begins with unit 24.

Unit	Lithology	Thickness (ft)
	Flechado Formation—partial thickness	1,023.5
	Poorly exposed section continues for at least an additional 500 ft along ridge to northeast.	
86	Covered; siltstone and sandstone talus	10
85	Sandstone, weathering buff, very coarse with grains averaging 1 to 2 mm, poorly sorted, partly conglomeratic	5
84	Siltstone, shale, and sandstone: unit weathers buff	

Unit	Lithology	Thickness (ft)
	to olive; siltstone, micaceous, partly sandy, mostly thin-bedded and platy; interbedded with silty shale and thin-bedded micaceous sandstone; unit is partly slumped and covered; forms long sloping terrace along ridge where trail is located; thickness approximate	80
83	Sandstone, weathers buff, medium- to coarse-grained, poorly sorted, partly conglomeratic with a pebble layer 2 ft above base containing subrounded quartz pebbles up to 15 mm; highly cross-bedded	
	(7 ft above base: medium sandstone; quartz-overgrowth-cemented, submature subarkose; 7% feldspar)	13
82	Sandstone, weathers olive buff, fine-grained	3
81	Shale, weathers buff, silty, micaceous, friable; partly covered	10
80	Sandstone and siltstone: weathers buff to olive; sandstone varies from fine- to coarse-grained, slightly arkosic, micaceous; interbedded with micaceous, platy siltstone; partly covered	9
79	Covered; talus of thin-bedded siltstone and fine-grained sandstone; forms terrace on ridge	14
78	Siltstone and sandstone: weathers olive buff; siltstone thin-bedded and platy; interbedded with 1-foot layer of fine-grained, hard sandstone; partly covered	5
77	Conglomerate and sandstone: weathers buff; conglomerate poorly sorted, grains average 2 to 3 mm with scattered quartz pebbles up to 20 mm, slightly arkosic; interbedded irregularly with coarse-grained, poorly sorted, partly conglomeratic sandstone, somewhat finer near top; forms cliff on ridge	
	(8 ft above base: coarse sandstone; quartz-overgrowth-cemented, submature arkose; 7% feldspar)	10
76	Covered; lowest part includes talus of dark-gray fossiliferous shale; entire unit probably thin bedded	15
75	Limestone, medium-gray, weathers rust-brown, impure; contains rare marine fossils and scattered wood fragments	1
74	Covered; probably thin-bedded	7.5
73	Sandstone, weathers buff, medium- to coarse-grained, poorly sorted, partly conglomeratic in lower part, becomes finer upward	
	(7 ft above base: medium sandstone; quartz-overgrowth-cemented, submature subarkose; 5% feldspar)	14
72	Conglomerate, weathers buff, coarse-grained, poorly sorted, grains average 2 to 3 mm with scattered subrounded pebbles of milky quartz, quartzite, and gray chert up to 30 mm; basal contact undulating; section at this point is 25 yds east of trail	
	(5 ft above base: very coarse sandstone; quartz-overgrowth- and calcite-cemented, submature, feldspar-bearing orthoquartzite; 4% feldspar)	10
	Unconformity, angle of truncation of underlying bed up to 20 degrees.	
71	Siltstone, sandstone, and shale: weathers olive-buff; siltstone, partly sandy, micaceous, thin-bedded, platy; interbedded with micaceous shales and fine-grained cross-bedded sandstone layers which are more common in upper part; truncated at top	33.5
70	Shale, dark-gray, weathers buff, calcareous; *Antiquatonia hermosana*	5.5
69	Limestone and shale: limestone, dark-gray, weathers rust brown, fine-grained, partly silty; crinoidal, fossiliferous, occurs in hard layers up to 6 inches thick; interbedded with thin layers of gray, calcareous, fossiliferous shale	
	(base: brachiopodal, algal biomicrosparrudite)	2
68	Siltstone, shale, and sandstone: siltstone, weathers olive buff, partly sandy, micaceous, thin-bedded, platy; interbedded with olive-buff weathering micaceous shale, and in the lower part a few fine-grained sandstone layers up to 1 ft thick	39.5
67	Sandstone, weathers buff, coarse-grained, poorly sorted, partly conglomeratic in lower part, upper part fine-grained, highly cross-bedded and interbedded with a few thin shaly siltstone layers	20
66	Conglomerate, weathers buff, coarse-grained, poorly sorted, grains average 2 to 5 mm with many scattered layers containing subrounded pebbles of milky quartz and dark gray chert up to 40 mm; basal contact undulating and apparently disconformable	
	(4 ft above base: very coarse sandstone; quartz-overgrowth-cemented orthoquartzite; feldspar 2%)	9.5
65	Siltstone weathers olive buff, argillaceous, micaceous, platy	3
64	Shale, weathers light gray, calcareous, friable, fossiliferous; includes a thin limestone layer in lower part, upper 3 ft silty and non-fossiliferous	8
63	Limestone, dark-gray, weathers light to buff gray, fine-grained, medium-bedded; platy algae common; weathered surface pitted and irregular; fossiliferous; *Antiquatonia hermosana*	
	(2 ft above base: heavily recrystallized, pelecypodal, algal biosparrudite; 7 ft above base: recrystallized algal biosparrudite)	11
62	Shale, weathers buff, calcareous, silty, sparsely fossiliferous	2
61	Limestone, dark-gray, weathers rust brown, medium-grained, silty, sparsely fossiliferous	
60	Siltstone, sandstone, and shale: siltstone, weathers olive brown, micaceous, partly shaly and thin-bedded, partly sandy and hard; interbedded with buff-weathering, fine-grained, poorly sorted sandstone and black, partly silty shale	
	(top: fine sandstone; quartz-overgrowth-cemented, submature orthoquartzite; 4% feldspar)	38.5
59	Sandstone, weathers buff, micaceous, medium-grained, poorly sorted	3
58	Siltstone, weathers olive brown, micaceous	1.5
57	Limestone, buff-gray, weathers rust brown, medium-grained, silty, nodular, sparsely fossiliferous	1.5
56	Siltstone; basal 1-ft weathers rust brown, overlying layer weathers buff, thin-bedded, calcareous	8
55	Shale, dark-gray, weathers light gray, calcareous; fossiliferous, *Antiquatonia hermosana*	25.5
	Section shifts westward 50 yds to arroyo in which section begins.	
54	Limestone, dark-gray weathers rust brown, medium-grained, very silty	
	(base: fine sandstone; calcite-cemented, submature orthoquartzite; feldspar 1%)	1.5
53	Siltstone, shale, and sandstone: weathers buff to olive buff; siltstone partly micaceous, thin-bedded ranging from platy and partly shaly to hard and nodular; alternates with silty, platy shale, and in the lower portion scattered layers of fine-grained, cross-bedded sandstone; partly covered	49
52	Sandstone and siltstone: sandstone weathers buff, coarse-grained, poorly sorted, highly cross-bedded, irregular beds 1 to 3 ft thick; interbedded with thin layers of olive-buff-weathering siltstone	9

Unit	Lithology	Thickness (ft)
51	Siltstone, shale, and sandstone: weathers olive buff; siltstone, micaceous, partly sandy, platy; interbedded with micaceous, silty shale and a few thin layers of fine- to medium-grained sandstone	8
50	Limestone, medium-gray, weathers rust brown, fine-grained, silty	1
49	Siltstone and shale: weathers olive-buff; siltstone includes hard layers 2 to 3 inches thick and thinner, platy, partly sandy layers; interbedded with dark-gray, partly silty and micaceous shale (12 ft above base: fine sandstone; clay-bonded, immature orthoquartzite; feldspar, 1%)	40
48	Sandstone, medium-gray, weathers buff, coarse-grained, in part highly cross-bedded; gradational with underlying unit; forms cliff	10
47	Sandstone, weathers buff, very coarse grained, poorly sorted, grains average 1 to 2 mm, with a few thin layers of subrounded quartz and quartzite pebbles up to 40 mm; interbedded layers medium-gray, partly silty sandstone in upper part of unit (top: coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; 1% feldspar)	8
	Section shifts ¼ mile west to small gully 20 yds east of gully in which section begins.	
46	Siltstone and shale: weathers buff; siltstone, micaceous, platy; interbedded with calcareous shale; partly covered	24
45	Shale, weathers buff gray, lower 5 ft partly calcareous and sparsely fossiliferous; upper portion slightly micaceous and silty; partly covered	21
44	Limestone, dark-gray, weathers red brown, fine-grained, silty	1.5
43	Covered, talus of calcareous, slightly fossiliferous shale	4
42	Limestone, dark-gray, weathers red brown, fine-grained, very silty, probably carbonaceous	1
41	Sandstone and siltstone: weathers buff; sandstone, medium-grained, poorly sorted; interbedded in upper part with sandy siltstone	6
40	Covered, probably siltstone	7
39	Siltstone, weathers brown, micaceous, poorly exposed	7
38	Sandstone, weathers buff, coarse-grained, poorly sorted, partly conglomeratic, highly cross-bedded	16
37	Conglomerate, weathers buff, poorly sorted, grains average 2 to 3 mm with scattered subrounded quartz pebbles to 15 mm (top: coarse sandstone; quartz-overgrowth-cemented, mature orthoquartzite; feldspar 2%)	4
36	Siltstone, shale and sandstone: siltstone, weathers buff, poorly sorted, sandy, micaceous, thin-bedded, platy; interbedded with olive-buff weathering, friable shale and occasional layers up to 1 ft of poorly sorted sandstone	25
35	Sandstone and conglomerate: weathers buff; sandstone, poorly sorted, conglomeratic, grains average 1 to 2 mm, thick-bedded; interbedded irregularly with conglomerate, grains average 2 to 3 mm with scattered quartz pebbles to 30 mm; unit highly cross-bedded	31
34	Shale and siltstone: weathers rust brown; shale, partly silty, weathers blocky; interbedded with few thin micaceous siltstone layers; unit partly covered	8
33	Sandstone, weathers buff, coarse-grained, poorly sorted, occasional thin, conglomeratic layers with scattered quartz and quartzite pebbles to 20 mm; thick-bedded (2 ft above base: granular, very coarse sandstone; quartz-overgrowth-cemented, submature orthoquartzite; feldspar 1%)	7
32	Shale and sandstone: shale, dark-gray, weathers buff, partly silty; interbedded with occasional hard, irregular layers up to 1 ft of sandstone, medium- to coarse-grained, poorly sorted, micaceous; unit partly covered	28
31	Covered, probably shale	2
30	Shale, weathers dark gray, highly calcareous in lower part, gradational with underlying unit; lower half fossiliferous; *Sandia brevis, Anthracospirifer* cf. *A. curvilateralis chavezae*	12
29	Limestone and shale: limestone, weathers medium gray, fine-grained, thin, nodular layers; interbedded with thin calcareous shale layers; fossiliferous	8
28	Limestone, weathers reddish brown, fine-grained, partly carbonaceous, silty, forms top of small cliff in draw	1
27	Sandstone, weathers buff, coarse-grained, poorly sorted, becomes fine grained in upper part (top: very coarse sandstone; quartz-overgrowth- and calcite-cemented, submature orthoquartzite; 3% feldspar)	8
26	Shale, gray, weathers same, silty, micaceous, friable, partly covered	4
25	Siltstone and sandstone: siltstone, weathers buff, micaceous, shaly, thin-bedded; interbedded with few hard, thin layers sandstone, dark brown weathering, very fine grained	9
24	Sandstone, weathers buff, medium-grained, highly cross-bedded; interbedded in middle part with thin layers of silty micaceous shale	10
23	Shale, weathers buff-gray, highly calcareous in lower part, silty in upper part and sandy in top 3 ft; interbedded with rare, thin, limestone layers; lower 10 ft highly fossiliferous, *"Orbiculoidea" youngi, Mesolobus striatus, Sandia brevis, Cleiothyridina* cf. *C. milleri, Neospirifer cameratus, Anthracospirifer* cf. *A. curvilateralis chavezae, Punctospirifer* cf. *P. kentuckyensis*	30.5
22	Limestone, weathers buff gray, fine-grained, micaceous at base	1.5
21	Sandstone and siltstone: weathers olive brown; sandstone, fine-grained, micaceous, cross-bedded; interbedded in thin layers with micaceous siltstone	3

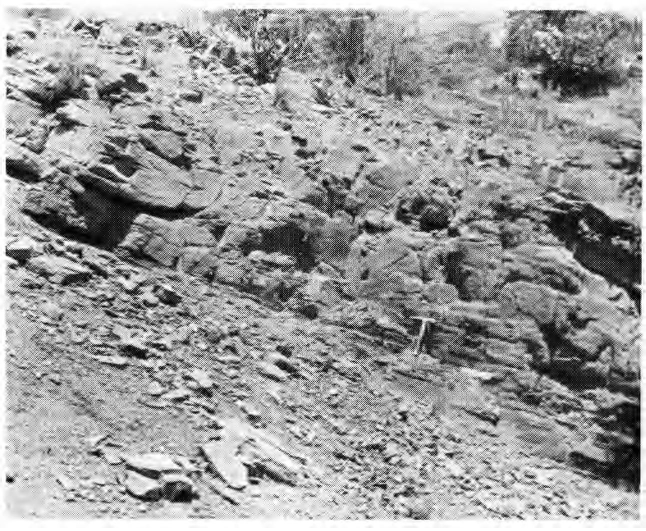

PHOTO 28- *Measured section 67, units 23 and 24, Flechado Formation. Unit 24 is basal sandstone in the best-exposed depositional cycle in the section. Unit 23 is a highly fossiliferous marine shale of Atokan age.*

Unit	Lithology	Thickness (ft)
20	Shale, weathers olive brown, very silty, micaceous, platy to friable	5
19	Sandstone, weathers olive brown, fine-grained, cross-bedded	3
18	Shale, weathers olive brown, very silty, micaceous, platy to friable	12
17	Sandstone and siltstone: weathers olive brown; sandstone, coarse-grained, poorly sorted, irregularly bedded, thick-bedded; interbedded with thin layers sandy, platy siltstone	6
16	Shale and siltstone: weathers brown; shale, micaceous, partly silty; interbedded, mainly in upper part, with thin-bedded, micaceous, partly sandy siltstone layers	7
	Section shifted eastward about 30 yds on top of unit 15 to next arroyo	
15	Limestone, dark-gray, weathers reddish brown, fine-grained, impure, rare fossils, thickness variable	2
14	Siltstone, weathers brown, micaceous, argillaceous and platy in lower 10 ft with higher layers better indurated, partly calcareous and up to 4 inches in thickness	17.5
13	Shale, dark-gray, weathers buff gray, calcareous, friable; highly fossiliferous; Fusulinid Zone I, *Fusulinella prolifica; "Orbiculoidea" youngi, Derbyia bonita?, Mesolobus striatus, Sandia brevis, Echinaria* n. sp. A?, *Cleiothyridina* cf. *C. milleri, Neospirifer cameratus, Anthracospirifer* cf. *A. curvilateralis tanoensis, Punctospirifer* cf. *P. kentuckyensis*	32
12	Limestone and shale: limestone, medium-gray, weathers buff gray, fine-grained, impure, occurring in thin, nodular layers; interbedded with dark-gray shale	
	(top: silty, partially silicified, bryozoan-pelmatozoan, brachiopod biomicrudite)	3
11	Shale, dark-gray, weathers buff-gray, silty in lower part	9
10	Sandstone, buff, weathers olive brown, fine-grained	
	(top: medium sandstone; quartz-overgrowth-cemented, immature, muscovite- and feldspar-bearing orthoquartzite; 7% feldspar)	7
9	Siltstone and shale: weathers olive brown; siltstone, micaceous, platy layers and thin, hard, sandy layers; interbedded with thin shale layers	22

PHOTO 29-*Measured section 67, units 7 and 8, Flechado Formation. Unit 8 is channeling sandstone that begins a depositional cycle.*

Unit	Lithology	Thickness (ft)
8	Sandstone, weathers buff, very coarse grained, conglomeratic, grains average 2 mm with rare scattered subrounded quartz pebbles to 20 mm, cross-bedded, thick-bedded; forms cliff in gulley; basal contact undulating and appears disconformable	
	(2 ft below top: coarse sandstone; quartz-overgrowth-cemented, mature orthoquartzite; 4% feldspar)	11.5
7	Siltstone and shale: weathers brown; siltstone micaceous, platy, partly argillaceous; interbedded with silty platy shale	21
6	Siltstone and sandstone: weathers brown; siltstone, micaceous, thin-bedded, partly sandy; interbedded with hard, irregular layers up to 1 ft of sandstone, partly micaceous and carbonaceous; unit includes few thin shale layers; strike N. 38° W., dip 20° NE	
	(3 ft above base: fine sandstone; quartz-overgrowth-cemented and clay-bonded, immature orthoquartzite; 4% feldspar)	10
5	Shale, dark-gray, weathers buff gray, calcareous, partly silty; fossiliferous	15
4	Siltstone, weathers buff, micaceous, partly sandy, scattered plants	1
3	Sandstone, weathers buff, coarse-grained, hard, 1 ft layers	2
2	Covered	1
1	Sandstone, weathers buff, very coarse grained, partly conglomeratic, forms massive cliff immediately north of National Forest sign on highway; lowest exposure	
	(top: medium sandstone; quartz-overgrowth- and calcite-cemented, submature orthoquartzite; 1% feldspar)	11

LOCALITY 68
SANTA FE QUARRIES-SOUTH

This is an isolated locality in the southernmost part of the Santa Fe Quarries, located 150 ft northeast of the dirt road near the 3 houses. For a detailed location see the introductory discussion of sections 61 and 62 and fig. 51. The exposure, a low ridge of limestone and shale in the lower part of the La Pasada Formation, is Morrowan in age and equivalent to the lower part of section 61, located about 400 ft to the northeast. Fossils included are: *Rhipidomella trapezoida, Plicochonetes? arkansanus, Desmoinesia nambeensis, Antiquatonia coloradoensis, Spirifer goreii.*

LOCALITY 78
NAMBE RESERVATION

On the Nambe Indian Reservation the middle part of the La Pasada Formation (Desmoinesian) is thrust eastward against the lower part of the formation (Morrowan). Locality 78 refers to an isolated exposure in the bank of a dry arroyo, located in NW$^1/_4$ NW$^1/_4$ NW$^1/_4$ sec. 32, T. 19 N., R. 10 E. (see fig. 50). The locality is about half way between Rio en Medio and Rio Nambe about 0.5 mile southwest of Nambe Falls. Fusulinids have not been found at this locality but well-preserved brachiopods occur in great numbers. They include an unusual combination of species, some of which are more characteristic elsewhere of the lower Desmoinesian and others that are more common in the middle Desmoinesian. The geographic position of the locality in the Desmoinesian outcrop belt, however, seems to place it stratigraphically somewhat higher than the lower Desmoinesian strata at locality 43, located 0.5 mile to the north, but not so high as middle Desmoinesian. The locality most probably represents a horizon high in the lower Desmoinesian.

Included are: *Lingula* cf. *L. carbonaria, "Orbiculoidea"* sp., *Mesolobus profundus, Chonetinella jeffordsi, Desmoinesia "missouriensis", Calliprotonia* n. sp. A, *Linoproductus planiventralis, Composita "ovata", Cleiothyridina pecosii, Neospirifer cameratus, Anthracospirifer curvilateralis chavezae, Anthracospirifer "opimus", Punctospirifer* cf. *P. kentuckyensis, Phricodothyris perplexa, Beecheria* cf. *B. millepunctata, "Buxtonia"* sp.

SECTION 90

SANTA FE RIVER, CERRO GORDO ROAD

This short section includes only the lowest part of the La Pasada Formation at an exposure in a small arroyo on the north side of the Santa Fe River valley, a short distance east of Santa Fe. The base of the sequence is in unconformable contact with the Tererro Formation (Mississippian). The exposed section, entirely Morrowan, is particularly interesting because it is highly fossiliferous, and because there are more carbonates and fewer sandstones (limestone = 46 percent, shale = 45 percent, siltstone = 9 percent) in the basal 100 ft of the Pennsylvanian sequence than in almost any other exposure in the Sangre de Cristo region.

The exposures are located in the steep arroyo immediately south of where Cerro Gordo Road crosses a small valley, 1.2 miles east of the junction of this road with Gonzales Road. Cerro Gordo Road makes a very sharp bend northward at this point to cross this unnamed arroyo by a steel culvert.

In June, 1958, P. K. Sutherland and Dean Gerber measured a section, beginning at the lowest layers then exposed immediately south of the culvert. Units 1 to 5 were measured on the east side of the creek bank a few feet south of the culvert. The section is offset southward on unit 5 for about 60 to 70 ft, past a small synclinal structure, to creek level on the east bank, at the most northerly point where an abandoned irrigation canal once crossed the creek. From this point, the section was measured eastward, up the steep valley side, to the road, at a point opposite the house located where the road turns sharply back to the east. Unit 18 can be traced diagonally northeast across the road where the unit is exposed in the east road bank north of the above-mentioned house.

In August, 1968, P. K. Sutherland and Thomas W. Henry visited the locality to collect conodont samples. By this time, the old culvert across the arroyo had been replaced, exposing additional rocks in the creek bed at the southern end of the culvert. At that time the base of the old measured section could be seen faulted against Precambrian gneisses and schists about 4 feet north of unit 1. An additional layer of highly fractured micritic limestone is now exposed between unit 1 and the gneiss.

In 1968, stratigraphically lower Morrowan rocks were discovered farther down the arroyo to the south, in unconformable contact with the Mississippian Tererro Formation. These units, designated as units B to G, were tied into the section measured earlier. The base of this sequence and the contact with the Mississippian rocks is exposed in the west bank of the arroyo a little more than 1/8 mile south of the culvert.

Unit G forms a prominent cliff in the creek bed where the old irrigation flume once crossed the arroyo. From the top of this unit to the base of unit 7, exposed in the valley side 20 ft east of the arroyo bed, are approximately 7.5 stratigraphic feet. Unit G would appear to be equivalent to units 1 and 2 of the old section, exposed upstream near the culvert. Thus, a composite section consists of units B-F added in sequence at the base to units 1 to 18. Units 1 to 6 are retained in the measured section because they include two important fossiliferous units.

Section 90 is possibly the same, or nearly the same, exposures described by Newberry (1876, p. 45) as section 2 (gorge of Santa Fe River) and section 3 (south base of Cerro Gordo).

The stratigraphically lowest conodonts recovered in section 90 are from unit 90-E, 26 ft above the base of the La Pasada Formation. This unit contains *Idiognathodus* sp. (= Lane, 1967, pl. 119, fig. 11) suggesting that this unit may correlate with the upper part of the Brentwood Limestone Member of the Bloyd Formation of the type Morrow of Arkansas. Units 90-7 to 90-18 contain, *Idiognathodus* n. sp. A, suggesting that this interval is late Morrowan in age and possibly correlates with the Dye Shale and Kessler Members of the Bloyd Formation in northwestern Arkansas.

Unit numbers in yellow were painted on the more resistant units in August, 1968.

Unit	Lithology	Thickness (ft)
	The top of the section is the highest exposure on bluff on east side of arroyo, 20 ft downslope (west) from point on Cerro Gordo Road opposite house and 0.1 mile southeast of culvert referred to in introduction.	
	La Pasada Formation—partial thickness	108.5
18	Limestone, light-gray, weathers buff, coarse-grained, slightly sandy, numerous silicified (?) fossils, beds 2 inches to 2 ft thick alternating with occasional thin shale partings, strike N. 55° E., dip 36° SE; *Zia novamexicana* Zone: *Pulchratia? pustulosa, Zia novamexicana, Hustedia gibbosa?, Anthracospirifer newberryi, Idiognathodus* n. sp. A (1 ft above base: sandy, pelmatozoan, brachiopodal, bryozoan biomicrosparrudite)	8
17	Shale and limestone: shale, weathers buff, thin-bedded, interbedded with thin limestone, light-gray, weathers buff, coarse-grained, fossiliferous	2
16	Limestone, weathers buff gray, coarse-grained, crinoidal, sandy, thick-bedded; top contains isolated quartzite cobble 3 inches long	3
15	Shale, weathers buff, poorly exposed; units 14 to 17 contain; *"Orbiculoidea"* sp., *Schizophora oklahomae, Derbyia bonita, Plicochonetes? arkansanus, Tesuquea formosa, Pulchratia? picuris, Buxtonia grandis, Antiquatonia coloradoensis, Linoproductus nodosus, Hustedia gibbosa?, Composita gibbosa, Composita deflecta, Spirifer goreii, Anthracospirifer newberryi, Anthracospirifer curvilateralis tanoensis, Phricodothyris perplexa, Idiognathodus* n. sp. A	1.5
14	Limestone, weathers buff, coarse-grained, thick-bedded, fossiliferous	2
13	Shale and limestone: shale weathers buff, alternating with thin nodular, coarse-grained limestone layers	2.5
12	Limestone, light-gray, weathers buff, thin- to thick-bedded with thin shale partings, fossiliferous, scattered silicified patches, top with	

Unit	Lithology	Thickness (ft)
	coarse pebbles of calcilutite; *Idiognathodus* n. sp. A	
	(2 ft above base: sandy, bryozoan, pelmatozoan biomicrosparrudite)	8
11	Shale, dark-gray, weathers buff, friable	2.5
10	Limestone, light-gray, weathers buff, coarse-grained, slightly sandy, thick-bedded, forms first prominent cliff on east side of creek 30 ft up steep hillside from north end of abandoned irrigation ditch, fossiliferous; *Idiognathodus* n. sp. A	
	(top: bryozoan, foraminiferal oobiomicrudite)	7.5
9	Covered, probably shale	1
8	Sandstone, green, weathers olive brown, coarse-grained with subangular quartz grains up to 4 mm diam. poorly sorted, argillaceous, contains red shale clasts	1
	This sandstone of unit 8 and covered interval of unit 9 grade southward on bluff side into interbedded limestones and shales similar to unit 7 (total thickness of units 7 to 9 is 10 ft).	
7	Limestone, and shale: limestone, light-gray, weathers buff, fine to coarse-grained, crinoidal, occurs as thick nodular layers 2 to 8 inches thick, interbedded with buff-weathering, thin, calcareous shales, very fossiliferous; *Schizophoria oklahomae, Meekella* n. sp. A, *Desmoinesia* sp. A, *Pulchratia? picuris, Buxtonia grandis, Antiquatonia coloradoensis, Linoproductus nodosus, Hustedia gibbosa?, Composita gibbosa, Anthracospirifer newberryi, Anthracospirifer curvilateralis tanoensis?, Punctospirifer morrowensis, Phricodothyris perplexa, Idiognathodus* n. sp. A	
	(2 ft above base: bryozoan biomicrudite)	8
6	Covered	1
5	Limestone and shale: limestone, olive-tan, weathers buff, crinoidal, hard, thin-bedded, nodular, micritic layers 2 inches thick in middle part to 1 ft thick at base and top, interbedded in lower part with thin calcareous shale, strike N. 20° E., dip 30° SE; *Spirifer goreii*	
	(1 ft from base: brachiopodal, pelmatozoan biomicrudite)	3.5
4	Covered and shale, weathers tan, friable	2
3	Covered, could conceal small fault	
	(1-ft-thick crinoidal limestone at top with anomolous dip is believed to be a slump block)	2
2	Limestone and shale: limestone, greenish-gray, weathers buff, coarse-grained, crinoidal, nodular-bedding 2 to 8 inches thick, interbedded with thin layers of shale, weathers buff, calcareous, highly fossiliferous; *"Orbiculoidea"* sp., *Schizophoria oklahomae, Schizophoria altirostris?, Leptalosia* sp., *Krotovia globosa, Tesuquea formosa, Pulchratia? picuris?, Linoproductus nodosus, Hustedia gibbosa?, Composita gibbosa, Anthracospirifer curvilateralis tanoensis, Spiriferellina campestris, Punctospirifer morrowensis, Beecheria stehlii*	3.5
1	Limestone, greenish-gray, weathers buff, coarse-grained, crinoidal, thick-bedded	1.5
	Units 1 and 2 are exposed a few ft south of culvert. Unit G, which forms a cliff in the arroyo bed about 80 ft to the south, is believed to be equivalent to units 1 and 2.	
G	Limestone, weathers light buff gray, thick-bedded, basal 1 ft micritic, grading upward into coarse-grained pelmatozoan calcarenite with rare quartzite pebbles, thick-bedded, forms prominent cliff in creek where old irrigation flume once crossed creek; strike N. 80° W., dip 10° N.; *Spirifer goreii.* Repeats units 1 and 2; thickness not included in total measurement	

Unit	Lithology	Thickness (ft)
	(base: biodismicrite; top: very sandy, pelmatozoan, bryozoan biosparrudite)	(5)
F	Shale and siltstone: siltstone occupies basal 2 ft, weathers olive-green, poorly exposed but apparently gradational into overlying shale; shale, weathers olive green, best exposed in creek below cliff formed by unit G, thickness approximate	11
E	Limestone, weathers buff, coarse-grained, thick-bedded, basal contact sharp and undulating, well-exposed in irrigation ditch on west side of valley and in creek where unit forms a small bluff, fossiliferous; strike N. 80° W., dip 28° N.; *Schizophoria oklahomae, Spirifer goreii, Buxtonia grandis, Idiognathodus* sp.	
	(top: sandy biomicrudite)	11
D	Shale and covered: shale, weathers olive gray, poorly exposed on hillside below irrigation ditch approximately 25 yds west of arroyo	5
C	Sandstone and shale: sandstone, weathers buff, fine- to coarse-grained, poorly sorted, conglomeratic, scattered feldspar grains, quartz-cemented, layers lensing and highly variable; interbedded in middle with silty shale; conglomeratic in top 0.5 ft with quartz grains to 15 mm; strike N. 80° W.	
	(top: granular, coarse sandstone; clay-bonded, quartz-overgrowth-cemented, immature orthoquartzite; feldspar 3%)	14
B	Shale, weathers buff, local coarse-grained sandstone filling in solution cracks up to 1 ft wide on unconformable surface with unit A (Mississippian), basal contact well exposed on west side of arroyo below trail and irrigation ditch	
	(base: granular, coarse sandstone; clay-bonded, immature orthoquartzite; feldspar 3%)	7
	Unconformity	
	Tererro Formation (Mississippian)	
A	Limestone, weathers light gray, upper surface highly irregular and undulating, thickness not measured	

SECTION 92
BISHOP'S LODGE

The lower part of the La Pasada Formation is exposed in the banks of Little Tesuque Creek in the grounds of Bishop's Lodge, located on Bishop's Lodge Road, about 4 miles north-northeast of Santa Fe. The base of the Pennsylvanian, in unconformable contact with the underlying Mississippian limestone, is exposed in the creek bank 0.25 mile south-southeast of the main building at Bishop's Lodge. Dips were observed up to 29 degrees to the northwest but the measured section is apparently unfaulted. Only 139.5 ft of Pennsylvanian rocks, all Morrowan, are exposed. The top of the section, located in the creek bank about 500 ft south of the lodge, is unconformably overlain by Cenozoic gravels. The section is shown graphically on fig. 7. It is not as well exposed as the Morrowan sequence described in measured section 41 at Nambe Falls. Few fossils could be collected because of the very small area of exposure of most units. The section was measured in July, 1958 by P. K. Sutherland and Dean Gerber. The same was measured by Kottlowski (1963, p. 235).

Unit	Lithology	Thickness (ft)
	La Pasada Formation–partial thickness	126-132
36	Limestone, gray, weathers buff gray, coarse-	

Unit	Lithology	Thickness (ft)
	grained, poorly sorted, crinoidal, partly sandy, thick-bedded; forms low cliff on southwest side of creek; top covered by Cenozoic gravels; *Pulchratia? pustulosa*	12.5
35	Shale and covered: shale, light-gray, weathers gray to maroon, poorly exposed	2
34	Limestone, light-gray, weathers buff gray, coarse-grained, crinoidal; fossiliferous; *Pulchratia? picuris, Linoproductus nodosus, Hustedia gibbosa?, Composita gibbosa, Anthracospirifer curvilateralis tanoensis, Sandia welleri*	2-3
33	Shale and sandstone: weathers maroon; shale, micaceous, silty, noncalcareous; interbedded with thin layers fine-grained, micaceous sandstone	2-3
32	Sandstone, weathers maroon to brown, medium-grained, noncalcareous, irregularly bedded	4
31	Limestone, weathers buff, coarse-grained, poorly sorted calcarenite; partly granular with scattered subrounded quartz grains to 4 mm	1.5
30	Siltstone and shale: siltstone, weathers greenish-gray, thin-bedded, banded; interbedded in upper part with platy, silty shale	5
29	Limestone, light-gray, weathers buff, coarse-grained, crinoidal calcarenite, with scattered subrounded quartz grains to 3 mm, thick-bedded; forms cliff in both creek banks	11.5
28	Shale, weathers buff, friable	1.5
27	Limestone, weathers light gray, coarse-grained, crinoidal calcarenite, thick-bedded; highly sandy and conglomeratic at base	5.5
26	Shale, weathers gray to maroon, friable	1
25	Limestone, weathers light gray, coarse-grained, crinoidal calcarenite scattered quartz grains	1.5
24	Shale, weathers gray to maroon, calcareous, platy	1.5
23	Limestone, weathers light gray, coarse-grained, crinoidal calcarenite, thick-bedded; highly fossiliferous; units 23 to 27 include: *Rhipidomella trapezoida, Plicochonetes? arkansanus, Pulchratia? picuris, Antiquatonia coloradoensis, Linoproductus nodosus, Composita gibbosa, Spirifer goreii, Anthracospirifer curvilateralis tanoensis, Spiriferellina campestris, Beecheria stehlii*	3
22	Shale, weathers gray to maroon, non-calcareous	3
21	Limestone, light-gray, weathers buff gray, coarse-grained, crinoidal calcarenite, thick-bedded	1
20	Covered, probably shale	4
19	Limestone, light-gray, weathers buff gray, coarse-grained, crinoidal, poorly sorted; occurring in hard nodular layers 0.5 to 2 ft thick; interbedded with very thin, calcareous, silty shale layers; forms cliff in creek bank about 100 yards northwest of old dam; highly fossiliferous; *Schizophoria altirostris?, Tesuquea formosa, Linoproductus nodosus, Hustedia gibbosa?, Composita gibbosa, Composita "ovata", Anthracospirifer curvilateralis tanoensis*	14
18	Covered, shale and limestone talus	14
17	Shale, weathers gray, calcareous, friable	5
16	Sandstone, weathers dark brown, highly calcareous, rounded quartz pebbles to 10 mm, fossiliferous	0.5
15	Shale, black, weathers same, noncalcareous, friable	10
14	Sandstone and limestone: sandstone, weathers rust brown, coarse-grained, poorly sorted, partly conglomeratic, highly calcareous; interbedded irregularly with lenses of very sandy, crinoidal, partly conglomeratic limestone; unit is cross-bedded, thick-bedded and has highly undulating lower contact which accounts for variation in thickness; ledge forming; strike N. 50° E., dip 29° NW	2-5
13	Shale and sandstone: shale weathers buff gray, non-calcareous, silty; interbedded with olive-buff-weathering, fine-grained sandstone	16
12	Sandstone, weathers olive green, fine-grained, poorly sorted, irregularly bedded; scattered small green shale pellets; fills in depressions on truncated Mississippian surface; lensing	2-3
	Unconformity	
	Tererro Formation (Mississippian)	

SECTION 93
LAMY

The section described here was measured in a poorly exposed area of Pennsylvanian outcrop located within a few hundred feet of the main Santa Fe Railway track, on the Bishop John Lamy Grant. The base of the Pennsylvanian sequence is located on the southwest side of a large arroyo about 2.9 miles northeast of Lamy (measured along the railway) and about 3.2 miles southwest of Cañoncito. It is located immediately southwest of the gorge cut through Precambrian granites and traversed by the railway. The Pennsylvanian strata dip at 25 to 30 degrees to the southwest and are seen as small exposures on the low hillsides 100 to 200 ft northwest of the railway, and exposed for a distance of about 1/4 mile along the track. The tops of these hills are covered by gravels of the Santa Fe Formation (Tertiary). The sequence is also disturbed by both major and minor faulting.

Even though poorly exposed and faulted, an evaluation of this section is important because Read and Andrews (1944, west-east cross-section) used this sequence as a primary basis for postulating the occurrence during Pennsylvanian time of a depositional high which they termed the "Canyoncito axis", based on their interpretation of the Lamy section as a depositionally condensed sequence. They do not give a detailed stratigraphic section but publish a small graphic section in which the total Pennsylvanian is shown as being only about 475 ft thick, consisting of what they term the upper clastic member of the Sandia Formation (about 200 ft) and the lower limestone member of the Madera Formation (about 275 ft). They show the Sangre de Cristo Formation resting directly on the lower limestone member of the Madera Formation, with the arkosic limestone member of the Madera Formation missing.

We would agree with the last point just mentioned. What is probably the Sangre de Cristo Formation rests unconfomably on the lower middle part of the La Pasada Formation. The highest strata preserved below the unconformity (top unit 44) contain one of the largest brachiopod faunas preserved in the entire Sangre de Cristo region. It correlates with the lower middle part of the La Pasada Formation at Dalton Bluff, approximately with the stratigraphic interval from units 36-127 to 36-133 (early Desmoinesian).

We find that the lower part of the Pennsylvanian sequence near Lamy is condensed by faulting, not depositionally condensed. The lower part of the sequence here is more clastic than at Dalton Bluff and includes several thin coal layers. The rocks are poorly fossiliferous, but unit 93-16, located 165 ft above the base, contains probable Morrowan brachiopods; unit 93-25, located 215 ft above the base, contains definite Atokan brachiopods. This lower sequence, 333.5 ft thick, is nearly equal in thickness to the combined Morrowan-Atokan interval at Dalton Bluff. These strata are faulted against nodular gray limestones (lower Desmoinesian) that occur higher in the La Pasada Formation (unit 44). Another important point is that the Precambrian bedrock in this area is granite. If the Lamy area had been a positive area during early Pennsylvanian time, these granites would have been exposed and provided arkosic sediments to the depositional area. To the contrary, the lower Pennsylvanian sandstones (Morrowan) at Lamy are orthoquartzites, with an apparent metamorphic source, and do not contain feldspar. Even the sandstones of Atokan age, higher in the section (unit 42) contain only 15% feldspar.

The section was measured in July, 1958, by P. K. Sutherland and Dean Gerber.

Unit	Lithology	Thickness (ft)
	Top of section stops arbitrarily at large southeast-flowing arroyo. To the southwest, and higher stratigraphically, are maroon shales and thin sandstones of the Sangre de Cristo Formation. Lower beds strike E-W, dip 30° S.	
	Sangre de Cristo Formation (or Alamitos)–partial thickness	115
46	Sandstone and shale: sandstone, weathers buff, coarse-grained, arkosic, medium-bedded; interbedded with thin layers of gray and maroon shale	55
45	Sandstone, weathers buff, coarse-grained, arkosic, thick-bedded, cross-bedded, basal 10 ft highly conglomeratic with scattered quartz pebbles to 20 mm and rare logs of petrified wood at base. One gray weathering coarse-grained sandy limestone layer or lense, 1 ft thick, seen at one small exposure only 15 ft above base. Base of unit clearly truncates underlying unit. Thickness of unit variable	60
	Unconformity	
	La Pasada Formation (Does not include unit 43)	513.5
44	Limestone and shale: limestone, weathers buff gray, fine- to coarse-grained, thin- to thick-bedded, nodular layers; interbedded with minor layers of gray shale; sequence poorly exposed on	

PHOTO 30- *Basal conglomerate of Sangre de Cristo Formation (unit 93-45) rests unconformably, in upper part of photo, on middle part of La Pasada Formation (unit 93-44). Nodular limestones, at hammer, are highly fossiliferous.*

Unit	Lithology	Thickness (ft)
	fourth ridge south of section base; top 10 ft of unit highly fossiliferous, containing: *"Orbiculoidea"* sp., *Crania* cf. *C. modesta, Rhipidomella* cf. *R. carbonaria, Orthotetes* sp., *Mesolobus striatus, Chonetinella jeffordsi?, Kozlowskia montgomeryi, Desmoinesia* cf. *D. "missouriensis", Sandia brevis?, Echinaria* cf. *E. knighti, Antiquatonia hermosana, Linoproductus planiventralis, Hustedia* cf. *H. "mormoni", Composita "ovata", Cleiothyridina pecosii, Neospirifer cameratus, Neospirifer tewaensis, Anthracospirifer curvilateralis chavezae, Anthracospirifer "occiduus", Anthracospirifer "opimus", Punctospirifer* cf. *P. kentuckyensis, Phricodothyris perplexa, Beecheria* cf. *B. millepunctata*	180
	Fault	
	La Pasada Formation (below fault)–partial thickness	333.5-334.5
43	Covered, conceals definite fault in third draw south of section base, cuts obliquely across strata with a regional strike of about N. 30° W. Unit not included in thickness	(30)
42	Sandstone, weathers tan to brown, coarse-grained, arkosic, poorly sorted, irregularly conglomeratic with scattered quartz pebbles to 5 mm in diam., unit cross-bedded; forms massive bluff facing railroad; contains large rounded masses of calcareous, dark-gray-weathering sandstone in lower part (20 ft above base: medium sandstone; quartz-overgrowth-cemented, submature subarkose; 15% feldspar)	32
41	Shale, dark-gray to black, noncalcareous, nonsilty, thickness variable	2-3
40	Limestone, gray, weathers buff, very sandy and conglomeratic in lower part, fossiliferous; forms gray layer in lower half of large bluff facing railroad	9
39	Shale, gray, weathers buff, silty in top and lower 2 ft; 2-inch lignite layer 8 ft above base	13
38	Limestone, dark-gray, weathers buff, fine- to medium-grained, medium-bedded; some layers silty and banded, weathers blocky; alternates with very thin silty shale layers; strike N. 90° W., dip 58° S.	11
37	Shale, black, friable, slightly calcareous	6.5
36	Limestone and sandstone: limestone, gray, weathers buff, partly crinoidal, sandy occurs in cross-bedded lenses up to 1 ft thick; interbedded with calcareous, poorly-sorted sandstone; thickness varies laterally	4
35	Shale and siltstone: shale weathers buff, interbedded in lower part with thin, sandy siltstone; upper part poorly exposed	10
34	Covered, probably shale	5
	Unit 33 is highest layer which can be measured with certainity. Section is covered above but in second gully south of section base, about 200 ft to the southwest, what are interpreted as units 31 to 33 are exposed and appear to have been repeated by faulting. These are exposed in gulley about 300 ft west of mouth and there is evidence of faulting at this point. Section measurement is resumed at top of unit 33 in second gulley and units 34 to 41 measured on third low ridge south of section base.	
33	Limestone, medium-gray, weathers brown, highly conglomeratic with subangular to subrounded quartz pebbles up to 10 mm in diam.; most layers highly crinoidal, scattered fossils; unit measured near crest of low ridge south of first draw	4
32	Shale	5
31	Coal; two 5-inch coal layers separated by 2-inch	

Unit	Lithology	Thickness (ft)
	underclay; exposed in abandoned coal-diggings on east point of low ridge facing railroad about halfway between mouths of first and second gullies south of section base	1
30	Covered, shale, and underclay (at top)	2
29	Conglomerate, weathers brown, poorly sorted, highly calcareous, becomes sandy at top	2
28	Covered	3
27	Conglomerate, weathers brown, poorly sorted, highly calcareous, scattered fossils at top	2.5
26	Covered	13
25	Shale and limestone: limestone, weathers gray, fine-grained, thin-bedded; interbedded with thin gray shale layers, unit fossiliferous; *Sandia brevis, Anthracospirifer newberryi*	4
24	Limestone, weathers brown, silty, fossiliferous	2
23	Covered	10
22	Limestone and siltstone: limestone, medium-gray, weathers buff, sandy, partly micaceous; interbedded with thin layers of calcareous siltstone; fossiliferous	3
21	Sandstone and shale: sandstone, weathers buff, coarse-grained, poorly sorted; interbedded with thin layers of thin-bedded, micaceous shale; some sandstone layers highly calcareous with scattered fossils	8
20	Shale, weathers buff, partly silty, friable	22
19	Coal	0.6
18	Underclay, contains plant fragments	0.4
17	Shale, weathers buff, micaceous	4
16	Limestone, medium-gray, weathers brown, coarse-grained, crinoidal, fossiliferous; strike N. 50° W., dip 24° SW.; units 15 and 16 contain *Composita "ovata", Anthracospirifer* cf. *A. newberryi, Anthracospirifer curvilateralis tanoensis*	1.5
15	Shale, weathers light gray, fossiliferous; exposed approximately 30 yds north of mouth of first draw south of section base	1
14	Covered, includes most of low ridge between base of section and first draw to south	120
13	Sandstone, weathers green, coarse-grained, poorly sorted; strike N. 60° W., dip 25° SW	1
12	Limestone, light-gray, weathers buff, highly conglomeratic with subangular quartz pebbles up to 10 mm in diam., fossiliferous	2
11	Covered, probably shale	6
10	Shale, weathers buff, silty	4
9	Sandstone, poorly sorted, conglomeratic	3
8	Shale and sandstone: weathers maroon and tan	7
7	Conglomerate, cream weathering, poorly sorted, mainly limestone pebbles with rare pebbles of quartz, subangular to subrounded, maximum diameter 3 inches; calcareous matrix (top: granule conglomerate; microcrystalline-silica and calcite-cemented, submature, chert-bearing orthoquartzite; no feldspar)	6
6	Shale and sandstone: shale weathers olive buff, platy shale interbedded with occasional siltstone and sandstone layers, occasional chert nodules, poorly exposed (2 ft above base: very fine sandstone; quartz-overgrowth-cemented, clay-bonded, immature, muscovite-bearing orthoquartzite; no feldspar)	3
	Tererro(?) Formation (Mississippian)	

SECTION 96
ALAMITOS VALLEY

Section 96 is located in the Alamitos valley northwest of the town of Pecos. It is one of the two typical sections of the Alamitos Formation. Sutherland (1963) described it (p. 60), depicted it graphically (p. 30), and prepared a detailed section (p. 60). It exposes most of the Alamitos Formation except for the lowest part. Rocks of upper Desmoinesian, Missourian and Virgilian are included.

Unit	Faunal Occurrence
	Virgilian
	Alamitos Formation
57	*Buxtonia?* sp. *C, Wellerella immatura, Composita "ovata", Neospirifer dunbari?*
	Missourian
51	*Neospirifer alatus, Buxtonia?* sp. C, *Linoproductus* cf. *L. platyumbonus, Antiquatonia* n. sp. A
40	*Echinaria* cf. *E. semipunctata, Antiquatonia* n. sp. A, *Neospirifer alatus*
30	*Antiquatonia* n. sp. A, *Composita "ovata", Neospirifer alatus*
	Middle or upper Desmoinesian
10	*Fusulina* sp.

SECTION 97
WEST OF PECOS VALLEY

Section 97 is one of the two typical sections for the Alamitos Formation. Sutherland (1963) described it (p. 63), depicted it graphically (p. 37), and prepared a detailed section (p. 63). The top of the Alamitos Formation is not exposed but its basal contact with the Alamitos Formation can be observed. Rocks of middle and upper Desmoinesian, Missourian and Virgilian are included.

Brachiopods occur commonly in the Missourian but are rare in the Desmoinesian part of the section. Fusulinids occur at several horizons as shown.

Unit	Faunal Occurrence
	Virgilian
	Alamitos Formation
74	*Derbyia* cf. *D. haesitans*
	Missourian
60	*Echinaria* cf. *E. semipunctata, Buxtonia?* sp. C, *Antiquatonia* n. sp. A, *Composita "ovata", Neospirifer alatus*
54	*Derbyia* cf. *D. haesitans, Buxtonia?* sp. C, *Composita "ovata", Neospirifer alatus*
	Upper Desmoinesian (Fusulinid Zone V)
48	*Fusulina* cf. *F. cappensis*
	Middle Desmoinesian (Fusulinid Zone IV)
24	*Fusulina* cf. *F. erugata, Fusulina* cf. *F. haworthi*
9	*Fusulina* cf. *F. erugata*
	La Pasada Formation
1	*Fusulina* cf. *F. haworthi, Fusulina* sp. A and sp. B of Waddell (1966)

SECTION 98
PECOS (town) RIVER BLUFF

The highest beds of the Alamitos Formation (Pennsylvanian) are exposed in the north edge of the town of Pecos, primarily in a prominent west-trending, north-facing bluff overlooking the Pecos River (fig. 4). The contact with the overlying Sangre de Cristo Formation (Permian), which underlies the town of Pecos, is apparently transitional and the contact is arbitrarily placed at the top of the highest limestone layer. The highest part of the Alamitos Formation at this locality is Virgilian, as indicated by the occurrence of fusulinids in unit 3. These occur about 125 ft below the top of the formation. The section correlates with the upper part of measured section 96, located about 1 mile west. Brachiopods found in unit 98-3 are similar to those found in unit 96-57.

A few brachiopods were found in unit 98-3, in addition to the Virgilian fusulinid *Triticites* cf. *T. cullomensis.* About 0.5 mile west along the bluff (locality 98-west) specimens possibly belonging to *Beecheria millepunctata* were collected. The original specimens collected by Marcou of *Orthis pecosii, Terebratula rocky-montana* and *Terebratula millepunctata* possibly came from an outcrop near the Pecos River at the sharp bend located 0.7 mile west-northwest of measured section 98 (fig. 4). See discussion on " Marcou's 1853 survey."

Unit	Lithology	Thickness (ft)
	The section was discontinued at the top of the highest limestone, at a point about 100 ft west of State Highway 63 and about 0.1 mile north of St. Anthony's church.	
	Sangre de Cristo Formation	
8	Shale and covered: shale weathers maroon, poorly exposed; thickness not measured	
	Alamitos Formation–partial thickness	210
7	Limestone, weathers light gray, coarse-grained, crinoidal, sandy, thick-bedded; lower and upper contacts concealed; forms most southerly and highest west-trending limestone ridge	15
6	Limestone and shale: limestone, weathers gray, coarse-grained; interbedded with maroon weathering shale; unit poorly exposed; thickness estimated	15
5	Shale, weathers maroon, poorly exposed; forms saddle between successive limestone ridges immediately west of State Highway 63, opposite gas station; thickness estimated	50
4	Limestone, weathers buff gray, coarse-grained, crinoidal, sandy, arkosic, thick-bedded; forms cliff at top of north-facing bluff overlooking Pecos River, 200 ft west of highway, south of bridge	35
3	Limestone and shale: limestone weathers light gray, medium-grained, medium-bedded; interbedded with gray and maroon shale; 2 to 5 ft above base: *Triticites* cf. *T. cullomensis;* 5 to 15 ft above base: *Wellerella immatura, Composita "ovata"* and *Neospirifer dunbari?*	15
2	Limestone, weathers buff gray, coarse-grained, crinoidal, sandy, arkosic, thick-bedded	10
1	Sandstone, siltstone and shale: sandstone, weathers buff, medium- to coarse-grained, arkosic, well-sorted; interbedded with siltstone and shale; forms lower part of north-facing bluff over river	70
	Base of section at river bank 200 ft west of highway bridge.	

LOCALITY 99
NEAR RIO EN MEDIO

The most southwesterly of the 3 Pennsylvanian inliers on the Nambe Indian Reservation is located between Rio en Medio and Rio Nambe (see fig. 50). Locality 99 refers to a general fossil collection of Morrowan age, made from the outcrop of the basal part of the La Pasada Formation located in SE$^1/_4$ NE$^1/_4$ sec. 31, T. 19 N., R. 10 E. The exposure is about 0.2 mile in length, the strata strike N. 50° E. and dip 32° to 51° NW. Only the basal 50 or 60 ft of the Pennsylvanian strata are exposed. This unit is equivalent to that part of section 41 from unit 38 and lower. The locality is 0.8 mile south-southwest of measured section 41 at Nambe Falls. Included are: *Schizophoria altirostris?, Krotovia globosa, Composita "ovata"* and *Beecheria stehlii.*

LOCALITY 105
SOUTH OF DALTON BLUFF

Locality 105 refers to brachiopod collections made on a bedding plane bench two-thirds of the way to the top, and at the north end, of a distinctive triangular-shaped hill located on the west side of the Pecos valley about 4.3 miles north of the road junction in the town of Pecos. For a road log see Montgomery and Sutherland (1967, p. 16). It is also located about 1.6 miles south of measured section 36 (Dalton Bluff) . The sequence can be traced southward along the bluffs on the west side of the Pecos. Locality 105 is equivalent to some part of the interval in measured section 36 from unit 122 to 128, and is lower Desmoinesian. Brachiopods collected are: *Derbyia crassa, Mesolobus striatus, Chonetinella jeffordsi, Kozlowskia haydenensis, L inoproductus planiventralis, Composita "ovata ", Anthracospirifer rockymontanus, Phricodothyris perplexa, Antiquatonia hermosana.*

Appendix 2—Tables of Statistics

Introduction

Descriptive statistics for various morphological features and reduced major axes (RMA) for width and length, height and length, and/or thickness and length are presented in this appendix. The values of the means are arbitrarily rounded off to 3 decimal places; the remaining statistics are rounded off to 4 decimal places. Such values are not intended to imply accuracy of mensuration but rather to assist other investigators comparing statistical samples from other horizons or localities. *Tables 1 through 20 are on microfiche film in small pocket inside rear cover of this volume.*

Symbols Used

$\bar{X}$	Mean
s	Standard deviation
M	Mode
R	Range
n	Sample size
$\bar{L}$, $\bar{W}$, $\bar{T}$, $\bar{H}$	Mean length, width, thickness, and height, respectively
S_L, S_W S_T, S_H	Standard deviation of length, width, thickness, and height, respectively
a	Intercept of reduced major axis
b	Slope of reduced major axis
r	Coeffecient of linear correlation
S_a	Standard error of intercept
S_b	Standard error of slope
S_d	Coeffecient of dispersion around reduced major axis

Appendix 3—Specimen Measurements

Introduction

This appendix includes measurements of figured specimens of species described previously. In some instances measurements are given for specimens from supplemental localities where only a small number of specimens of newly described species were collected from the type locality. For the few species that have been reestablished, for example *Neochonetes? platynotus* (White), measurements are also given for topotypes. *All measurement data are on microfiche film in small pocket inside rear cover of this volume.*

Symbols Used

Loc.	Locality collected
No.	Catalogue number. Number may be succeeded by (H), (N), (P), (L), or (T) for figured holotype, neotype, paratype, lectotypes, or topotypes, respectively
OU	University of Oklahoma, Invertebrate Paleontology Repository
WM	Walker Museum, University of Chigaco
USNM	United States National Museum of Natural History
BMNH	British Museum of Natural History
MCZ	Museum of Comparative Zoology, Harvard University
L	Length
W	Width
H	Height
T	Thickness
SL	Surface length
SLR	Surface length to end of reticulation
C	Number of costae, costellae, capillae, or lirae measured in a designated distance across the venter at a specified surface length
SLC	Surface length to beginning of coarse costation

Fossil Plates

PLATE 1

Figures		*Page*
1	*Lingula* cf. *L. carbonaria* Shumard OU 7529, locality 78, X1.	15
2	*Lingula* sp. A. OU 7530, unit 41-32, X3.	15
3-5	*"Orbiculoidea" youngi* n. sp. **3)** holotype OU 7531, unit 67-23, side, note slight extension of pedicle opening below plane of commissure, surface decorticated, X2. **4)** paratype OU 7532, unit 67-23, *a,* brachial, X2; *b,* brachial, note paired ridges on anterior slope, X5. **5)** paratype OU 7533, unit 67-13, pedicle, X2.	15
6	*"Orbiculoidea"* sp. OU 7534, unit 62-28, brachial, X1.	16
7	*Crania* cf. *C. modesta* White and St. John OU 7535, unit 93-44, interior of attached pedicle valve, X2.	16
8	*Schizophoria altirostris?* (Mather) OU 7538, unit 90-2, X1, *a,* pedicle; *b,* brachial; *c,* posterior; *d,* side.	17
9	*Rhipidomella* cf. *R. carbonaria* (Swallow) OU 7539, unit 93-44, *a,* pedicle, X2; *b,* brachial, X2; *c,* brachial, X1.	18
10-12	*Rhipidomella trapezoida* n. sp. **10)** holotype OU 7540, unit 41-33, *a,* pedicle, X1; *b,* brachial, X2; *c,* side, X2; *d,* anterior, X2. **11)** paratype OU 7541, unit 41-33, X2, *a,* pedicle; *b,* brachial. **12)** OU 7542, locality 68, pedicle interior, X2.	18
13-14	*Schizophoria oklahomae* Dunbar and Condra **13)** OU 7536, locality 51, X1, *a,* side; *b,* brachial; *c,* pedicle. **14)** OU 7537, unit 90-14 to 17, pedicle interior, X1.	16
15	*Isogramma* sp. OU 7543, unit 36-97, exterior of crushed brachial valve with interior of crushed pedicle valve partly exposed near top, X½.	19
16-17	*Meekella* n. sp. A. **16)** OU 7544, unit 41-42, X1, *a,* side; *b,* pedicle; *c,* brachial; *d,* posterior. **17)** OU 7545, unit 90-7, brachial, note fine radiating lirae superimposed on plications, X3.	19
18	*Meekella* cf. *M. striatocostata* (Cox) OU 7546, unit 29-3, brachial, X1.	20

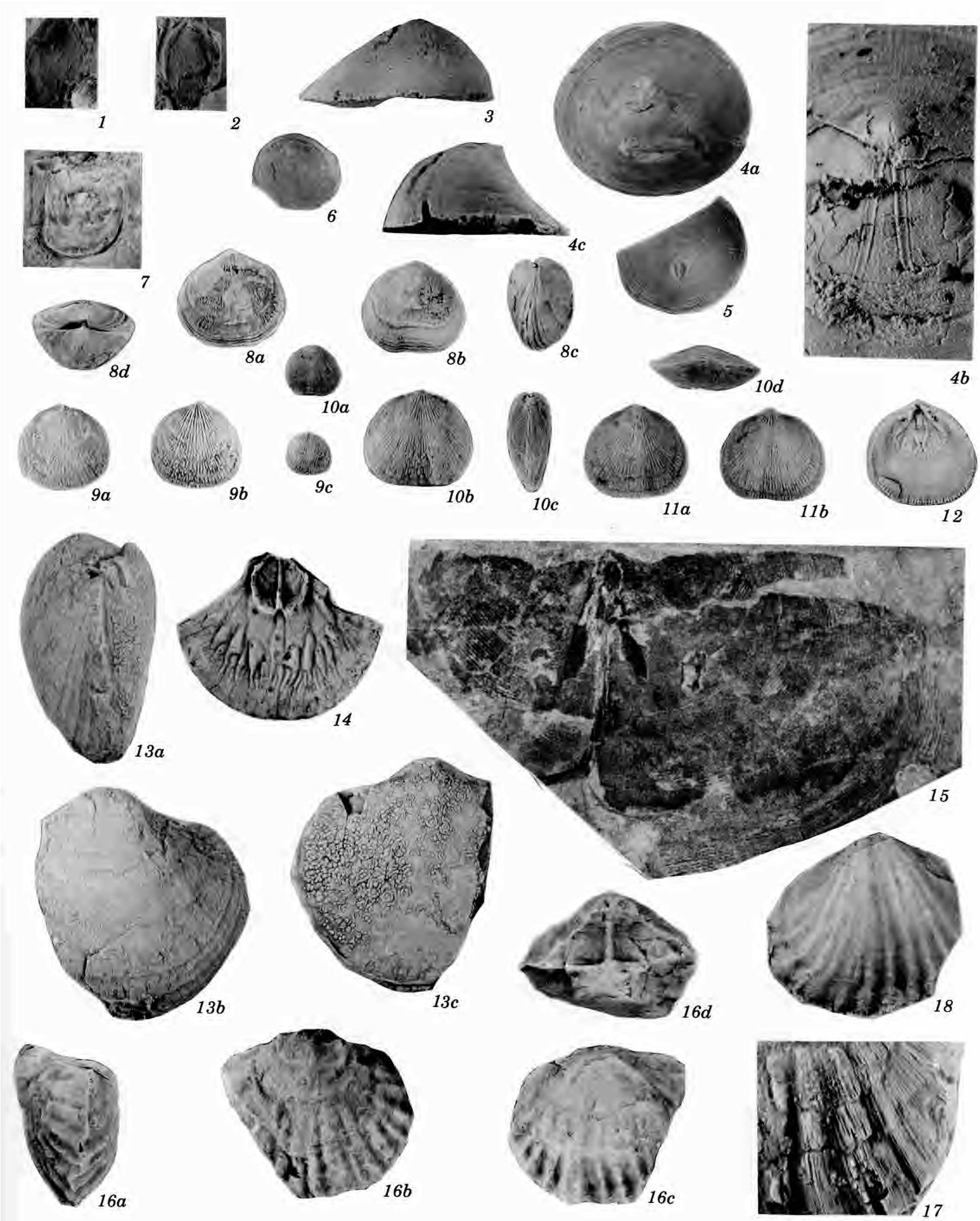
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PLATE 2

Figures — *Page*

1-3 *Orthotetes* sp. 20

1) OU 7547, unit 93-44, X1, *a*, pedicle; *b*, brachial; *c*, side. **2)** OU 7548, unit 93-44, pedicle interior, note spondylium, X1. **3)** OU 7549, unit 93-44, brachial, X1.

4-7 *Derbyia bonita* n. sp. 20

4) holotype OU 7550, unit 90-14 to 17, *a*, pedicle, X1; *b*, brachial, X1; *c*, side, X1; *d*, posterior, X2. **5)** paratype OU 7551, unit 90-14 to 17, *a*, pedicle, X1; *b*, brachial, X1; *c*, posterior, X2. **6)** *D. bonita?*, OU 7553, unit 62-28, brachial interior, X2. **7)** *D. bonita?*, OU 7552, unit 62-28, pedicle interior, X2.

8-12 *Derbyia crassa* (Meek and Hayden) 21

8) OU 7554, locality 105, X1, *a*, posterior; *b*, pedicle; *c*, brachial; *d*, side. **9)** OU 7557, locality 105, X1, *a*, posterior, note marked distortion of growth; *b*, pedicle. **10)** OU 7555, locality 105, pedicle, X1. **11)** OU 7556, locality 105, X1, *a*, pedicle; *b*, posterior. **12)** OU 7558, locality 105, young individual, X1, *a*, brachial; *b*, pedicle.

13 *Derbyia* cf. *D. haesitans* Dunbar and Condra 21

OU 7559, unit 97-74, X1, *a*, pedicle; *b*, brachial, note repair of injury.

14-26 *Neochonetes? platynotus* (White) 23

14) lectotype USNM 8498a, locality "near Santa Fe," *a*, brachial, compare with 15a, X1; *b*, brachial, X2; *c*, pedicle, compare with 15b, X1; *d*, pedicle, X2; *e*, anterior, note lack of a distinct mesial lobe, X2; *f*, posterior, X2. **15)** White's (1877, pl. 9, figs. 6a, 6b, 6d, 6e) original drawings of specimen herein selected as lectotype, USNM 8498a, compare figs. 14a-f, *a*, brachial, X1; *b*, pedicle, X1; *c*, tilted view of posterior margin, X3; *d*, cross section, X2. **16)** figured paralectotype USNM 8498b (White, 1877, pl. 9, fig. 6c), locality "near Santa Fe," X2, *a*, pedicle interior; *b*, anterior. **17)** White's (1877, pl. 9, fig. 6c) original drawings of paralectotype USNM 8498b, pedicle interior, compare fig. 16a, X2. **18)** unfigured paralectotype USNM 8498c, locality "near Santa Fe," X2, *a*, pedicle; *b*, anterior. **19)** unfigured paralectotype USNM 8498d, locality "near Santa Fe," X2, *a*, pedicle; *b*, anterior. **20)** topotype OU 7560, unit 41-49, *a*, pedicle, X1; *b*, anterior, X2; *c*, brachial, X2; *d*, side, X2. **21)** topotype OU 7566, unit 41-49, pedicle interior, X2. **22)** topotype OU 7567, unit 41-49, pedicle interior, X2. **23)** topotype OU 7568, unit 41-49, pedicle interior, immature specimen, X3. **24)** topotype OU 7565, unit 41-49, pedicle, X3. **25)** topotype OU 7562, unit 41-49, X2, *a*, anterior; *b*, pedicle. **26)** topotype OU 7561, unit 41-49, X3, *a*, pedicle; *b*, brachial.

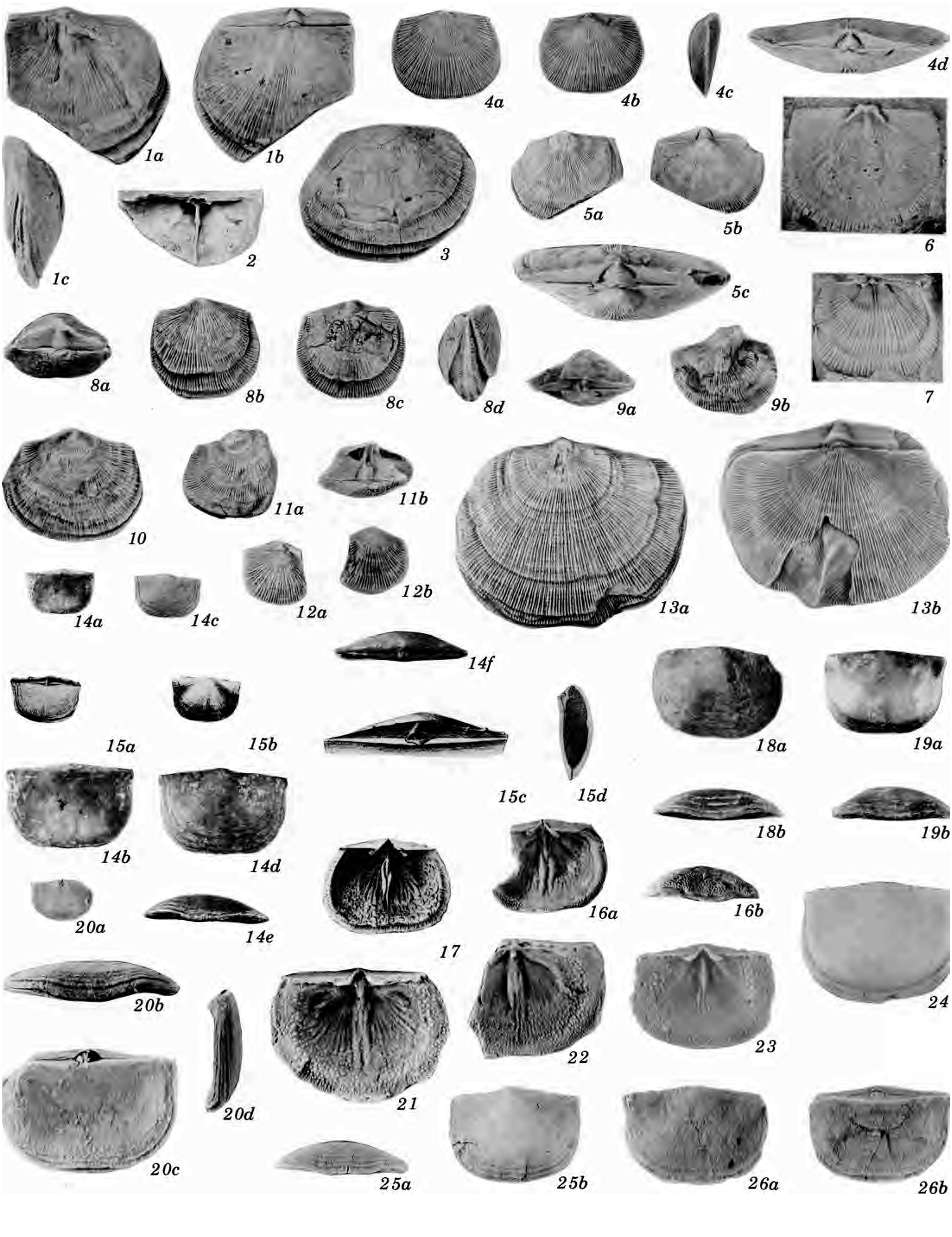
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PLATE 3

Figures *Page*

1-9 *Plicochonetes? arkansanus* (Mather) 22

1) OU 7577, unit 41-33, ×3, *a,* pedicle; *b*, side; *c,* anterior. **2)** OU 7578, unit 41-33, pedicle, ×3. **3)** OU 7579, unit 41-33, *a,* pedicle, ×2; *b,* brachial, ×3. **4)** OU 7580, locality 68, pedicle, ×4. **5)** OU 7583, locality 68, brachial interior, cardinal process broken off, ×3. **6)** OU 7584, unit 41-42, brachial interior, ×3. **7)** OU 7585, locality 68, brachial interior, ×3. **8)** OU 7581, locality 68, pedicle interior, ×3. **9)** OU 7582, locality 68, pedicle interior, left half of specimen crushed, ×3.

10-14 *Neochonetes? platynotus* (White) 23

10) topotype OU 7569, unit 41-49, brachial interior, interpreted as older individual with marked secondary interval thickening, ×3. **11)** topotype OU 7570, unit 41-49, brachial interior, ×3. **12)** topotype OU 7571, unit 41-49, brachial interior, immature individual, cardinal process broken, ×3. **13)** topotype OU 7564, unit 41-49, pedicle, ×2. **14)** topotype OU 7563, unit 41-49, ×2, *a,* pedicle; *b,* anterior.

15-19 *Neochonetes* n. sp. A 25

15) OU 7572, unit 61-6A, ×2, *a,* pedicle; *b,* anterior. **16)** OU 7575, unit 90-14 to 17, pedicle, ×2. **17)** OU 7573, unit 61-2, ×2, *a,* pedicle; *b,* anterior. **18)** OU 7574, unit 90-2, ×2, *a,* pedicle; *b,* brachial. **19)** OU 7576, unit 61-2, pedicle interior, ×3.

20-34 *Neochonetes henryi* n. sp. 26

20) holotype OU 7586, unit 62-28, *a,* pedicle, ×1; *b,* pedicle, ×2; *c,* anterior, ×3; *d,* brachial, note valve slightly crushed, ×3. **21)** paratype OU 7587, unit 62-28, *a,* pedicle, ×1; *b,* pedicle, ×2; *c,* anterior, ×3; *d,* brachial, note valve slightly crushed, ×3. **22)** paratype OU 7589, unit 62-28, ×3, *a,* pedicle; *b,* anterior. **23)** paratype OU 7590, unit 62-28, ×3, *a,* side; *b,* pedicle, surface weathered; *c,* anterior. **24)** paratype OU 7592, unit 62-28, pedicle, immature specimen, ×3. **25)** paratype OU 7588, unit 62-28, ×3, *a,* pedicle; *b,* anterior. **26)** paratype OU 7591, unit 62-28, ×3, *a,* pedicle, surface weathered; *b,* anterior. **27)** paratype OU 7593, unit 62-28, pedicle interior, ×3. **28)** paratype OU 7594, unit 62-28, pedicle interior, ×3. **29)** paratype OU 7595, unit 62-28, pedicle interior, ×3. **30)** paratype OU 7596, unit 62-28, brachial interior, ×4. **31)** paratype OU 7600, unit 62-28, brachial interior, immature specimen, ×4. **32)** paratype OU 7597, unit 62-28, brachial interior, ×4. **33)** paratype OU 7598, unit 62-28, brachial interior, ×3. **34)** paratype OU 7599, unit 62-28, brachial interior, immature specimen, ×3.

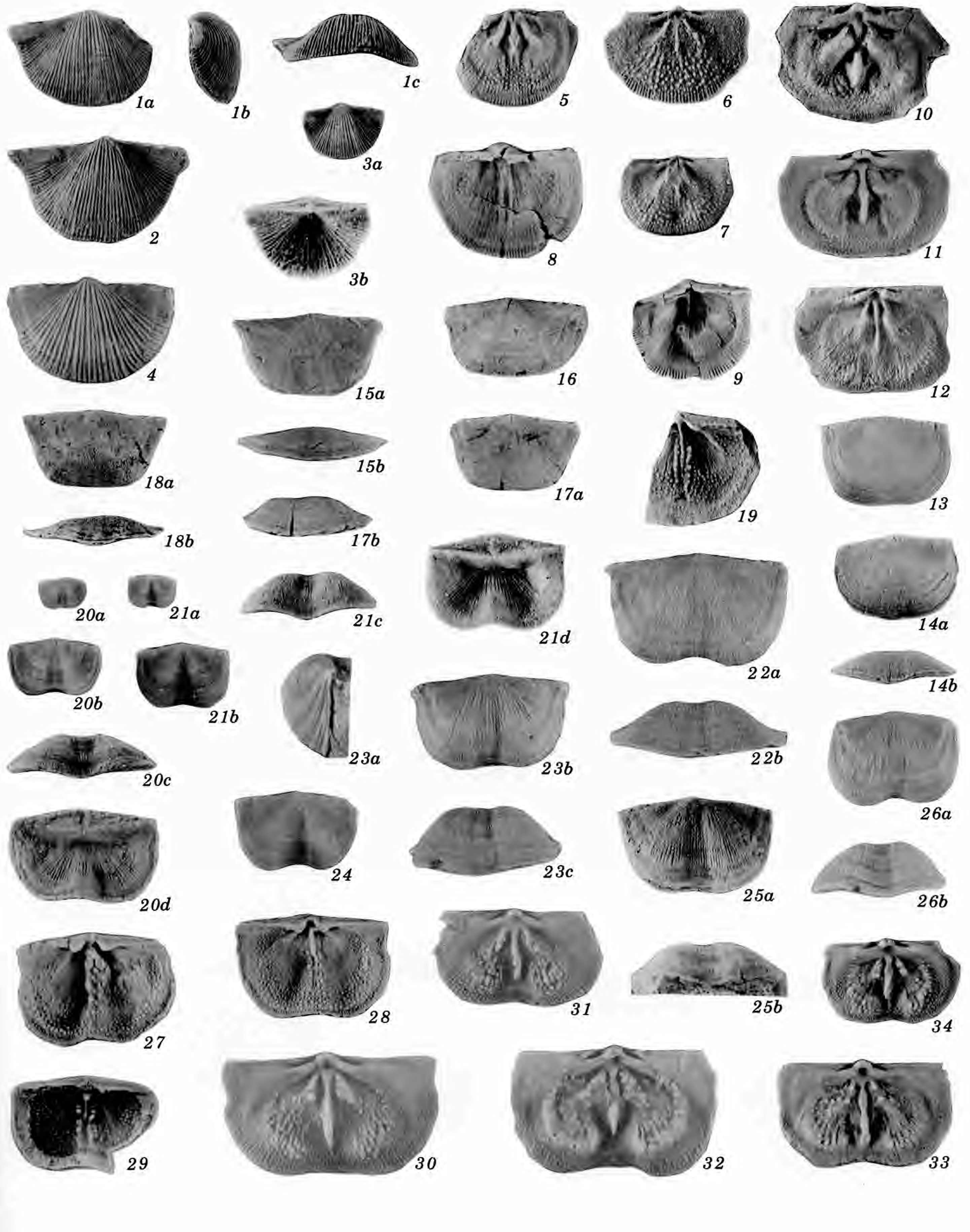
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PLATE 4

Figures		*Page*
1-13	*Neochonetes whitei* n. sp.	27
	1) holotype OU 7601, unit 62-17 and 18, X2 unless otherwise indicated, *a*, brachial; *b*, pedicle; *c*, pedicle, X1; *d*, anterior; *e*, posterior; *f*, side. **2)** paratype OU 7603, unit 62-17 and 18, X2, *a*, pedicle; *b*, anterior. **3)** paratype OU 7604, unit 62-17 and 18, X2, *a*, pedicle; *b*, brachial; *c*, anterior. **4)** paratype OU 7609, unit 62-17 and 18, anterior, immature specimen, X2. **5)** paratype OU 7610, unit 62-17 and 18, tilted view of interarea, pseudodeltidium shown but chilidium mostly worn away, giving false impression of narrow chilidial plates, X4. **6)** paratype OU 7605, unit 62-17 and 18, X2, *a*, pedicle; *b*, anterior; *c*, posterior. **7)** paratype OU 7608, unit 62-17 and 18, pedicle, immature specimen, X3. **8)** paratype OU 7606, unit 62-17 and 18, X2, *a*, side; *b*, anterior, most mesolobate shell observed; *c*, pedicle. **9)** paratype OU 7607, unit 62-17 and 18, pedicle, immature specimen, X2. **10)** paratype OU 7602, unit 62-17 and 18, *a*, pedicle, X1; *b*, anterior, X2. **11)** paratype OU 7612, unit 62-17 and 18, pedicle interior, artificial mold of natural cast, X2. **12)** paratype OU 7611, unit 62-17 and 18, pedicle interior, X3. **13)** paratype OU 7613, unit 62-17 and 18, brachial interior, middle part of median septum is broken, X3.	
14-24	*Mesolobus striatus* Weller and McGehee	30
	14) OU 7614, unit 10-11, X2 unless otherwise indicated, *a*, brachial; *b*, pedicle; *c*, pedicle, X1; *d*, anterior. **15)** OU 7618, unit 93-44, *a*, pedicle, X1; *b*, brachial, X3. **16)** OU 7615, unit 10-11, pedicle, X2. **17)** OU 7619, unit 93-44, *a*, pedicle, X3; *b*, brachial, X2; *c*, anterior, X2. **18)** OU 7617, unit 10-11, pedicle, X1. **19)** OU 7616, unit 10-11, X2, *a*, pedicle; *b*, brachial. **20)** OU 7620, unit 93-44, pedicle, X2. **21)** OU 7624, unit 93-44, brachial interior, X2. **22)** OU 7623, unit 93-44, brachial interior, X3. **23)** OU 7622, unit 93-44, brachial interior, X3. **24)** OU 7621, unit 93-44, pedicle interior, X2.	
25-32	*Mesolobus profundus* n. sp.	32
	25) holotype OU 7626, locality 78, X2, *a*, brachial; *b*, pedicle; *c*, side; *d*, anterior. **26)** paratype OU 7627, locality 78, *a*, pedicle, X1; *b*, brachial, X2; *c*, anterior, X2; *d*, posterior, X2. **27)** paratype OU 7628, locality 78, pedicle, note extended ears, X2. **28)** paratype OU 7629, locality 78, *a*, pedicle, X2; *b*, pedicle, X1; *c*, brachial, X2. **29)** paratype OU 7630, locality 78, pedicle, X2. **30)** paratype OU 7631, locality 78, X2, *a*, anterior; *b*, pedicle. **31)** paratype OU 7633, locality 78, pedicle interior, artificial cast of natural mold, X3. **32)** paratype OU 7632, locality 78, pedicle interior, artificial cast of natural mold, X3.	

PLATE 4

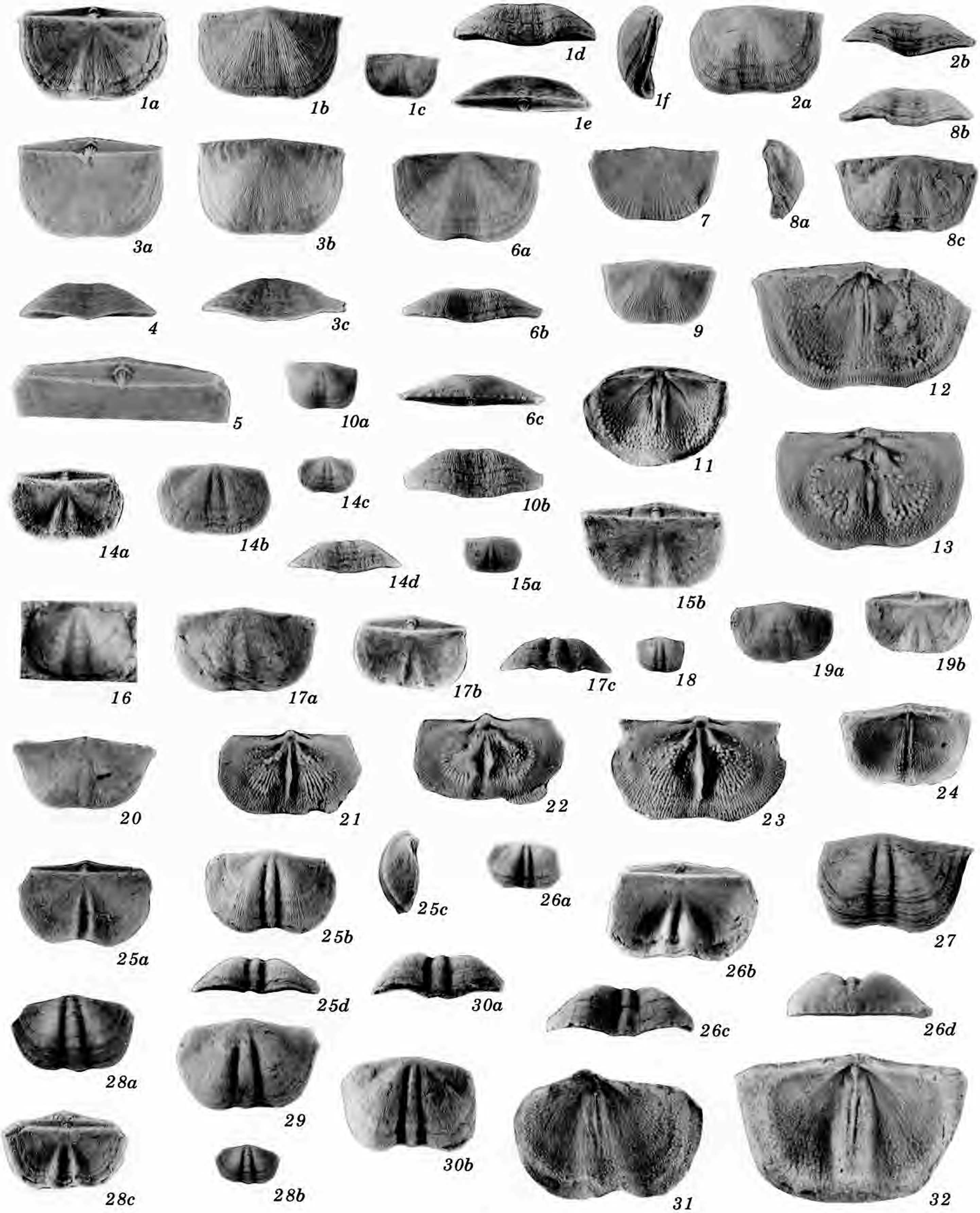
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PLATE 5

Figures | *Page*

1-2 *Mesolobus profundus* n. sp. 32
1) paratype OU 7635, locality 78, brachial interior, artificial cast of natural mold, X3. **2)** paratype OU 7634, locality 78, brachial interior, artificial cast of natural mold, X3.

3-5 *Mesolobus euampygus* (Girty) 33
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17-18 *Kozlowskia haydenensis* (Girty) 36
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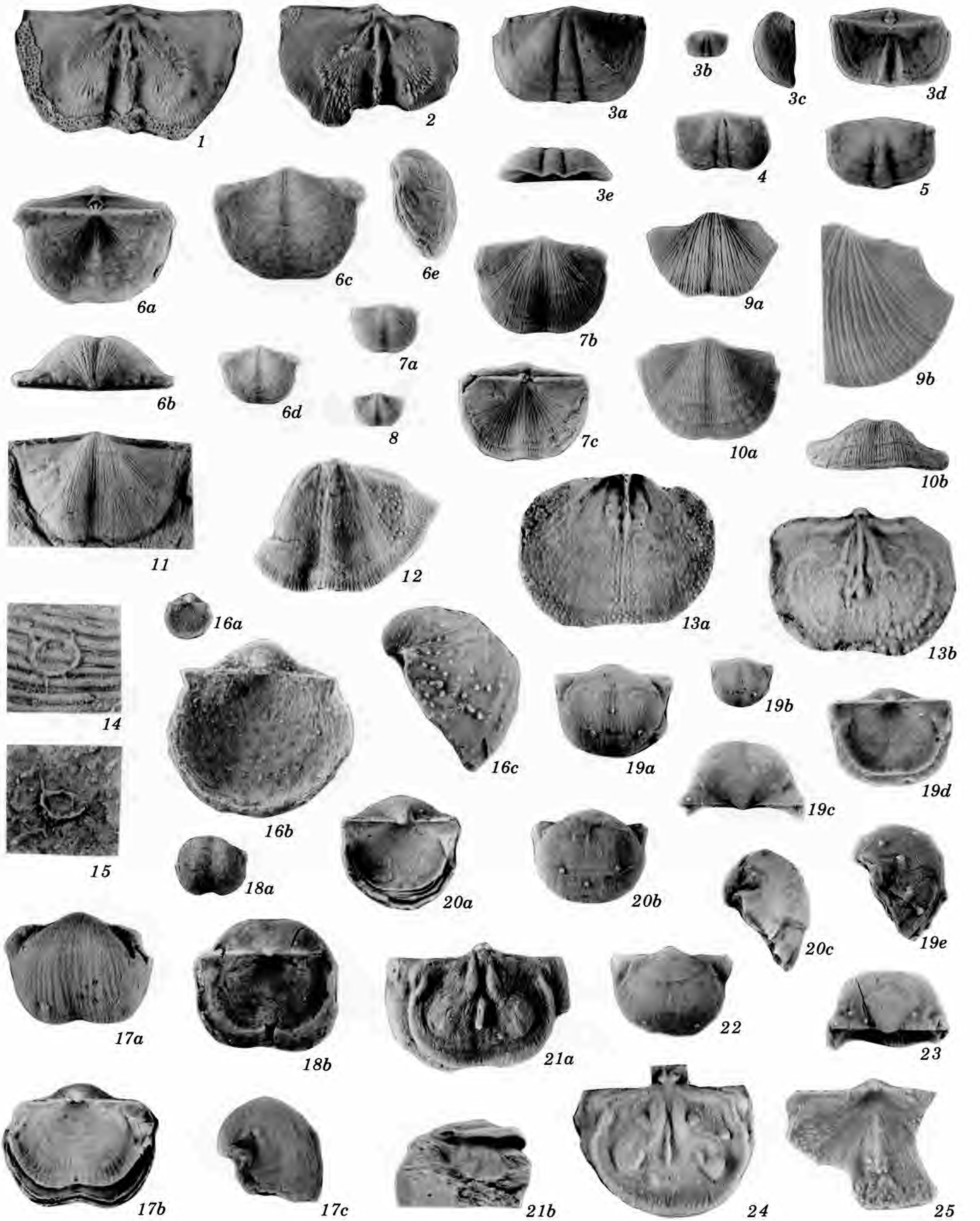
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16 *Desmoinesia* sp. A. 38

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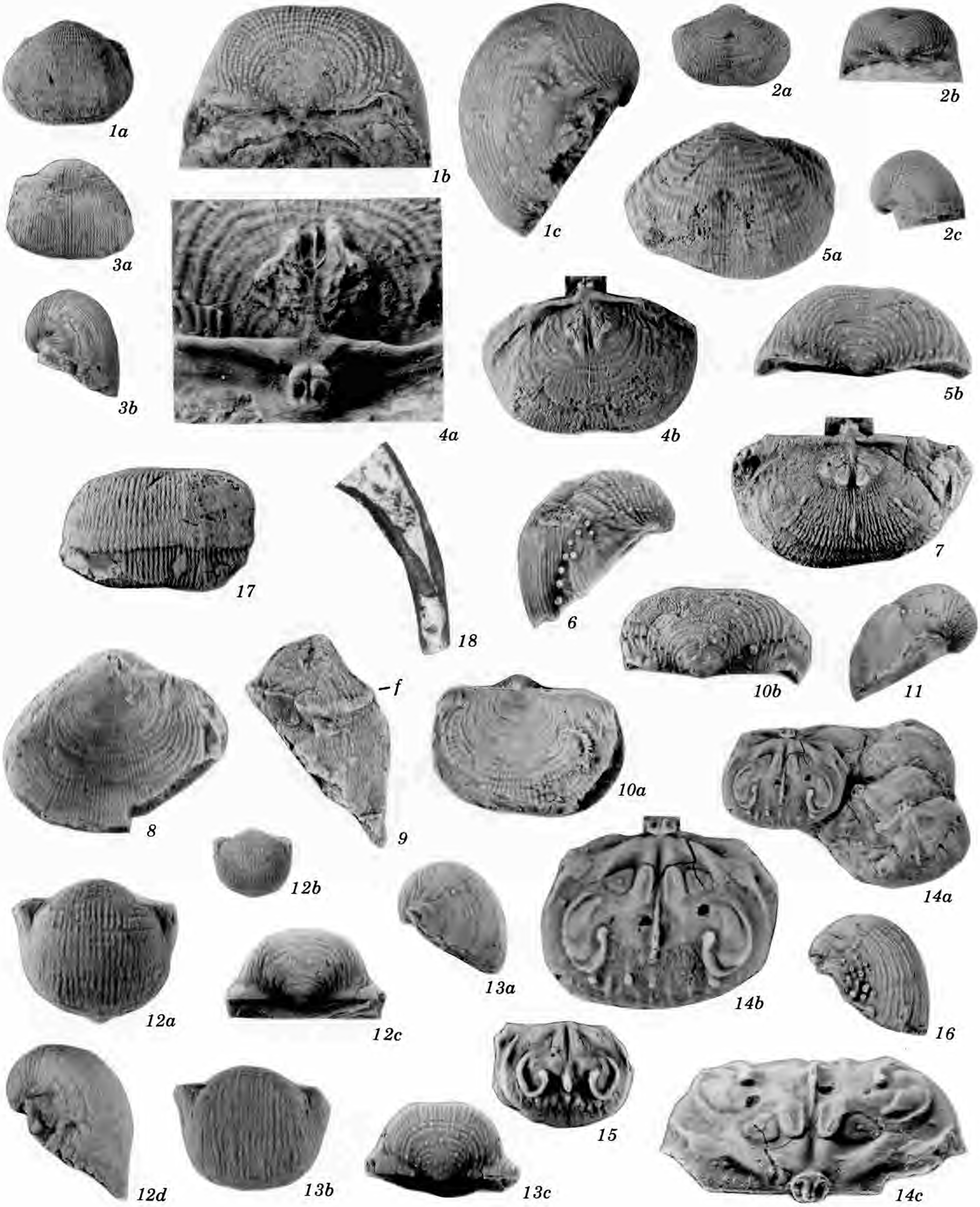
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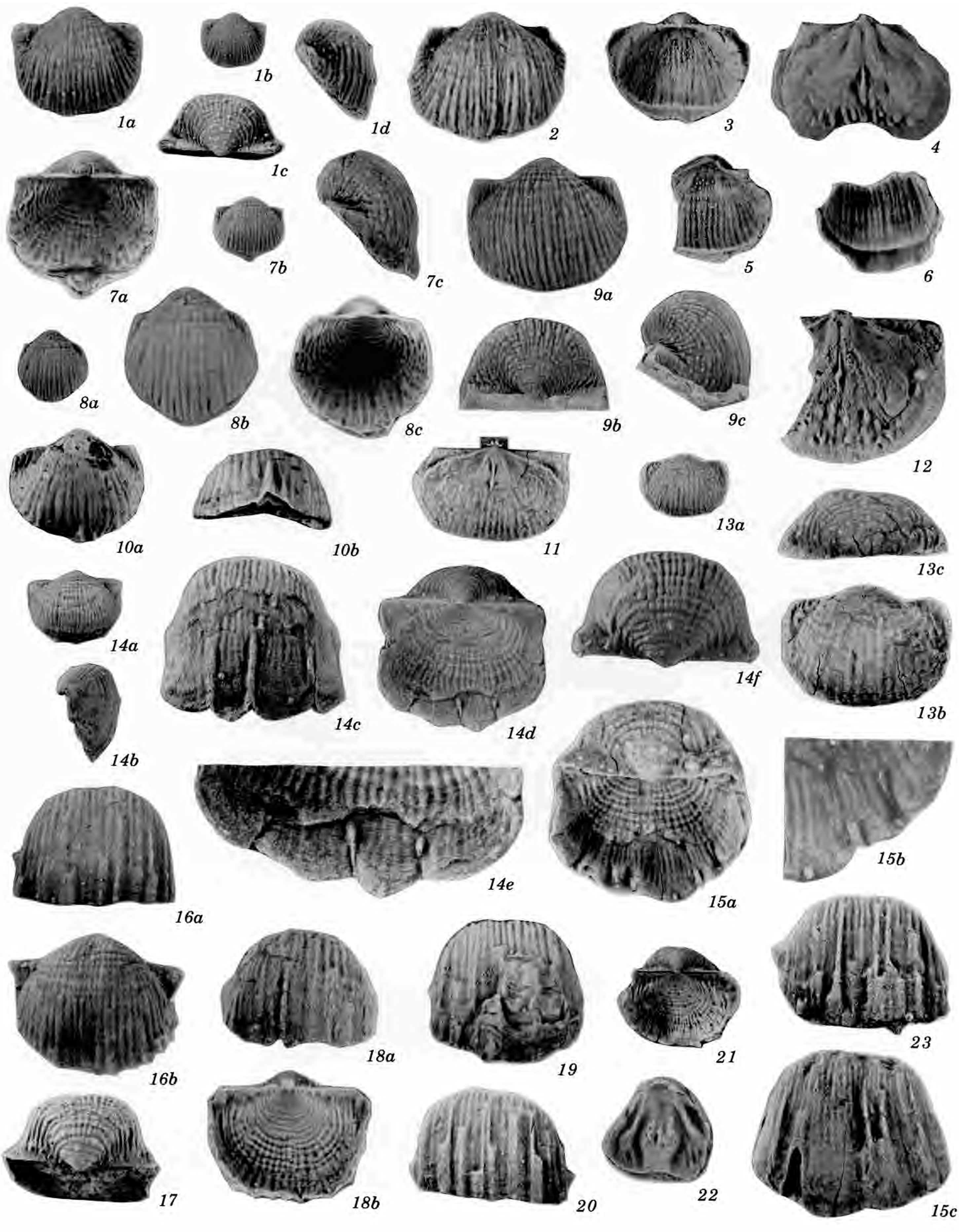
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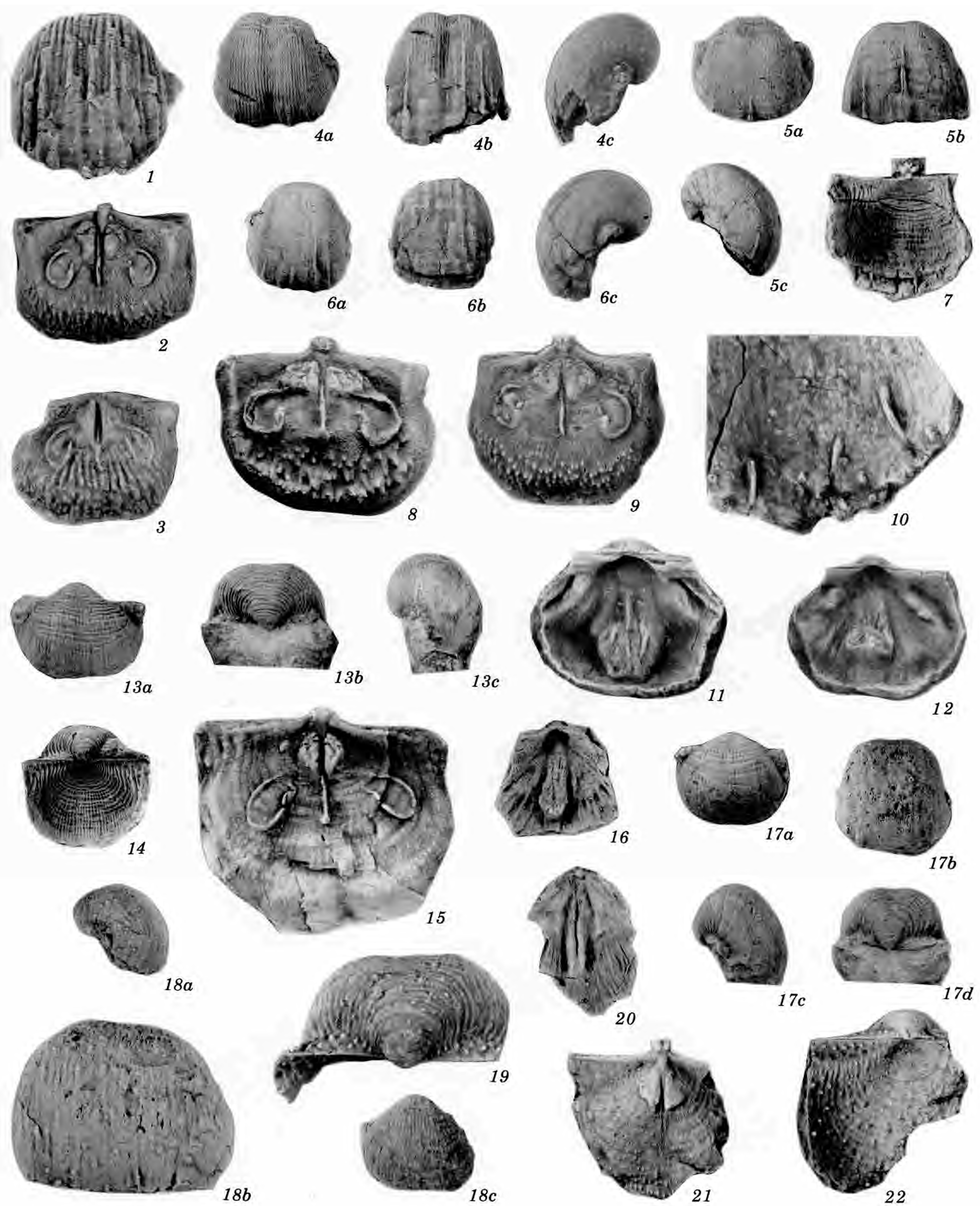
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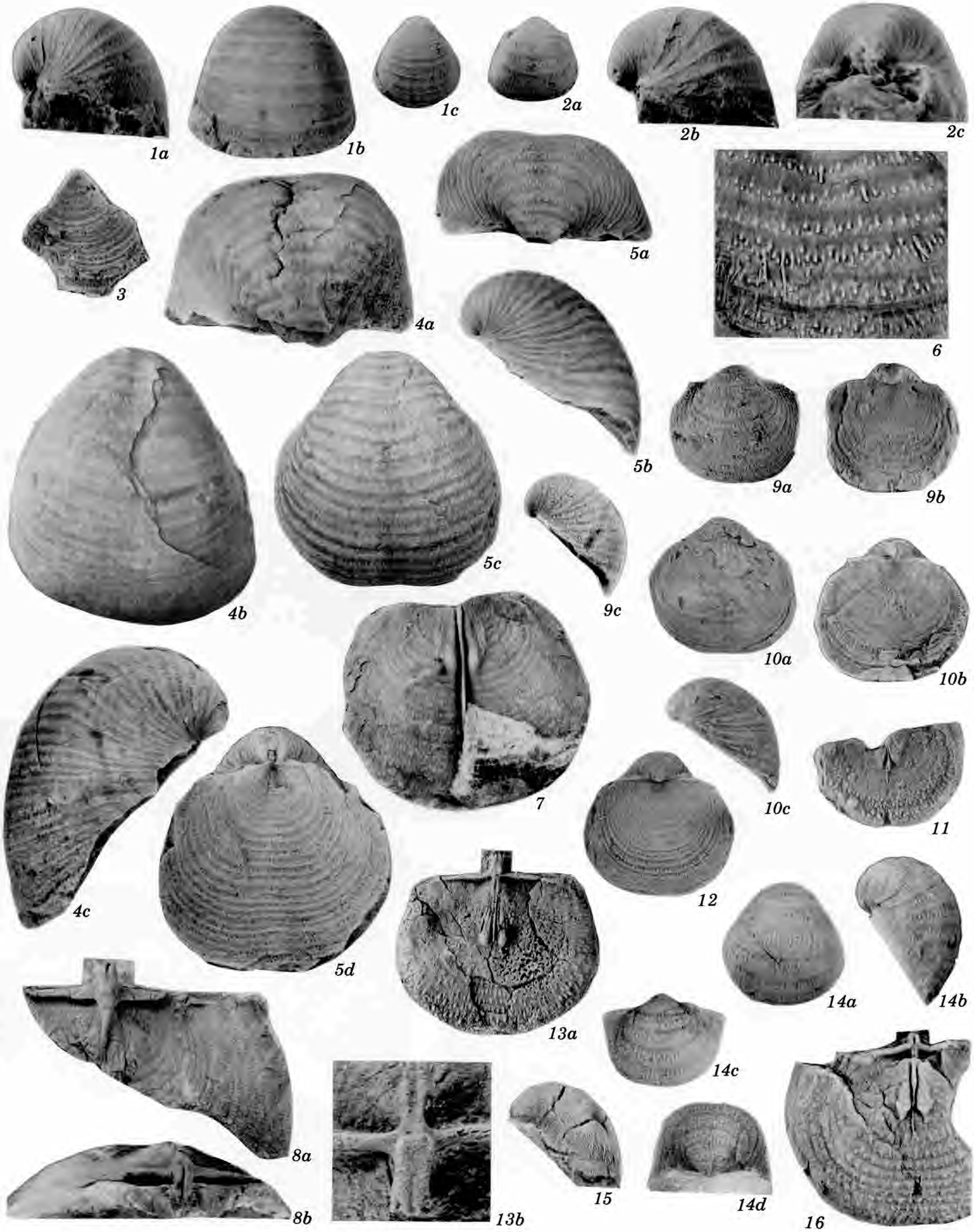
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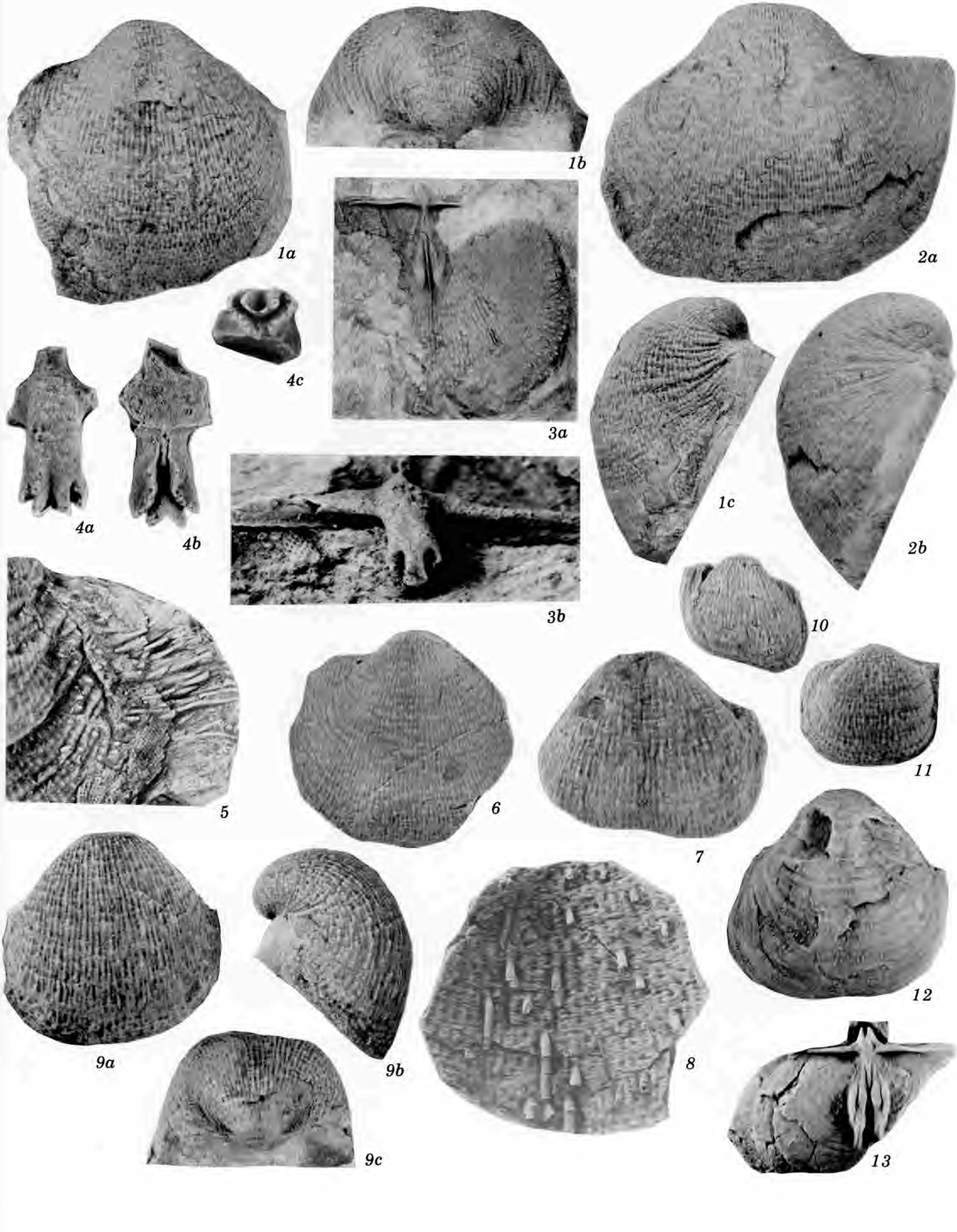

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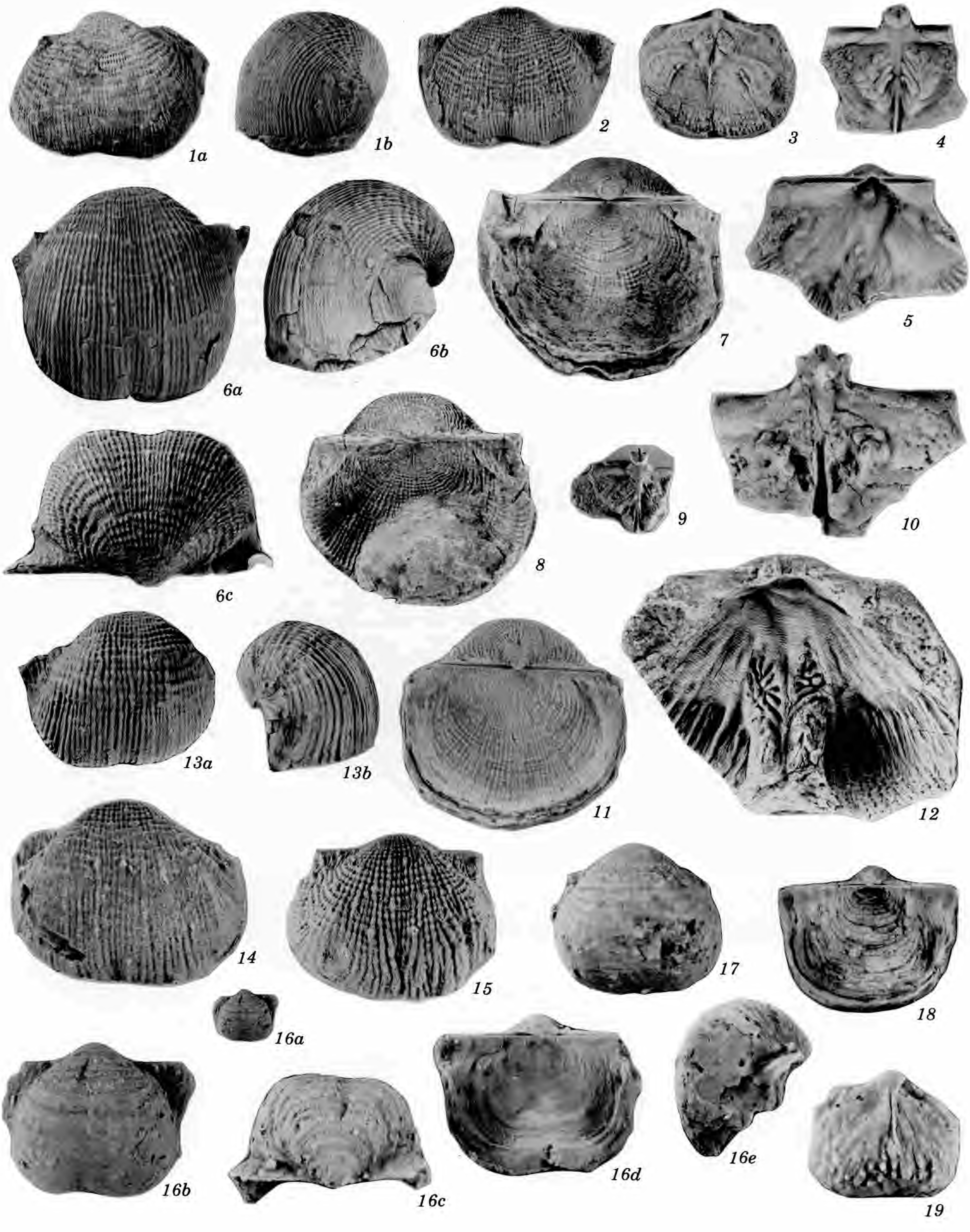
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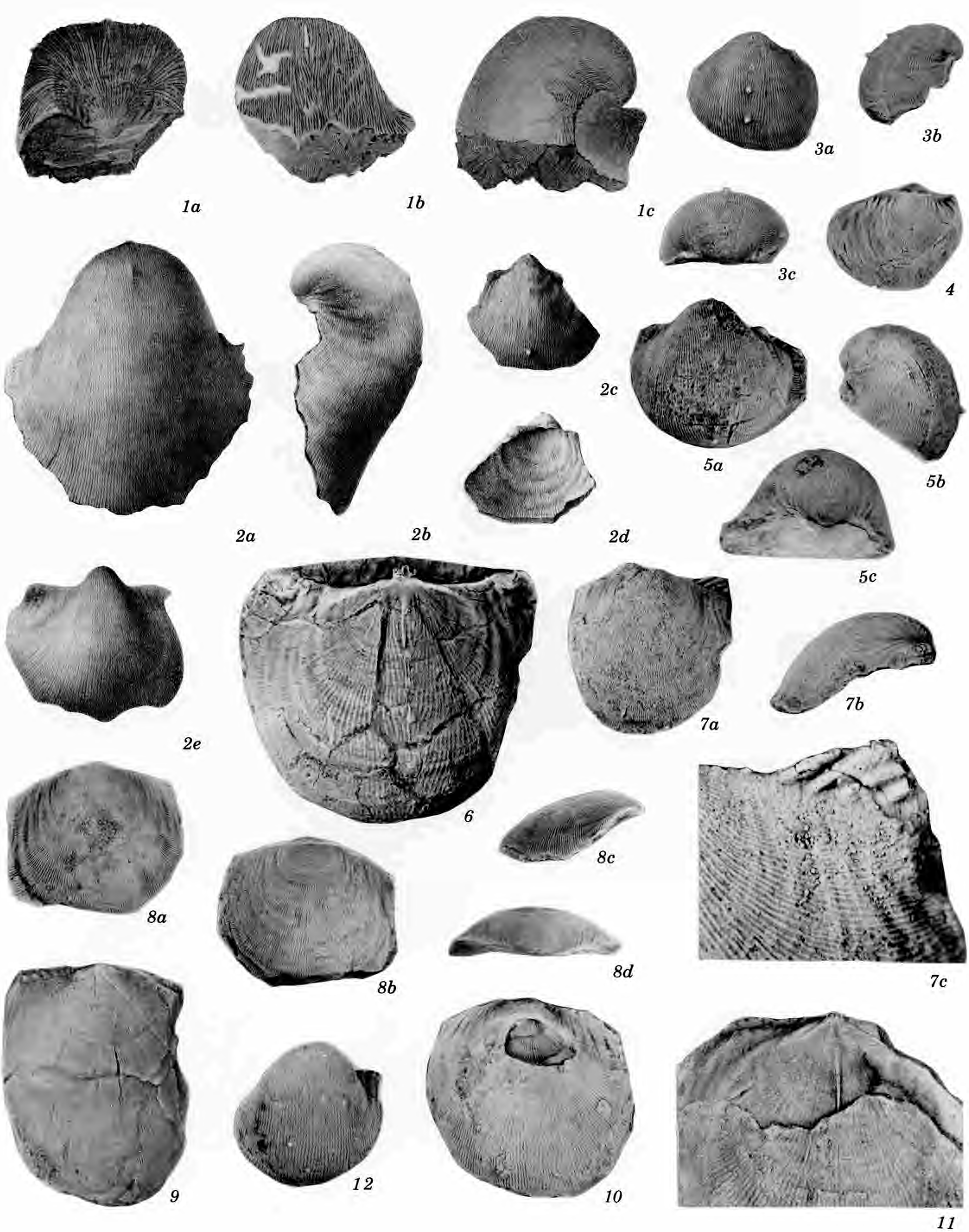
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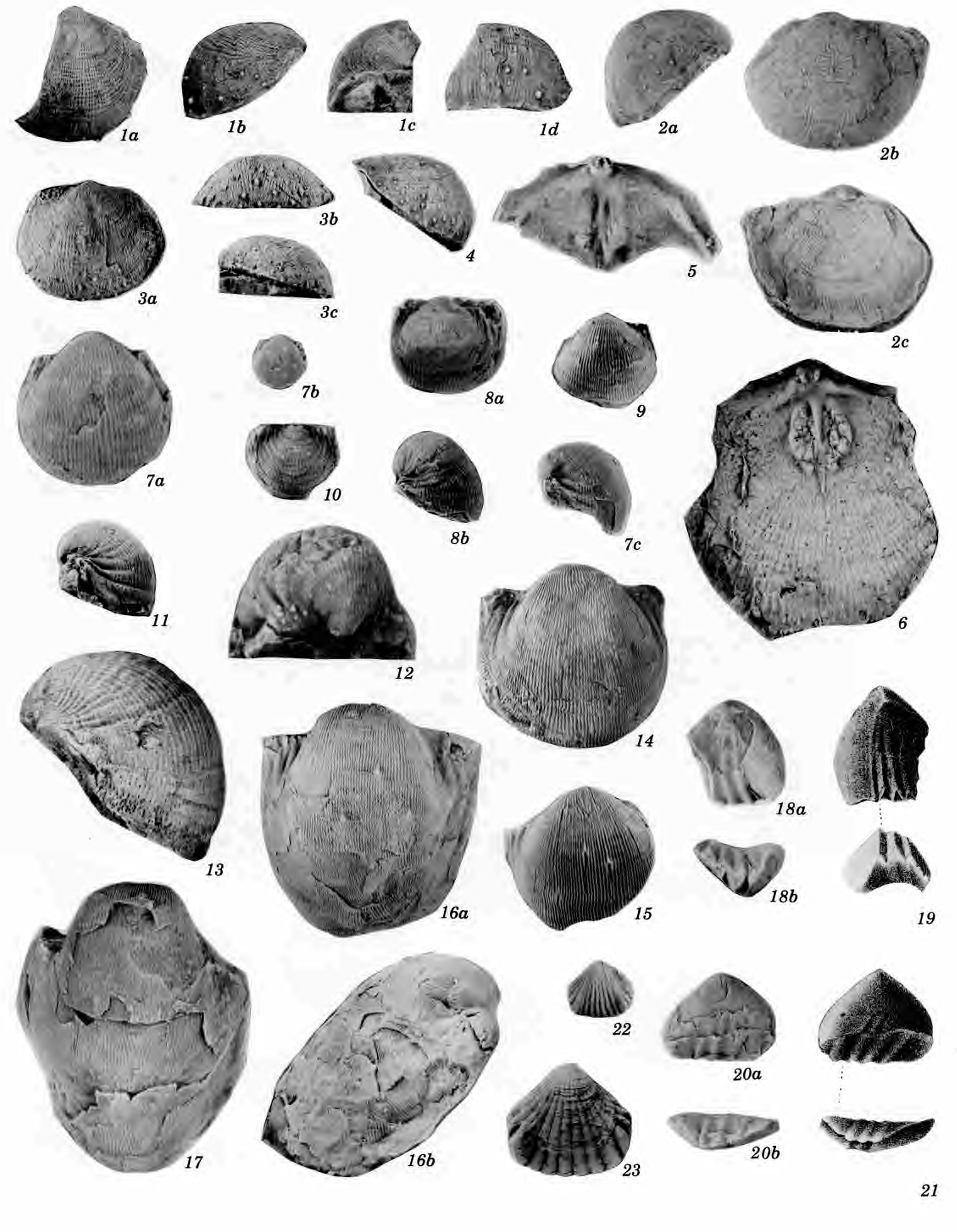
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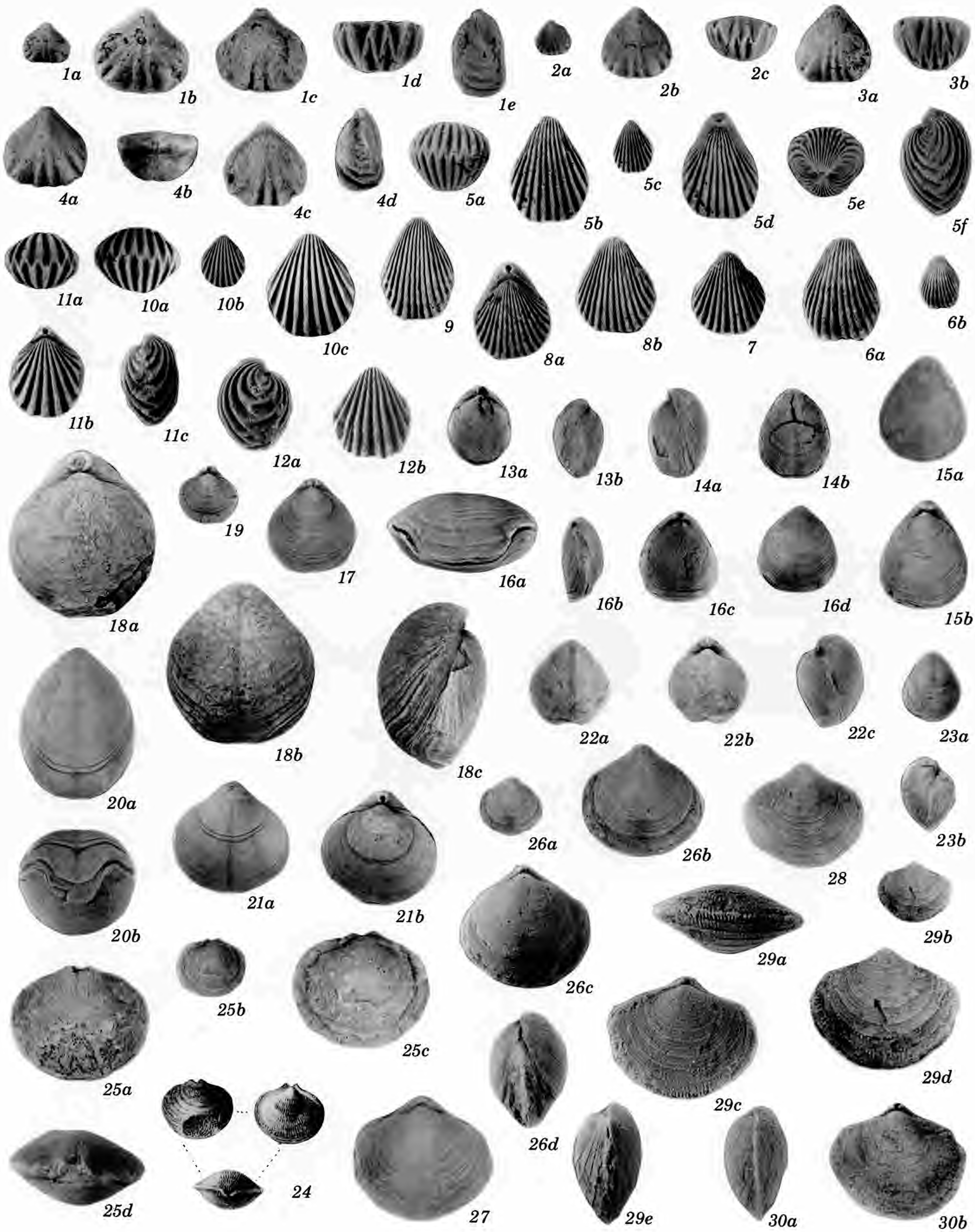
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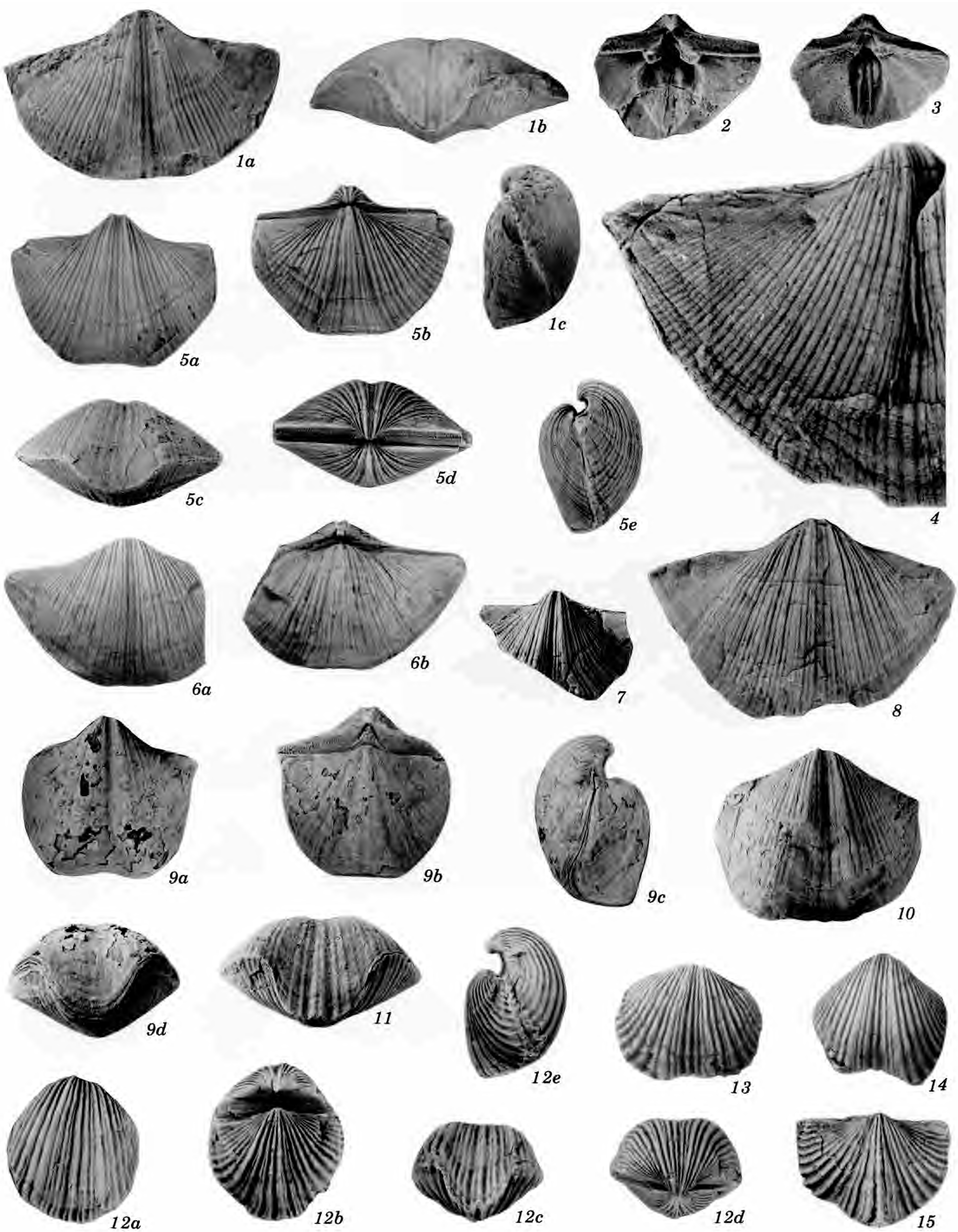
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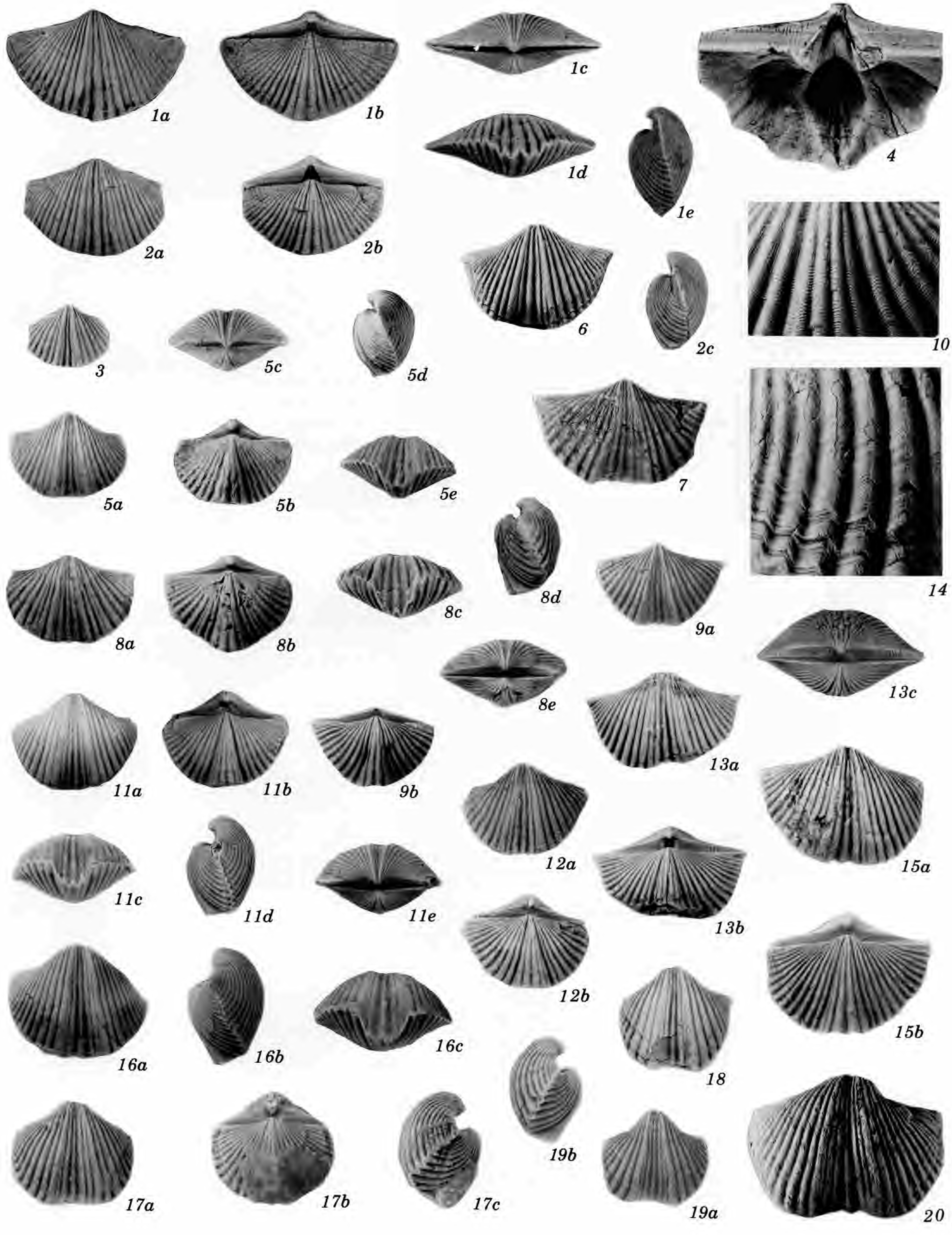

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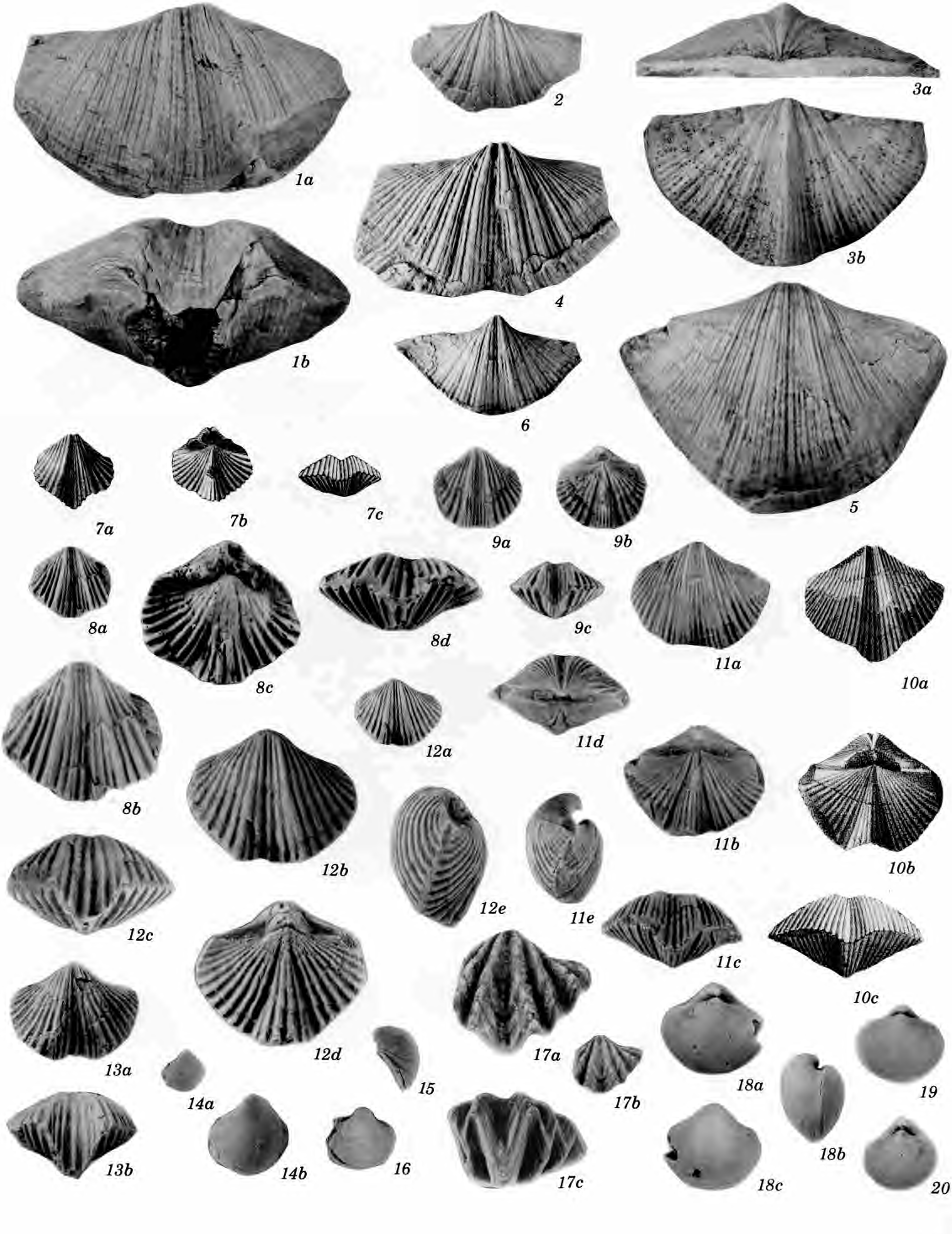
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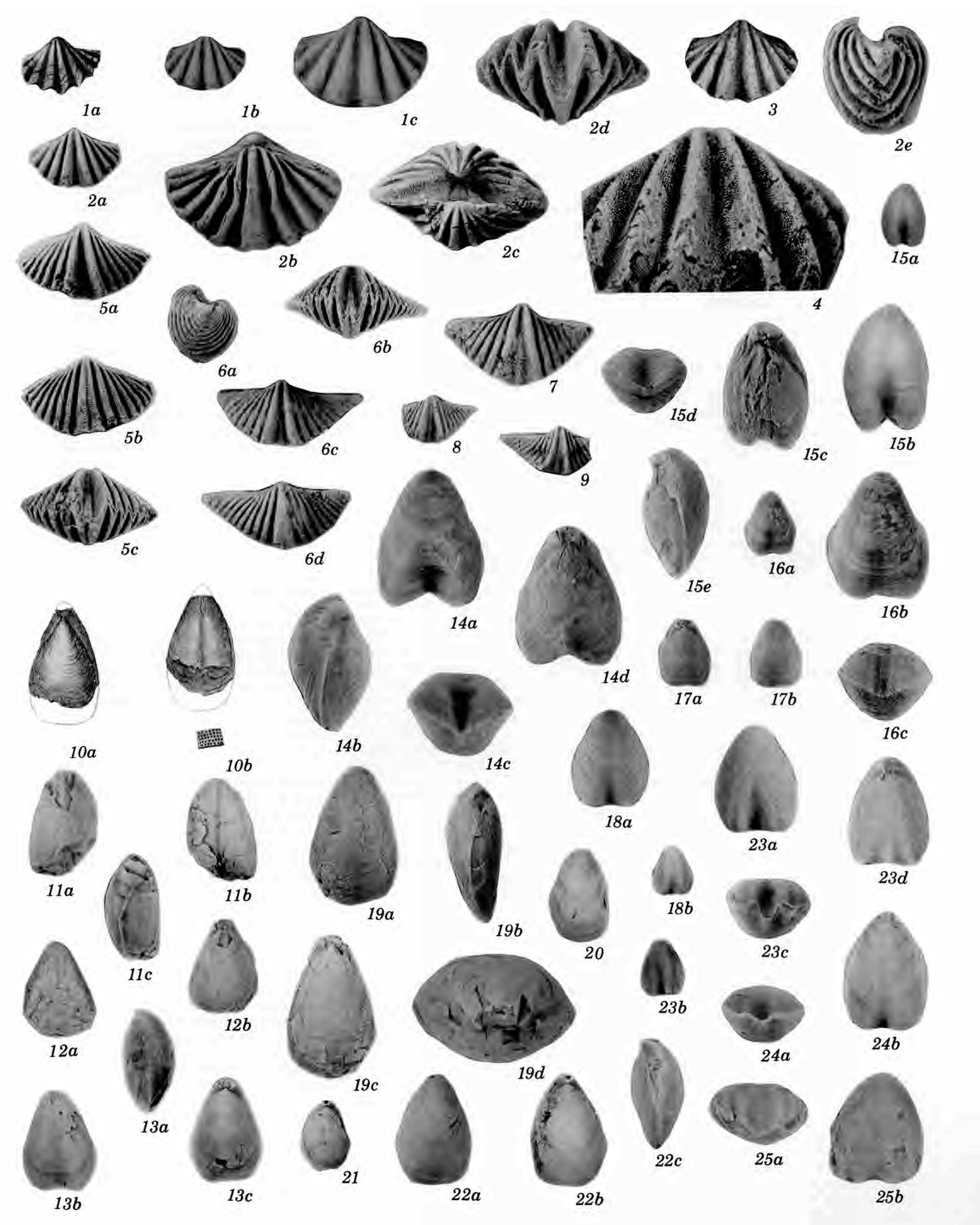
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Pocket Contents

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