MEMOIR 5

The Mississippian of West-Central New Mexico

By AUGUSTUS K. ARMSTRONG

1 9 5 8

STATE BUREAU OF MINES AND MINERAL RESOURCES NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

CAMPUS STATION **SOCORRO, NEW MEXICO**

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY E. J.
Workman, *President*

STATE BUREAU OF MINES AND MINERAL RESOURCES Alvin
J. Thompson, *Director*

THE REGENTS

MEMBERS EX OFFICIO

The Honorable Edwin L. Mechem .... *Governor of New Mexico*

Mrs. Georgia L. Lusk .... *Superintendent of Public Instruction*

APPOINTED MEMBERS

Robert W. Botts .... Albuquerque

Holm 0. Bursum, Jr. .... Socorro

Thomas M. Cramer .... Carlsbad

John N. Mathews, Jr. .... Socorro

Richard A. Matuszeski .... Albuquerque

Contents

Illustrations

Tables

Figures1

Abstract

Mississippian rocks were studied in detail in the Ladron, Lemitar, and Magdalena Mountains, and Coyote Hills, of west-central New Mexico.

The oldest Mississippian strata in this area belong to the Caloso formation, which contains a small brachiopod fauna suggestive of a Kinderhookian or lower Osagian age. The Caloso formation rests on a truncated igneous and metamorphic complex of Precambrian age. The base of the Caloso formation (o to 8 feet) consists of intergrading arkoses, sandstone, shales, and limestones. This is followed by about 30 feet of dark-gray fine-crystalline algal limestone.

The Caloso formation is overlain disconformably by the Kelly formation, which varies from o to 70 feet in thickness and is a light-tan to gray crinoidal limestone that contains a brachiopod and blastoid fauna of upper Osagian (Keokuk) age. The Kelly formation is overlain unconformably by the Sandia formation of Pennsylvanian age in the Lemitar and Magdalena Mountains. In the Ladron Mountains the Kelly and Caloso formations pinch out northward beneath the Sandia unconformity.

The brachiopod, blastoid, and coral fauna of the Kelly and Caloso formations are described and illustrated.

Introduction

GENERAL STATEMENT

This paper presents the results of faunal and stratigraphic studies of the Mississippian of west-central New Mexico. Exposures are limited largely to the Magdalena, Lemitar, and Ladron Mountains. From a regional viewpoint, the Mississippian strata of this region fill a gap between those of southern New Mexico, described by Laudon and Bowsher (1949), and those of northern New Mexico, described by Armstrong (1955). The region covered in the present report is indicated in Figure I.

From a stratigraphic viewpoint, the Mississippian of west-central New Mexico has proved somewhat anomalous in relation to either southern or northern New Mexico. The two formations in the region under discussion, the Caloso and the Kelly formations, are not typically developed in any section containing either the Arroyo Penasco formation of the north or the Caballero and Lake Valley formations of the south.

This report is concerned almost exclusively with the Mississippian strata present in the Magdalena, Lemitar, and Ladron Mountains. The Magdalena Mountains are a northward trending range with a maximum elevation of over 10,000 feet. They consist of tilted and faulted sedimentary and volcanic rocks on a Precambrian basement. The stratified rocks form the western slope of the range. The eastern side of the range consists mainly of Precambrian granite.

The Ladron Mountains are some 20 miles north of the Magdalena Mountains and are separated from them by a dissected pediment. The Ladron Mountains have an altitude of 9,200 feet and consist mainly of Precambrian metamorphic rocks. A large ridge or hogback, composed in part of Mississippian, but dominantly of Pennsylvanian and Permian rocks, is present on the western slope of the mountains.

The Lemitar (Socorro) Mountains are an east-facing, north-south-trending escarpment of predominantly Tertiary volcanic rocks. In the northern half of the mountains a small linear band of Precambrian, Mississippian, and Pennsylvanian rocks is exposed near the base of the scarp.

Access to all the areas in west-central New Mexico where the Mississippian rock can be studied and fossils collected is very difficult. In the Magdalena Mountains a bulldozer road, suitable for a jeep, was opened in the summer of 1956 from the town of Kelly to the crest of the range.

The Paleozoic section in the southern Ladron Mountains can be reached only by jeep or similar vehicle. Even so, access is still extremely difficult because of some 13 miles of rough terrain and deep sand.

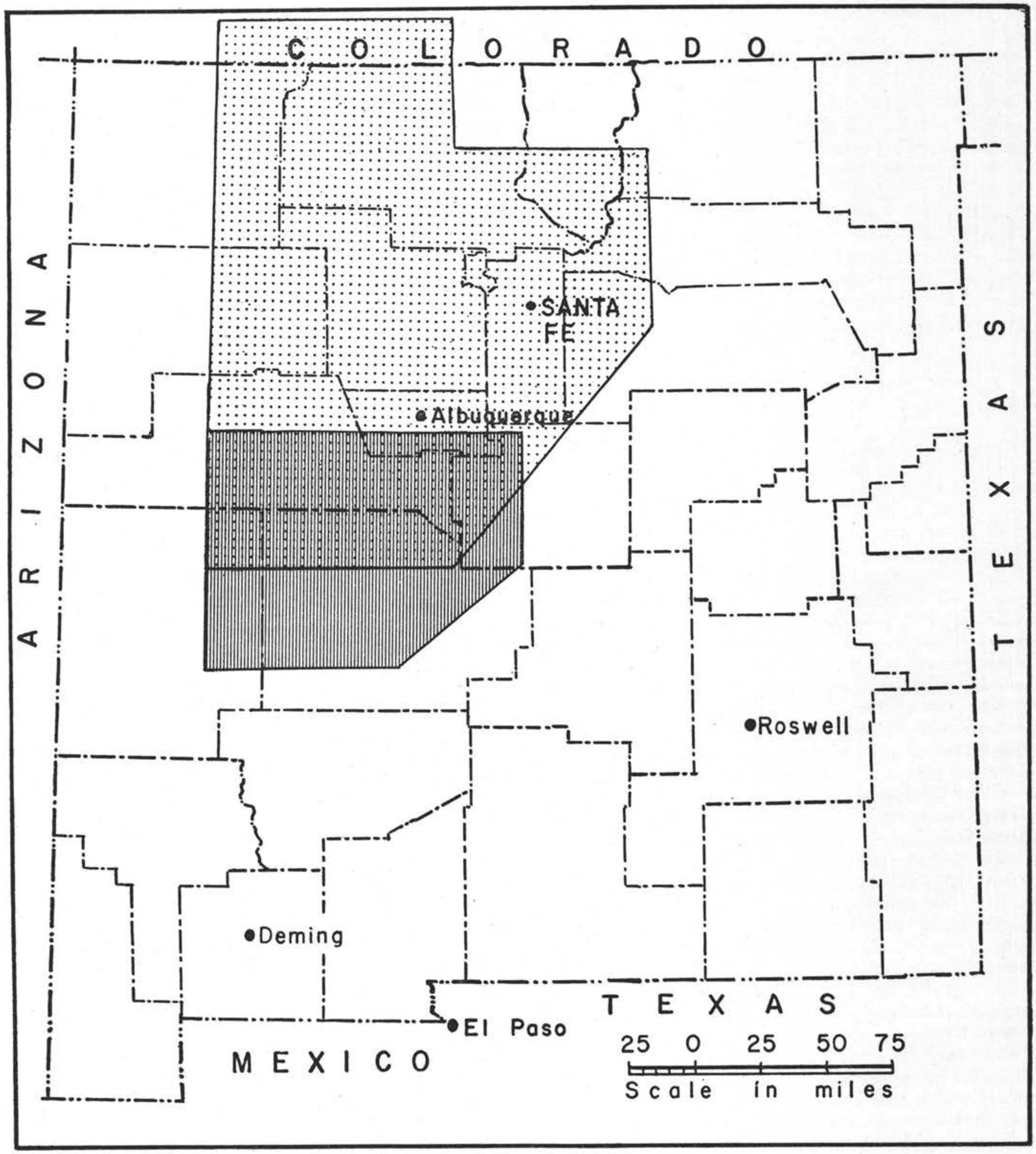
ACKNOWLEDGMENTS

The writer is greatly indebted to many individuals for their encouragement, support, and criticism of this paper. Appreciation is due the New Mexico Bureau of Mines and Mineral Resources, especially the former director, Dr. Eugene Callaghan, and the present director, Mr. A. J. Thompson, for financial support of the field work and publication of the completed study.

The writer is indebted to Dr. W. Jenks and the staff of the geology department of the University of Cincinnati. He is particularly grateful to Dr. K. E. Caster, who loaned many rare books from his personal library and gave much of his time in helping the writer to organize and write the original manuscript.

Adequate appreciation cannot be expressed to Dr. R. H. Flower, who originally suggested the research, accompanied and counseled the writer in the field, and freely helped and advised on paleontological matters, the writing of the final manuscript, and the photographing of the fossils.

Dr. Christina Lochman-Balk did the trilobite identification and inspected with the writer critical Mississippian sections in the Ladron and Magdalena Mountains. Dr. P. K. Sutherland, of the University of Oklahoma, helped the writer in the identification of the coral fauna. Dr. E. H. Kase, Jr. prepared the manuscript for publication.



Area in which Mississippian strata are considered in detail by this report.

Area in which Mississippian strata are considered in New Mexico Bureau of Mines and Mineral Resources Circular 39.

Figure 1

INDEX MAP SHOWING THE AREA COVERED BY THIS REPORT

Stratigraphy

GENERAL SUCCESSION

The Mississippian of west-central New Mexico consists of two recognized formations, the lower Caloso formation and, over it, the Kelly limestone. The geographic and stratigraphic relationships of the individual sections are shown in Figure 2. The Caloso formation consists of a lower, massive, rather fine-grained limestone, altered in many sections to a dolomite, with coarse basal elastics which vary in character and thickness from one section to another. The overlying Kelly formation varies from a coarsely crinoidal to a finely crystalline limestone. The Mississippian surface has been eroded, notably in the removal of the Kelly formation completely from some sections, particularly in the Coyote Hills at the southern end of the region under discussion, and in the Ladron Peak section and other sections farther to the north.

Age relationships of the formations have been determined necessarily from the faunal evidence. Neither formation has been found in juxtaposition with the Arroyo Penasco formation of northern New Mexico. In the southwest, beds tentatively identified with the Kelly by Laudon and Bowsher (1949) occur above the Tierra Blanca member of the Lake Valley. However, the extremely meager fauna obtained from these beds is insufficient to demonstrate their relationships; their identity with the Kelly formation remains little more than a suggestion.

The relatively large fauna yielded by the typical Kelly limestone indicates affinities with the Keokuk limestone of late Osage age. This fact restricts the possible age of the underlying Caloso formation to the Kinderhook and lower Osage. The Caloso formation has yielded a fauna of only a few species. Their affinities seem somewhat ambiguous, some suggesting a Kinderhook and others an early Osage age. It has nevertheless been considered significant to record the evidence now available and to point out that the Caloso fauna is not strikingly similar to that of the Caballero formation or to any of the faunules in members of the Lake Valley formation. The Caballero formation is recognized as of Kinderhook age; indeed, its fauna is reminiscent of that of the Chouteau limestone, whereas the Lake Valley formation is generally accepted as of early Osage age.

PREVIOUS WORK

The Mississippian section in the Magdalena Mountains originally was named the "Graphic-Kelly limestone" by Herrick (1904, p. 311), after the two leading mines of the district. The rocks later were renamed the Kelly limestone by Gordon (1907, p. 62-63), after the town of Kelly. In 1905, Lee collected Mississippian fossils on the south side of the Ladron Mountains; Girty identified these fossils as "Lower Mississippian" (Gordon, 1907, p. 58). Darton (1917, p. 50) believed the rocks exposed in the southern Ladron Mountains to be the most northern occurrence of the Mississippian in New Mexico. His list (p. 52) of Mississippian fossils identified by Girty from the southern Ladron Mountains included such typical Keokuk brachiopods as *Spirifer* aff. S. *logani* Hall, Spirifer aff. S. *tenuicostatus* Hall, and *Dimegelasma* aff. *D. neglectum* (Hall).

Loughlin and Koschmann (1942), in their study of the ore deposits of the Magdalena Mountains, collected a small lot of fossils at the base of the Mississippian section, near the contact with the Precambrian, and another at the top of the limestone. They gave two lists (p. 16) of fossils identified by Girty, who noted that "the two collections are markedly unlike, thus suggesting a marked difference in age." Girty went on to say that "the fauna of the Kelly limestone is rather strikingly different from the fauna of the (lower Osagian) Lake Valley limestone."

Laudon and Bowsher (1949, p. 15), after examining the Kelly formation in the Magdalena and Lemitar Mountains, reported fossils to be so scarce that they were unable to collect any for laboratory study. They tentatively considered some poorly preserved fragmental material to be of late Osage age. They did not examine the Mississippian rocks of the Ladron Mountains because of the difficulty of access.

Noble (195o, p. 38; Kelley and Silver, 1952, p. 86-87) proposed the name Caloso formation for the entire Mississippian section in the Ladron Mountains. Noble found a fauna near the base of his Caloso formation. The fossils were identified by S. A. Northrop (Kelley and Silver, p. 86), who ventured the opinion that the fauna of the Caloso formation is more closely related to that of the Escabrosa formation, of southeastern Arizona, than to the fauna of either the Caballero or Lake Valley formations, of southern New Mexico.

Armstrong (1955, p. 3o-33) divided the Mississippian rocks of the Ladron Mountains into two formations. He limited the Caloso formation to 3o to 4o feet of sandstones, shales, and algal limestone, which contains specimens identified by S. A. Northrop as *Dielasma chouteauensis* Weller and Spirifer *centronatus* Winchell. Armstrong (1955) identified the Kelly formation in the Ladron Mountains as the o to 6o feet of crinoidal limestone which rests disconformably upon the Caloso formation and unconformably below the shales and sandstones of the Pennsylvanian Sandia formation. He (1955, p. 33) suggested a possible lower Osage age for the Kelly formation. Further study of the fauna involved has demonstrated clearly that the Kelly formation is of Keokuk (upper Osage) age.

KELLY FORMATION

In the Magdalena, Lemitar, and Ladron Mountains, the Kelly formation is represented by o to 75 feet of limestone overlying the Caloso formation. The formation is gray, crinoidal, and medium crystalline, with white to light-gray chert. It disconformably overlies the dark-gray fine-crystalline algal Caloso limestones. The Kelly formation is unconformably overlain by the shales and sandstones of the Pennsylvanian Sandia formation. It is typically developed on the crest of the Magdalena Mountains, 2,200 feet south of Tip Top Mountain (NE1/4SW1/4 sec. 31, R. 3 W., T. 2 S.).

The brachiopod, blastoid, and endothyrid faunas indicate a Keokuk age for the Kelly formation. This development of the Kelly formation has yielded 18 species of brachiopods, belonging to 13 genera. *Tetracamera subcuneata* (Hall) is characteristic of the *Tetracamera* zone of the Mississippi Valley, which embraces beds ranging from Keokuk to Salem (Weller et al., 1948, p. 114). *Tetracamera* cf. T. *subtrigona*

(Meek and Worthen) is restricted in the Mississippi Valley to beds of Keokuk age. Spirifer *tenuicostatus* Hall is a Keokuk and Warsaw species and is not known to occur in lower Osage. *Dimegelasma neglectum* (Hall) is recorded from the Keokuk and Warsaw strata of the Mississippi Valley. The *Spirifer grimesi-S. logani* complex is indicative of a late Osage age. Five species of brachiopods, one of which is questioned, occur both in the Lake Valley formation and the Kelly formation. These five species in the type region of the Mississippian system have a long Osagian range (table 2). Certain very characteristic lower Osagian brachiopods, *Leptaenella analoga* (Phillips) and Spirifer *louisianensis* Rowley, which typify the Lake Valley formation, have not been found in the Kelly formation.

Orbitremites floweri, n. sp. is fairly abundant in the Kelly formation. The genus ranges in the eastern United States from the Kinderhook to possibly the St. Louis limestone, and appears to have had its maximum development in the Burlington beds. *Pentremites conoideus* Hall is present in the upper zo feet of the Kelly formation in the Ladron, Lemitar, and Magdalena Mountains. Galloway and Kaska (1957, p. 43) report that P. *conoideus* has a range from Keokuk to Ste. Genevieve time in the midcontinent.

Endothyrids are extremely rare in the Kelly formation. They are represented by a unique and characteristic type of *Plectogyra* sp. The individuals are about 0.4 to o.5 mm in diameter and show a collapsed condition in the final two chambers. Zeller (195o, p. 12, pl. 2, fig. *5,* 6, 8) observed that the collapse of the final two or three chambers of the endothyrid shells seems to be peculiar to Upper Osagian (Keokuk) species of the midcontinent region.

Zaphriphyllum casteri, n. sp. is the characteristic coral of the Kelly formation. Sutherland (1954, p. 363-365) described the genus *Zaphriphyllum* from the Northwest Territory, Canada, in rocks containing a fauna suggestive of Middle Mississippian age.

TABLE 1. FAUNA OF THE KELLY FORMATION OF THE MAGDALENA, LEMITAR, AND LADRON MOUNTAINS, NEW MEXICO

	MAGDALENA MOUNTAINS	LEMITAR MOUNTAINS	LADRON MOUNTAINS
Brachiopoda			
"Orthotetes?" sp.	×	×	×
Streptorhynchus? sp.	×	—	—
Rhipidomella sp.	×	×	×
Linoproductus sp.	×	×	×
Productus, sensu lato, several species	×	×	×
Echinoconchus? sp.	×	—	—
Chonetes cf. *illinoisensis*	—	—	×
Tetracamera cf. *subtrigona* (Meek and Worthen)	×	×	×
Tetracamera subcuneata (Hall)	×	×	×
Rhynchopora persinuata (Winchell)	—	—	×
Spirifer tenuicostatus Hall	×	×	×
Spirifer grimesi Hall	×	×	×
Spirifer? sp.	×	×	×
Spirifer? sp.	×	×	×
Brachythyris suborbicularis (Hall)	×	×	×
Athyris aff. *lamellosa* (Léveillé)	×	×	×
Cleiothyridina hirsuta (Hall)	×	×	×
Cleiothyridina? parvirostris (Meek and Worthen)	×	—	—
Cleiothyridina obmaxima (McChesney)	×	×	×
Dimegelasma neglectum (Hall)	—	×	×
Blastoidea			
Pentremites conoideus Hall	×	×	×
Orbitremites floweri, n. sp.	×	×	×
Mollusca			
Platyceras sp.	×	×	×
Straparolus spp.	×	×	×
Pelecypods, several genera	×	×	×
Coelenterata			
Zaphriphyllum casteri, n. sp.	×	×	×
Rare fragments of an indeterminable genus	×	×	×
Bryozoa			
Large fauna, unstudied	×	×	×
Arthropoda			
"Phillipsia" sp.	×	×	×
Vertebrata			
Shark's tooth	×	×	×
Protozoa			
Plectogyra sp.	×	×	×

REGIONAL CORRELATION

Laudon and Bowsher ([1]949, p. 15, 62-84) tentatively correlated the Kelly formation, of west-central New Mexico, with a sequence of tan to gray cherty relatively unfossiliferous crinoidal limestone which is exposed in southwestern New Mexico, in the Mimbres and Cooks Ranges and in the Silver City area. Their "Kelly formation" of southwestern New Mexico overlies the typical Lake Valley formation, with a possible slight disconformity, and is overlain, with a marked unconformity, by beds of Pennsylvanian age. Laudon and Bowsher made their correlation on the basis of the presence in both sequences of *Spirifer grimesi* Hall and on the ground of analogous lithology, particularly the similarity of chert nodules. Their correlation on the basis of the single species Spirifer *grimesi* Hall, which elsewhere ranges from the lower Burlington to the Keokuk, permits some doubt that the Kelly formation, which is apparently of Keokuk age in west-central New Mexico, is equivalent to all, or possibly even part of, the thick crinoidal limestone in the Mimbres and Cooks

TABLE 2. STRATIGRAPHIC RANGE OF KELLY FORMATION SPECIES IN NEW MEXICO AND OTHER AREAS

	NEW MEXICO *		ILLINOIS-IOWA-MISSOURI †				
	CABALLERO FM.	LAKE VALLEY FM.	FERN GLEN	L. BURLINGTON	U. BURLINGTON	KEOKUK	WARSAW
Chonetes illinoisensis? Worthen	×	×	×	×	×	×	×
Tetracamera subtrigona (Meek and Worthen)	—	—	—	—	—	×	—
Tetracamera subcuneata (Hall)	—	—	—	—	—	×	×
Rhynchopora persinuata (Winchell)	—	×	×	×	—	—	—
Spirifer grimesi Hall	—	?	—	×	×	×	—
Spirifer tenuicostatus Hall	—	—	—	—	—	×	×
Brachythyris suborbicularis (Hall)	—	×	?	×	×	×	×
Cleiothyridina? parvirostris (Meek and Worthen)	—	—	—	×	×	×	×
Cleiothyridina hirsuta (Hall)	—	—	—	—	?	—	×
Cleiothyridina obmaxima (McChesney)	—	×	×	×	?	×	—
Dimegelasma neglectum (Hall)	—	—	—	—	—	×	×
Pentremites conoideus Hall	—	—	—	—	—	—	×

* Laudon and Bowsher (1949).
† Moore (1928).

Ranges and the Silver City area. A detailed study of the paleontology of the "Kelly formation" of southwestern New Mexico will have to be made before it can be correlated with greater dependability with the type Kelly of west-central New Mexico.

From the small fossil collections and the reconnaissance studies in southern New Mexico, it now appears that the Mississippian seas in lower Osagian time began to transgress progressively northward onto the craton in New Mexico, and by Keokuk time had advanced to the latitude of the Ladron Mountains. In the Silver City area the more than 36o feet of the Mississippian limestone may prove to contain strata ranging in age from lower Burlington to Keokuk time.

Detailed examination of the Kelly formation in west-central New Mexico fails to show any marked lithological or faunal change. Thus, it seems safe to assume that the Kelly formation in the Ladron Mountains was not deposited close to the northern strand line. The Kelly formation, therefore, may have extended many miles northward. The present northward thinning and eventual pinchout of the Kelly formation north of Cerro Colorado, Ladron Mountains, is the result of pre-Sandia erosion (fig. 11).

CALOSO FORMATION

The term Caloso formation was proposed by Noble (195o; Kelley and Silver, 1952, p. 86-87) for the exposures of Mississippian rock in the Arroyo Caloso, Ladron Mountains, T. 2 N., R. 2 W. Armstrong (1955, p. 32-33) restricted the Caloso formation to the lower 3o to 4o feet of the Mississippian section in the Ladron Mountains.

The Caloso formation contains a pre-Tetracamera-zone fauna; therefore, a pre-Keokuk age is indicated. The formation is a sequence of basal sandstones, arkoses, and shales, followed by a series of gray fine-grained cherty, algal, and massive limestone. Similar massive beds at the bottom of the Mississippian section in the Lemitar and Magdalena Mountains and Coyote Hills were suspected as representing the Caloso formation in those regions. Collecting has yielded small faunas supporting this correlation.

The Caloso formation rests on a flat erosion surface of truncated Precambrian igneous and metamorphic rocks, and is overlain unconformably in the Magdalena and Lemitar Mountains and south of Cerro Colorado, in the Ladron Mountains, by the crinoidal Kelly formation of Keokuk (upper Osage) age. North of the northern end of Cerro Colorado, Ladron Mountains, the Caloso formation progressively wedges out and is overlain by the Sandia formation, of Pennsylvanian age. The fine-grained algal limestone of the Caloso formation contains a very meager fauna, consisting mainly of the brachiopods listed in Table 3.

TABLE 3. OCCURRENCE OF CALOSO BRACHIOPODS IN SOUTHERN NEW MEXICO, ILLINOIS, IOWA, AND MISSOURI

INDEX FOSSILS OF THE CALOSO FORMATION	NEW MEXICO*		ILLINOIS-IOWA-MISSOURI†				
	CABALLERO FM.	LAKE VALLEY FM.	KINDERHOOK	FERN GLEN	L. BURLINGTON	U. BURLINGTON	KEOKUK
Camarotoechia tuta (Miller)	×	×	×	—	×	—	×
Dielasma chouteauensis Weller	—	—	×	—	×	—	—
Spirifer centronatus ladronensis, n. subsp.	—	—	—	—	—	—	—
Spirifer louisianensis Rowley	×	×	×	—	×	—	—

* Laudon and Bowsher (1949).
† Moore (1928).

REGIONAL CORRELATION

The age and correlation of the Caloso formation are perplexing problems because of the poverty of its fauna. Northrop (Kelley and Silver, 1952, p. 86-87), on the basis of the presence of *Dielasma chouteauensis* Weller, *Straparolus luxus* (White), and *Spirifer centronatus* Winchell, from the Ladron Mountains, finds in the Caloso fauna suggestions of Kinderhookian age and possible affinities with the Escabrosa limestone of Arizona.

The fossils which the writer collected from the Caloso formation in the Magdalena, Lemitar, and Ladron Mountains add little to the meager knowledge of its regional setting. *Spirifer centronatus* Winchell is a member of a large and relatively diversified group of western Mississippian Spirifers which have been masked in the literature under the name *Spirifer centronatus,* sensu lato. S. *centronatus* was described originally from the Cuyahoga formation of northern Ohio. It is rare in the Central States. In New Mexico its only known occurrence is in the Caloso formation, where a geographic subspecies, *Spirifer centronatus ladronensis,* occurs. In the Western States, Spirifer *centronatus,* sensu lato, occurs abundantly in the Madison, Redwall, and Escabrosa formations. The western stratigraphic range of S. *centronatus,* sensu lato, is from Kinderhook to Meramec or younger (Palmer et al., 1956, p. 34). Although the range of S. *centronatus ladronensis* probably is much more restricted, its proper limits are unknown.

The other three species combine to suggest Caballero and Lake Valley affinities, although the association is typical of neither. Data on the vertical range of the Caloso brachiopods is taken from Moore (1928).

TABLE 4. FOSSILS FROM THE CALOSO FORMATION, COYOTE HILLS AND MAGDALENA, LEMITAR, AND LADRON MOUNTAINS, NEW MEXICO

	COYOTE HILLS	MAGDALENA MOUNTAINS	LEMITAR MOUNTAINS	LADRON MOUNTAINS
BRACHIOPODA				
Schuchertella? sp.	—	×	—	—
Camarotoechia tuta (Miller)	×	×	×	—
Rhynchotreta? sp.	—	×	—	—
Dielasma chouteauensis Weller	—	—	?	×
Spirifer louisianensis Rowley	—	×	—	—
Spirifer centronatus ladronensis, n. subsp.	—	?	—	×
Composita? sp.	—	×	—	—
Syringothyris? sp.	×	×	—	—
Streptorhynchus? sp.	—	×	—	—
MOLLUSCA				
Conocardium sp.	—	—	—	×
Pelecypods, several genera	×	×	—	×
Straparolus luxus (White)	×	?	—	×
COELENTERATA				
Michelinia sp.	—	×	—	—
Aulopora sp.	—	×	×	—
Cyathophyllum? sp.	—	×	×	×

The Kelly formation, which lies disconformably above the Caloso formation, contains the genus *Tetracamera,* which is restricted in range in the Mississippi Valley from Keokuk to Spergen time (Weller et al., 1948, p. 115). The absence of *Tetracamera* in the Caloso formation is not in itself conclusive evidence of an appreciably older age than the Kelly formation. The Caloso formation contains, however, a number of pre-Tetracamera-zone species, suggesting in part a Kinderhookian and in part a lower Osagian age. Affinities are not close with either the Kinderhookian Caballero formation or the lower Osagian Lake Valley formation of southern New Mexico.

From the lack of clastic material in the upper limestones of the Caloso formation, it appears either that the Mississippian setting was far from shore or that New Mexico had very little relief at that time. Armstrong (1955, p. 3o) called attention to the presence of a limestone remnant of pre-Sandia age 44 miles northeast of Ladron Peak, on Bosque Peak, in the Manzano Mountains (NW1/4NE1/4 sec. 4, T. 6 N., R. 5 E.). Twenty-one feet of fine-grained brown dolomitic limestone, arenaceous in the lower half, rests on Precambrian granitic gneiss and is overlain unconformably by massive sandstones of the Sandia formation. Although this limestone has not yielded fossils, it is remarkably similar in lithology to the distinctive lower limestones of the Caloso formation in the Lemitar and Ladron Mountains.

DISCUSSION OF LOCAL AREAS

MAGDALENA MOUNTAINS

At the northern end of the Magdalena Mountains,[1] Mississippian rocks are exposed almost continuously for nearly 4 miles in two narrow, sinuous bands (pl. 5, fig. 8). The band which follows the crest of the range affords good lateral and vertical exposures of the Mississippian strata, thus offering an excellent opportunity to study the contact of the Mississippian with both the Precambrian and the Pennsylvanian Sandia formation.

Caloso Formation

The oldest Paleozoic rocks in the Magdalena Mountains belong to the Mississippian Caloso formation, which rests on an even surface of truncated Precambrian igneous and metamorphic rocks (fig. 5). The basal bed of the Caloso formation shows rapid facies changes in a distance of a few hundred yards.

The basal bed is 2 to 8 feet thick and is characterized by rounded and angular Precambrian pebbles of quartz, granite, greenschist, and epidote, up to 4 inches in diameter. The basal bed is at one exposure a quartz sandstone, elsewhere an arkose or a shale, and in places an arenaceous to arkosic medium-crystalline gray to green fossiliferous limestone.

The arkosic limestone is of particular interest, for it has produced all but one of the fossils collected from the Caloso formation in the Magdalena Mountains. This horizon has yielded very poorly preserved bryozoans, crinoid stems, pelecypods, gastropods, and brachiopods, of which *Spirifer louisianensis* Rowley, a possible Spirifer *centronatus ladronensis,* n. subsp., *Camarotoechia tuta* (Miller), *Schuchertella?* sp., and *Camposita?* sp. have been identified.

Above the basal bed there is generally some 10 to 15 feet of very fine-grained arenaceous gray to brown algal limestone, with thin lenses of clear quartz sand and gray shale. The higher beds of the Caloso formation are 18 to 22 feet of pure fine-grained massive dark-gray to brown algal limestone. The unconformity between the top of the Caloso formation and the Kelly formation is marked by a gently undulating surface and a zone of clean disseminated sand z to 6 inches thick, which fills the slightly irregular erosion surface at the top of the Caloso formation (pl. 5, fig. 9).

Kelly Formation

The Kelly formation is a medium-bedded gray to light-brown crinoidal limestone which contains white nodular chert (fig. 6). The lower 7 to 12 feet of the Kelly formation is a crinoidal limestone with a thin, clean quartz sand at its base. Above this crinoidal unit is a zone, some 6 to 10 feet thick, of lithographic to fine-crystalline argillaceous dark-gray to light-gray dolomitic limestone. Individual beds range from a few inches to z or more feet in thickness. This distinctive horizon marker is recognized in the Magdalena Mountains by miners, who refer to it as the "silver pipe" (Loughlin and Koschmann, 1942, p. 15). Above the "silver pipe" there is 5o to 7o feet of medium-bedded light-gray to light-brown crinoidal limestone which contains large lenticular masses of white to light-gray chert. The highest 5 to 8 feet of the Kelly formation becomes progressively finer grained and thinner bedded. Fenestellid bryozoans are abundant in this highest unit.

The unconformity between the Kelly formation and the Sandia formation has possibly 3o feet of relief. The top of the Kelly formation is marked by numerous broad and shallow pre-Sandia stream channels filled with shale and angular pebbles of chert derived from the Kelly formation.

The base of the Sandia formation is marked by 1 to 6 feet of red, green, and purple ferruginous shales. This is followed by the typical coarse-grained to conglomeratic calcareous to siliceous crossbedded sandstone of the Sandia formation, which contains numerous specimens of *Lepidodendron.*

From Tip Top Mountain southward, the Kelly formation has been silicified extensively as the result of the emplacement in the Magdalena Mountains of a Tertiary(?) granite. Silification is most persistent in the beds above the "silver pipe," but in a few places, particularly in the southeastern Mississippian exposures, the entire thickness of the Kelly and Caloso formations is silicified. The silicification is of such intensity that where it has taken place the fossils are obliterated.

LEMITAR MOUNTAINS

Mississippian strata in the Lemitar Mountains are exposed in a linear belt for about a mile north and south of Corkscrew Canyon (pl. 6, fig. 1). The best exposures occur in the first two deep arroyos south of this canyon. The beds dip to the west at a high angle, which in places approaches the vertical. Because of the lack of bedding-plane exposures, fossil collecting is difficult, particularly in the Kelly formation.

Caloso Formation

The Caloso formation averages about 38 feet thick. Half a mile south of Corkscrew Canyon, the basal bed of the Caloso formation is 1 foot of green shale resting on truncated Precambrian greenschist. About a mile north of Corkscrew Canyon, near Polvadera Peak, the basal bed of the Caloso

1. An excellent geologic map of the Magdalena Mountains can be found in Loughlin and Koschmann (1942).

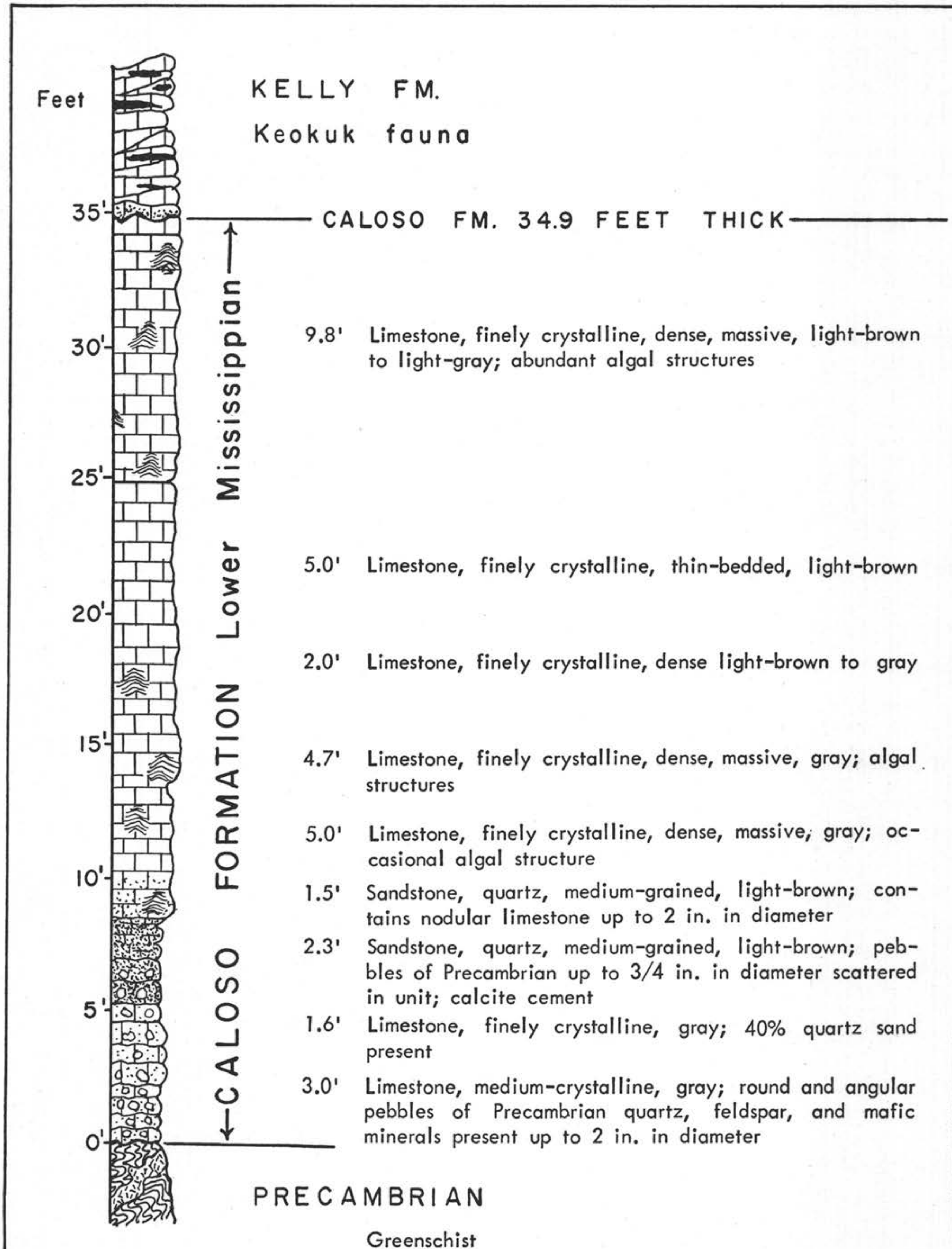


Figure 3

CALOSO FORMATION, MAGDALENA MOUNTAINS
NE¼SW¼ sec. 31, R. 3 W., T. 2 S.

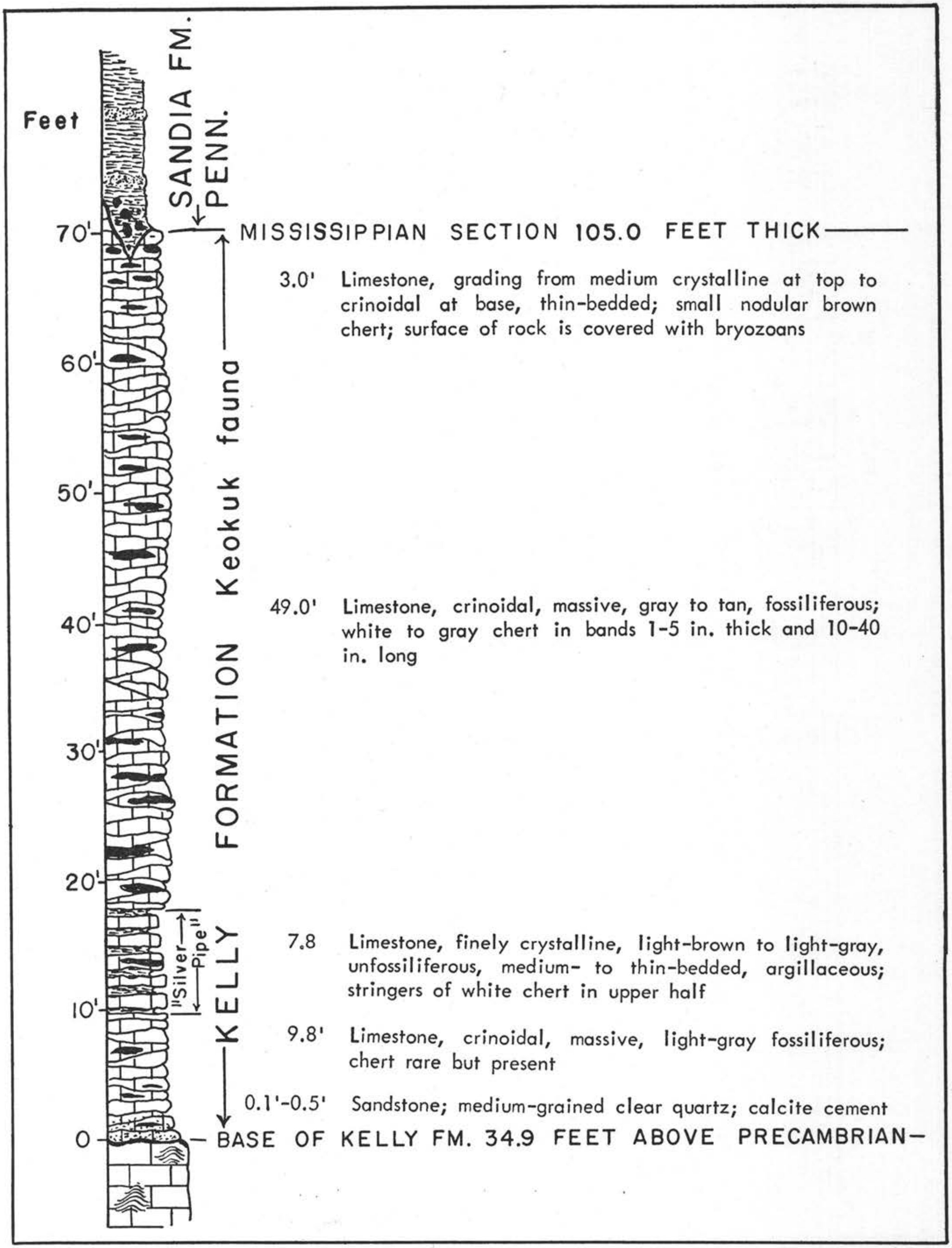


Figure 4

KELLY FORMATION, MAGDALENA MOUNTAINS
NE¼SW¼ sec. 31, R. 3 W., T. 2 S.

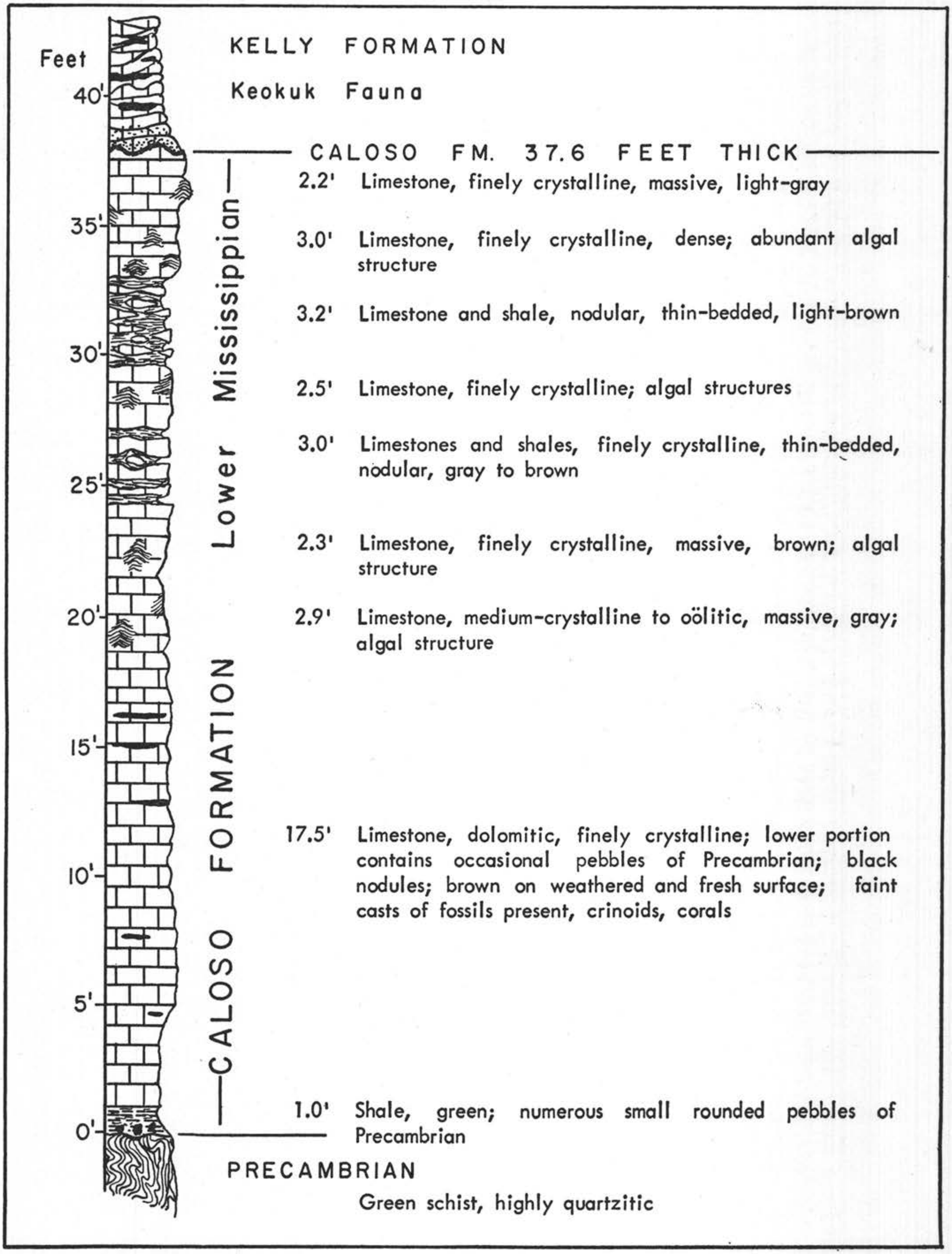


Figure 5

Caloso formation, Corkscrew Canyon, Lemitar Mountains

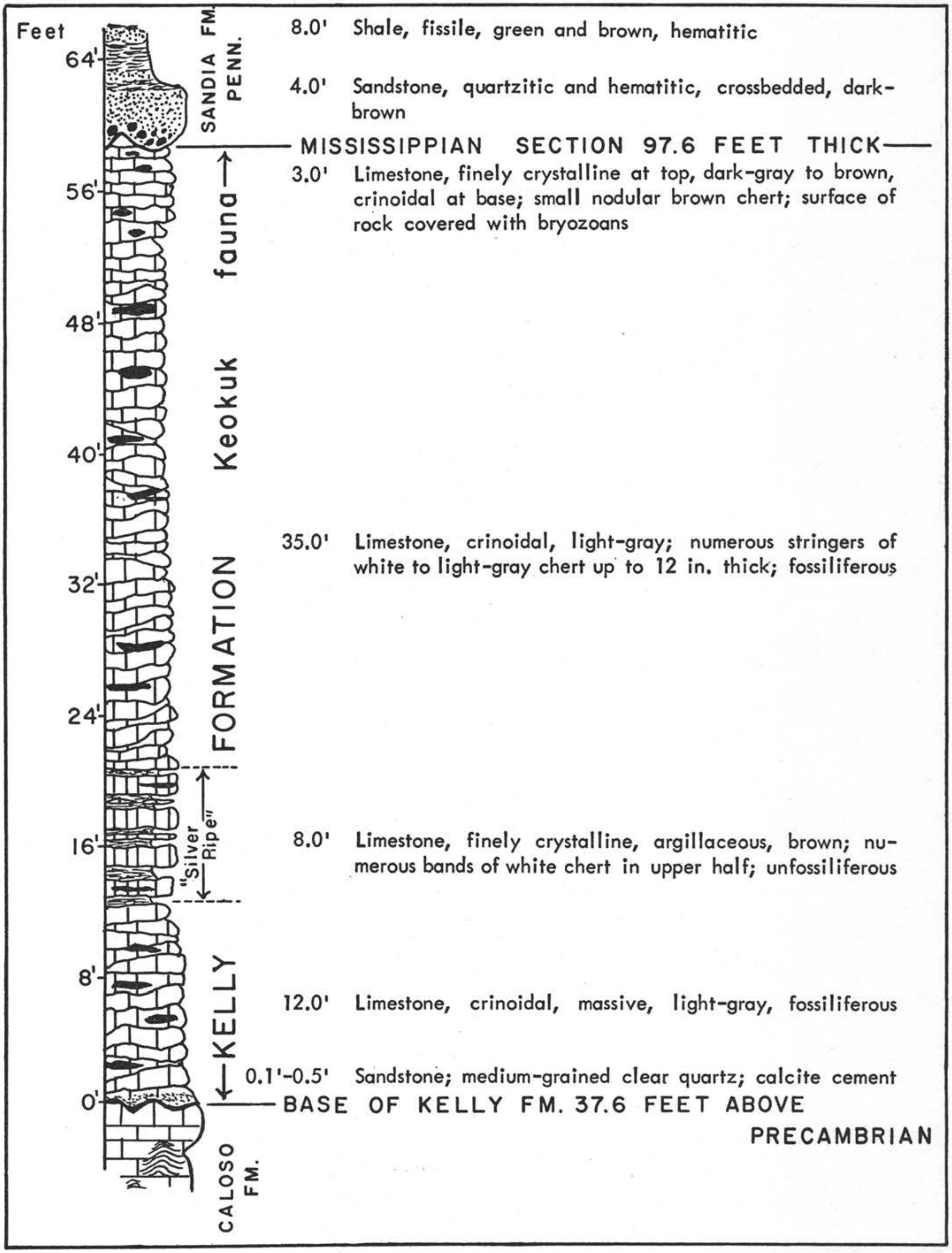


Figure 6
KELLY FORMATION, CORKSCREW CANYON, LEMITAR MOUNTAINS

formation is 3 feet of medium-grained white quartz sandstone resting on truncated Precambrian granitic gneiss. At both locations the basal bed is followed by 17 feet of massive brown fine-crystalline arenaceous dolomitic limestone. Above this is about 19 feet of fine-grained gray algal limestones and thin-bedded gray shales. A single, silicified *Camarotoechia tuta* (Miller), several very poorly preserved and questionable specimens of *Dielasma chouteauensis* Weller, a poorly preserved tetracoral, and several silicified colonies of *Aulopora* sp. were collected from the lower brown dolomitic limestone.

Kelly Formation

The unconformity between the Caloso formation and the Kelly formation is marked by a slightly irregular surface and a 1- to 6-inch zone of medium-grained disseminated quartz sand which grades vertically into the crinoidal limestones of the Kelly formation. The latter can be divided into three units (fig. 8). The lowest of these is 12 feet thick and consists of light-gray crinoidal limestone, with occasional bands of white chert; it lies unconformably above the Caloso formation. Above this unit is an 8-foot bed of fine-grained dolomitic limestone composed of smaller beds, 2 to 3 feet thick, with interbedded gray shale. In the Lemitar Mountains this fine-crystalline argillaceous dolomitic limestone is lithologically very similar to, and occurs at the same stratigraphic position as, the "silver pipe" horizon of the Kelly formation in the Magdalena Mountains.

The upper part of the Kelly formation in the Lemitar Mountains consists of 38 feet of crinoidal to medium-crystalline limestone, with thick bands of white to light-gray chert. The highest 3 to 5 feet of the Kelly formation becomes progressively less crinoidal, finer crystalline, thinner bedded, and darker gray. These uppermost limestones contain numerous bryozoans and occasional crushed blastoid thecas. The Sandia formation unconformably overlies the Kelly formation with a marked unconformity. The basal bed of the Sandia formation is a crossbedded coarse hematitic sandstone.

LADRON MOUNTAINS

Mississippian strata are exposed in a continuous north-south outcrop, 4.4 miles long, in the southern Ladron Mountains[2] (pl. 6, fig. 2, 3, 4). The Mississippian is well exposed from north of the Rio Salado (fig. 11) northward to where it is faulted against Pennsylvanian strata near Ladron Peak. The most northerly known exposure of definite lower Mississippian rocks in New Mexico is 2 miles north of Ladron Peak, or 2 miles south of Navajo Gap. There a small synclinal erosional remnant of the Caloso formation is preserved between Precambrian granitic gneiss and the basal beds of the Sandia formation. The Mississippian strata at the southernmost exposures near the Rio Salado are about 90 feet thick. They were beveled progressively northward by pre-Sandia erosion (fig. 11). Near Ladron Peak about 45 feet of Mississippian strata escaped erosion, whereas a mile north of Ladron Peak no such strata are present except for the synclinal remnant 2 miles south of Navajo Gap. Excellent exposures of the pre-Sandia folding and erosion surface are preserved in the Mississippian section at the base of the Paleozoic hogback southwest of the north end of Cerro Colorado. This fold and the pre-Sandia stream channels are shown in Figure 12. Neither the Kelly nor the Caloso formation shows any evidence at its most northerly outcrop of proximity to a strand line.

z. The only known and reliable geologic map of the southern Ladron Mountains is provided by Noble (195o).

Caloso Formation

The basal bed of the Caloso formation is 2 to 4 feet thick and rests on the Precambrian. This basal bed displays a progressive lithologic change northward from the Rio Salado to the pre-Sandia outlier north of Ladron Peak. It changes from an arkose which rests on Precambrian gneiss, near the Rio Salado, to a dirty, impure medium-grained brown sandstone which rests on greenschist, north of Cerro Colorado. It is a pure white quartzitic conglomerate which rests on granitic gneiss in the pre-Sandia outlier north of Ladron Peak.

Above the basal sandstone and arkose there is an indefinite zone of 5 to 8 feet of alternating and intergrading arenaceous and argillaceous algal limestones, gray shales, and thin quartz sandstones. This is followed by fine-bedded massive slightly algal dark-gray dolomitic limestone. This zone carries long stringers of black to dark-gray chert. Due east of the north end of Cerro Colorado this chert is abundantly fossiliferous, with *Spirifer centronatus ladronensis*, n. subsp., *Dielasma chouteauensis* Weller, *Straparolus luxus* White, *Conocardium* sp., and fragments of various genera of pelecypods.

Kelly Formation

The unconformity between the fine-grained Caloso formation and the light-gray crinoidal Kelly formation is marked by a slightly irregular surface filled with 1 to 6 inches of clean rounded medium-grained quartz sand which intergrades vertically into the crinoidal limestone of the Kelly formation. At its maximum development in the Ladron Mountains, the Kelly formation is about 5o feet thick and consists of predominantly crinoidal, but occasionally medium-crystalline, fossiliferous light-gray to light-brown limestone, which carries large bands of white to light-gray nodular chert. In the Ladron Mountains the "silver pipe" facies of the Kelly formation is absent. At a horizon some 45 feet above the Caloso formation, the limestone becomes progressively thinner bedded and finer grained, with brown chert. The fauna of the Kelly formation in the Ladron Mountains is relatively large in the number of individuals and the diversity of species. Fragments of brachiopods are very abundant, but identifiable individuals are rare (see table I). Bryozoans and *Pentremites conoideus* Hall are present in the upper fine-crystalline limestones. Abundant specimens of the tetracoral species Zaphri*phyllum casteri*, n. sp. have been collected from the section. Large gastropods of several genera, and an occasional trilobite, *"Phillipsia"* sp., have been found. Blastoids are generally rare, and complete crinoid calyxes are very rare.

Three miles north of the Rio Salado, the Kelly formation is truncated sharply by pre-Sandia (Lower Pennsylvanian) erosion. Four miles north of the Rio Salado, the Kelly formation is removed completely by pre-Sandia erosion; it is not known north of this point in New Mexico (fig. 9). The unconformity between the Kelly and Sandia formations is marked by considerable relief. Numerous, deep pre-Sandia stream channels are filled with black and brown clays and cobbles of Mississippian chert and limestone. In most exposures the unconformity between the two systems is marked by a few tens of feet of red to black shales, followed by typical coarse crossbedded sandstones of the Sandia formation.

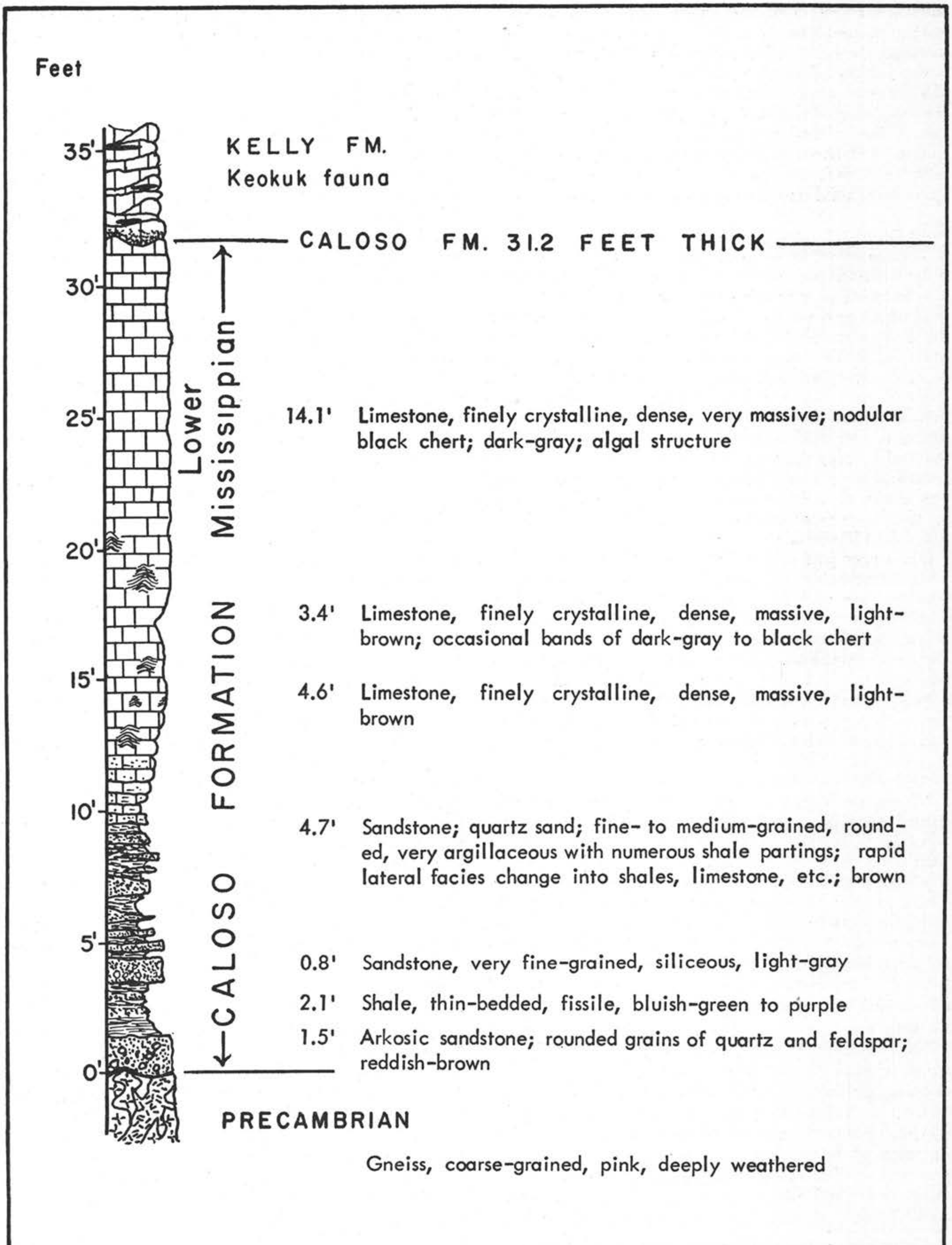


Figure 7

Caloso formation, Ladron Mountains

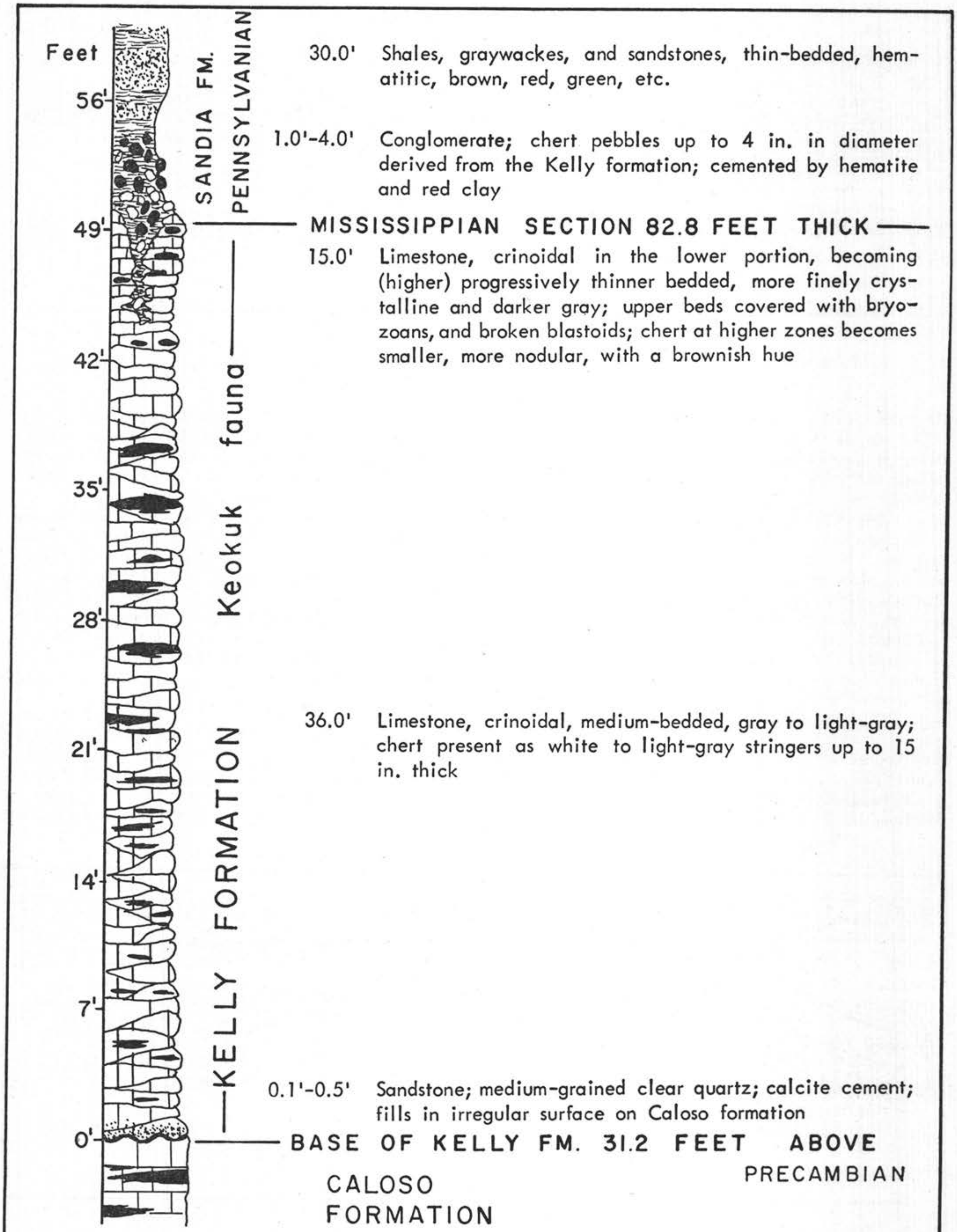


Figure 8

Kelly formation, Ladron Mountains

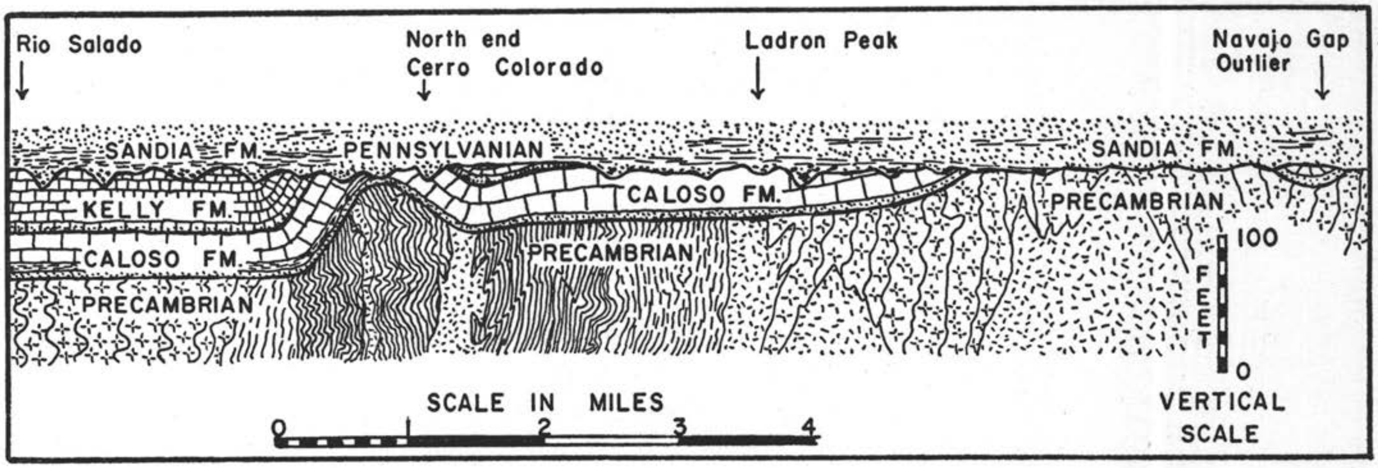


Figure 9

EROSIONAL PINCHOUT OF MISSISSIPPIAN STRATA NORTHWARD FROM THE RIO SALADO TO NAVAJO GAP

COYOTE HILLS

Due east of the Bosque del Apache Fish and Wildlife Refuge in the Coyote Hills, at longitude 33°30'30" N. and latitude I06° 56' W., is a small east-west-trending fault block exposing Precambrian granite, metamorphic rocks, and the Mississippian Caloso formation. The Caloso formation ranges in thickness from o to 36 feet. The Kelly formation apparently was removed previous to the extrusion of the Tertiary volcanics. In some of the deep pre-Tertiary volcanic stream channels in the Caloso formation, there are large angular boulders of Kelly limestone and chert.

The basal unit of the Caloso formation is a 3- to 5-foot bed of massive crossbedded white siliceous sandstone to conglomeratic arkose. This unit is lithologically very similar to the same horizon in the Lemitar and Ladron Mountains. In this basal dolomitic limestone are small lenticular black chert nodules, which in places contain abundant, poorly preserved pelecypods and an occasional *Straparolus luxes* White. This lower dolomitic limestone is overlain by about 7 feet of medium-crystalline to crinoidal gray limestone, with occasional black unfossiliferous chert. This zone has yielded a *Camarotoechia tuta* (Miller), a shark's tooth, and a *Syringothyris?* sp. The crinoidal zone is overlain by about 14 feet of massive medium-crystalline to fine-crystalline gray unfossiliferous limestone. The highest unit is overlain disconformably by Tertiary volcanic rocks.

Lithologically, and by reason of its meager fauna, the lowest, brown dolomitic limestone is typical of the basal carbonates of the Caloso formation in west-central New Mexico. The higher limestone beds in the Coyote hills are somewhat unique because of the presence of a true crinoidal zone and the lack of algal structure. The unfossiliferous nature of the rocks, their general texture and color, and the black chert suggest, however, a Caloso correlation.

REGIONAL RELATIONSHIPS

Although, admittedly, information is still incomplete, a picture of the Mississippian paleogeography of New Mexico begins to emerge. At the beginning of Mississippian time, what is now New Mexico was apparently a peneplain. An expression of this can be found in the lack of appreciable

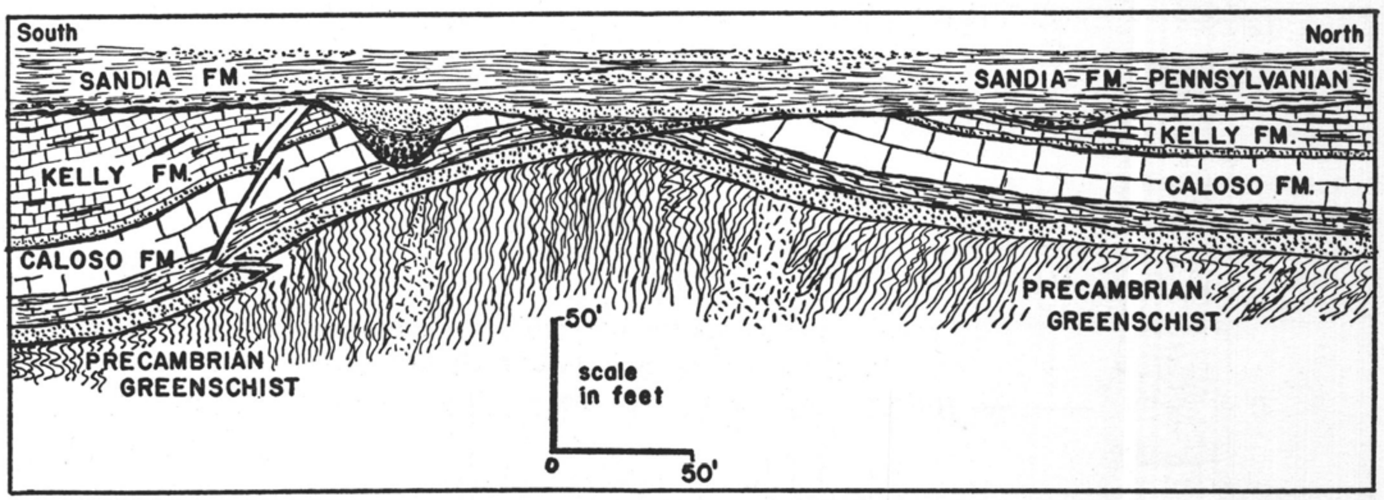


Figure 10

PRE-SANDIA FOLDING, FAULTING, AND EROSION, AT THE NORTH END OF CERRO COLORADO, LADRON MOUNTAINS

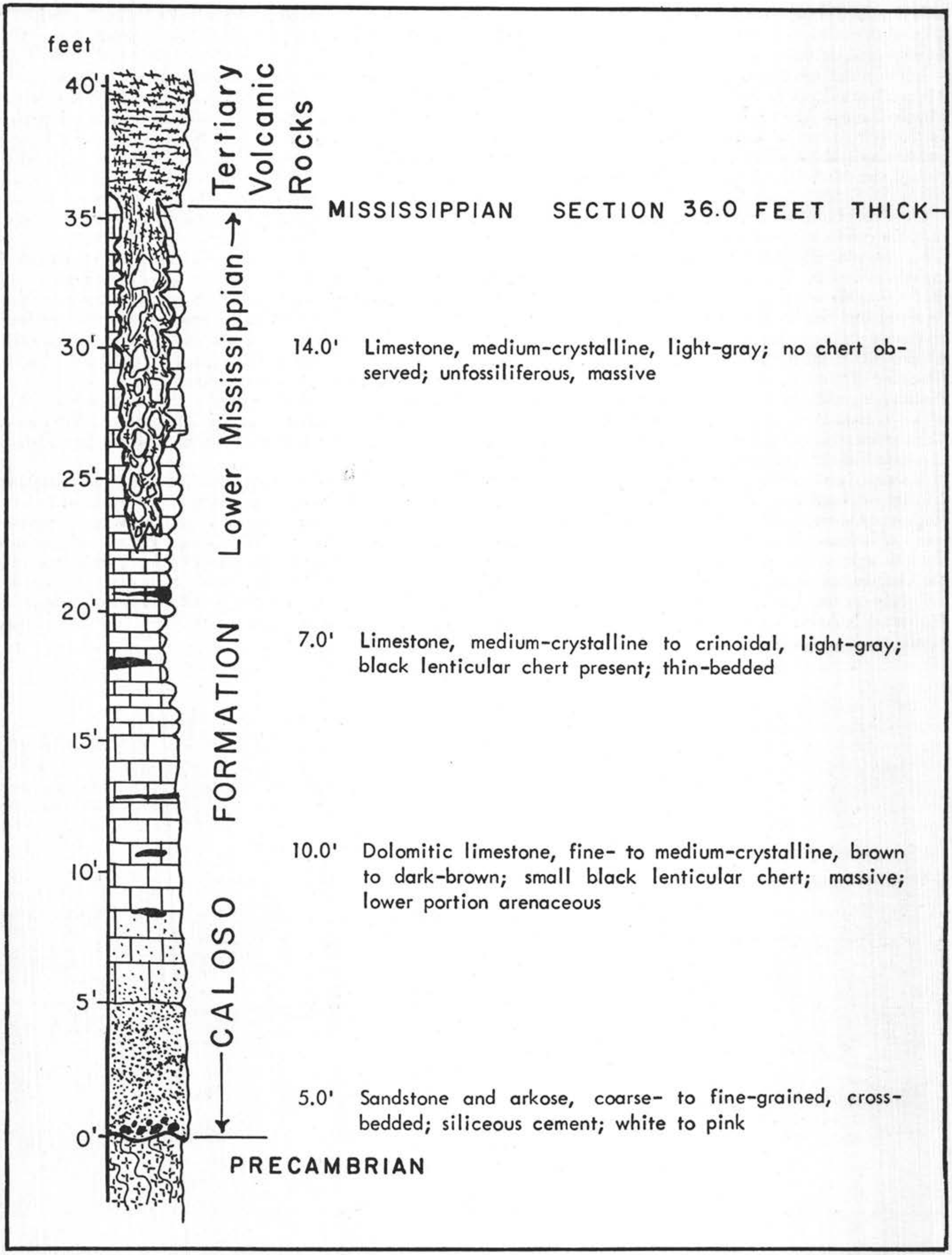


Figure 11

Caloso formation, Coyote Hills

elastic material in the Upper Devonian Ouray limestone, of southwestern Colorado, or in the Box member of the Percha formation, in southern New Mexico.

In Chouteau Kinderhookian time much of southern New Mexico was submerged by the Caballero seas (Laudon and Bowsher, 1949). The deposition of a thin sheet of limestone in the western half of northern New Mexico may have occurred also in the Kinderhook. There is present in the lower part of the Meramecian Arroyo Penasco formation, in the Manzano, Sandia, Nacimiento, and San Pedro Mountains, o to 4o feet of unfossiliferous limestone. This limestone rests on a flat surface of truncated Precambrian rock and is overlain, with a possible masked disconformity, by Meramecian endothyrid-bearing beds of the Arroyo Penasco formation. The unfossiliferous limestone in its known exposures in the Manzano and Sandia Mountains displays a lithology similar to that of the lower portion of the Caloso formation in the Ladron and Lemitar Mountains. This unfossiliferous basal limestone of the Arroyo Penasco formation in the Jemez, Nacimiento, and San Pedro Mountains exhibits a lithology which is transitional from south to north from that of the Caloso formation to the Leadville limestone of southwestern Colorado (for detailed sections, see Armstrong, 1955, 1958).

It seems clear, both from present data and those given by Laudon and Bowsher (1949), that lower Osagian (lower Burlington) sediments were restricted in New Mexico to an area south of latitude 33°3o' N. During upper Burlington time the seas began to transgress northward, until by Keokuk time the Osagian sea of southern New Mexico had transgressed definitely to the Ladron Mountains and probably much farther north. A detailed paleontologic and stratigraphic study of the thick Osagian crinoidal limestone which is present above the Nunn member of the Lake Valley formation in the Cooks Range, Bear Mountain, the Mimbres Range, and the Sacramento Mountains will, no doubt, shed further light on the matter. Apparently this northward transgression ended in Keokuk time. The Meramecian transgression of the Arroyo Penasco formation appears to have had a different geography. There is ample evidence in both North America and Europe of a major break at the end of the Osage epoch (Laudon, 1948, p. 288-302). In New Mexico, Laudon (1948, p. [2]94295) and Laudon and Bowsher (1949) have demonstrated the truncation of Osagian rocks by sediments of lower Meramec age in the San Andres and Sacramento Mountains.

The Arroyo Penasco formation is possibly a correlation of the Meramecian St. Louis limestone (Fitzsimmons et al., 1956). It appears to represent a submergence of northern New Mexico by a lime-depositing episea transgression from western Kansas, Oklahoma, and northwestern Texas. From the faunal evidence now known, the Arroyo Penasco formation of northern New Mexico appears to be unrelated to the Las Cruces or Rancheria formations of southern New Mexico, despite their Meramecian age. This may, of course, prove eventually to be a facielogic difference in the broad Meramecian episea.

In general it can be stated that New Mexico throughout most of the Mississippian period was a peneplained surface, with a shallow, persistent marine basin in the extreme southwestern part of the area. What is now central and northern New Mexico was a peneplain near sea level, which was submerged shallowly by very small epeirogenic or eustatic changes. Perhaps as early as initial Chester time the characteristic late Paleozoic diastrophism of New Mexico was under way.

Systematic Paleontology

INTRODUCTION

In the summers of 1952. and 1955, the writer studied the Mississippian exposures of the Ladron and Magdalena Mountains to ascertain their relationship to the Meramecian Arroyo Penasco formation of northern New Mexico. It became obvious that the Mississippian strata in west-central New Mexico were unique and could be approached only from a paleontologic standpoint if any knowledge was to be gained on regional relationship. The summer of 1956 was spent in the field in an effort to collect a fauna. Although the Caloso and Kelly formations are poor in fossils in comparison to the prolific Nunn member of the Lake Valley formation, diligent hunting revealed an identifiable fauna. The Kelly formation has a reasonably large, poorly preserved fauna of corals, brachiopods, and bryozoans, with lesser amounts of molluscan, blastoids, and trilobites.

In the time available to the author, specific identifications and descriptions could be made only of the brachiopods, blastoids, trilobites, and one of the corals. Identification of these four groups, however, renders possible a reasonably accurate age determination of the Mississippian strata of west-central New Mexico. It is hoped that at some future date a study will be made of the abundant bryozoan faunas of the Kelly formation.

Genus RHIPIDOMELLA Oehlert, 1890 *Rhipidomella* sp.

Pl. 3, fig. 25-27

Description. The shell is a little wider than long. It is subtrigonal in outline in larger specimens, subovate in smaller individuals. The anterior margin is slightly truncated. The posterolateral margins are gently convex, becoming straighter as they approach the beak, where they meet at an angle of 90 degrees. The hinge lines are very short. The valves are subequally biconvex. The ventral valve is flattened medially in the posterior half, the surface curving abruptly to the posterolateral margins. The curvature is much more gentle at the cardinal extremities. The sinus is present only on the anterior third of the shell as a very shallow, broad, almost imperceptible depression. The beak is flattened and very slightly incurved. Cardinal area and delthyrium were not observed.

The dorsal valve is more rotund than the ventral. The greatest convexity is in the posterior half; the anterior fifth of the shell is axially flattened (presumably a low-lying "fold"). The beak is small and pointed.

The surface of both valves is covered by costellae of which 3 occupy the space of i mm at the anterior of the shell. The dimensions (in mm) of the specimens studied are:

VENTRAL VALVE

SPECIMEN	WIDTH	LENGTH
537	33.6	32.9
538	25.0	24.4
539	22.0	20.5

DORSAL VALVE

SPECIMEN	WIDTH	LENGTH
539a	19.5	18.0
539b	27.5	26.0

Internal structure. No internal structures were preserved on the specimens collected.

Remarks. Because of the poor preservation of the *Rhipidomella* species of the Kelly formation, their relationship to described species is unknown. They share with Weller's (1914, pl. 20, fig. 22-26) illustration of *R. dubia* Hall a similar contour, but differ in being a little wider than long, in being almost twice as large, and in having a slightly more convex anterior.

Campbell (1957, p. 51-53) studied the genus *Rhipidomella* from the Mississippian of New South Wales and found, after the examination of populations from several localities and horizons, that the valves are variable and the range of variation is similar in almost all populations. Since most American species of Mississippian *Rhipidomella* are based largely on shell shape, Campbell believes variation studies may reduce the number of American species.

Horizon. The specimens studied were from the Kelly formation, south end of the Paleozoic hogback, Ladron Mountains. Numerous fragments of *Rhipidomella* were observed in the Kelly formation of the Lemitar and Magdalena Mountains.

Specimens studied. Nine disassociated, poorly preserved valves were studied. New Mexico Bureau of Mines and Mineral Resources, nos. 537-539.

Genus LINOPRODUCTUS Chao, 1927

Linoproductus sp.

P1.4, fig. 19

The specimen under consideration has been flattened and crushed. The anterior portion and commissure are absent. The ventral valve appears to be swollen. The umbonal region protrudes beyond the hinge line. The mesial portion of the valve is broadly flattened. The sinus is very obscure. The beak is pointed and incurved. The ventral valve is covered with fine, somewhat flexuous costae, which are subrounded. The costae increase anteriorly by bifurcation. Reticulation is absent on the umbo.

Dimensions. One poorly preserved valve was available for study. Width, 25 mm; length, 26 mm.

Remarks. The specimen is believed to be a *Linoproductus* by virtue of its shape and particularly by its fine, radiating, somewhat flexuous costae and nonreticulated surface.

Horizon. The specimen is from the Kelly formation, Paleozoic hogback, Ladron Mountains. *Linoproductus* has been observed as fragments in the Kelly formation of the Ladron, Lemitar, and Magdalena Mountains.

Specimen studied. One incomplete ventral valve. New Mexico Bureau of Mines and Mineral Resources, no. 557.

Genus CHONETES Fisher, 1837

Chonetes cf. illinoisensis Worthen

P1.3, fig. 14

Chonetes Illinoisensis Winchell, 1865, Acad. Nat. Sci. Philadelphia Proc., v. 17, p. r r 6.

——— Meek and Worthen, 1868, Illinois Geol. Survey, v. 3, p. 505; pl. 15, fig. 8a-b.
Chonetes illinoisensis Herrick, 1891, Geol. Soc. Am. Bull., v. 2, p. 48; pl. 1.
——— Keyes, 1894, Missouri Geol. Survey, v. 5, p. 53.
——— Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 279.
——— Weller, 1914, Illinois Geol. Survey Mon. 1, p. 81-82; pl. 8, fig. 63-70.

The single specimen available for study is an exfoliated ventral valve.

Description. The ventral valve is depressed convex, with the greatest convexity posterior to the middle. The surface of the valve is compressed toward the cardinal extremities, flattened along the axial region, and depressed into a shallow, obscure sinus. The hinge line is slightly shorter than the maximum width. The hinge extremities are nearly straight, passing with a regular curvature into the anterior margin. The beak is very small and slightly extended beyond the cardinal margin. The cardinal area lies at an angle of 148 degrees to the plane of the valve.

The surface of the valve is exfoliated, but the anterior margins are marked by fine radiating costae; the total number present appears to be from **120 to 140.** On the lateral margins of the exfoliated specimen, numerous papillae or "pits" are present on the internal mold, becoming less numerous and smaller in size toward the axial region. No cardinal spines were observed.

The comparative dimensions of the ventral valve are:

	WELLER'S SPECIMEN (1914, p. 81-82)	KELLY FORMATION (specimen 532)
Width (mm)	16.3	13.8
Length (mm)	11.9	10.0
Convexity (mm)	3.6	3.5
Costae	175-225	120-140

Internal features. A low, median septum is present from the apex of the beak to beyond the middle of the valve.

Remarks. **The** Kelly formation specimen is a *Chonetes,* in that it possesses a long, low median septum on the ventral valve and has a hinge line approximately equal to the greatest width of the shell. The contour and the dimension of the shell agree with the average size given for C. *illinoisensis* as cited in the literature. Weller's (194) specimens of C. *illinoisensis* were from the Burlington and Keokuk limestones of Missouri. In the midcontinent, Moore (1928) cites the species from beds ranging from Sedalia to Warsaw age. In southern New Mexico, Laudon and Bowsher (1941, 1949) have identified C. *illinoisensis* from various members of the Lake Valley formation.

The specimen from the Kelly formation is so poorly preserved that an emphatic and precise identification cannot be made. New Mexico Bureau of Mines and Mineral Resources, no. 532.

Genus CAMAROTOECHIA Hall and Clarke, 1895

Camarotoechia tuta (Miller)

Pl. 1, fig. 22-29; pl. 2, fig. 8

Rhynchonella tuta Miller, 1881, Cincinnati Soc. Nat. History Jour., v. 4, p. 315; pl. 7, fig. 11a, b.
Camarotoechia chouteauensis Weller, 1910, Geol. Soc. Am. Bull., v. 21, p. 510; fig. 10.
——— Weller, 1914, Illinois Geol. Survey Mon. 1, p. 176; pl. 24, fig. 34-49.
Camarotoechia tuta Weller, 1914, Illinois Geol. Survey Mon. 1, p. 179; pl. 24, fig. 9-28.
——— Branson, 1938, Missouri Univ. Studies, v. 13, n. 3, pt. 1, p. 45-46; pl. 5, fig. 14-18.

Description. The shell is subequal, somewhat longer than wide, and subovate in outline. The greatest width is anterior to the midlength. The posterolateral margins are straight. The anterolateral and anterior margins are rounded.

The ventral valve is convex on the umbo, the surface curving abruptly to the posterolateral margins, and gently from the umbo to the anterolateral margins. The sinus begins at the middle of the valve, becoming pronounced on the anterior commissure. It is broad and flattened throughout its course. Anteriorly, the sinus produces a rather broad, slightly rounded or subrectangular lingual extension. The beak is small, pointed, and incurved. The plications originate on the umbo; they are initially rounded but become angular in their course toward the anterior. The sinus is occupied by 3 or 4 simple plications (3 specimens had 3 plications, and **2** specimens had 4 plications in the sinus). Five to six simple plications are present on each lateral slope; they become smaller toward the cardinal extremities. Very obscure varices are present on the valve.

The dorsal valve is more strongly convex than the ventral. The greatest convexity is anterior to the middle. The curvature is more convex toward the posterolateral margins, and strongest toward the anterolateral margins. The axial fold originates slightly anterior to the middle and is not very pronounced in its course to the anterior commissure. On the dorsal umbo, an extremely faint, shallow depression is present, which disappears where the fold originates. Four simple plications are present on the fold, and 5 or 6 on each lateral slope.

SPECIMEN	LENGTH (mm)	WIDTH (mm)	THICKNESS (mm)	WIDTH OF SINUS AT ANTERIOR COMMISSURE (mm)
510	7.1	8.2	4.3	3.9
511	8.8	9.4	4.8	4.6
Weller (1914, p. 176)	9.3	10.0	8.0	5.6
Weller (1914, p. 179)	7.3	7.5	5.0	4.3

Internal features. The majority of the internal features were not observed, but traces of a very well developed median septum were seen on the dorsal valve.

Remarks. Branson (1938, p. 45-46) found complete gradations from C. *tuta* (Miller) to C. *chouteauensis* Weller:

> Specimens from the Lake Valley limestone of New Mexico, from which C. *tuta* was described, show the C. *chouteauensis* types as well as the C. tuta types. Weller described C. *chouteauensis* under the impression that the larger specimens did not occur in New Mexico.

C. *tuta* and *Hustedia circularis* (Miller) have similar contours, but C. *tuta's* median septum is apparent, whereas in ***H.*** *circularis* a median septum is distinguished with difficulty.

Weller (1914) illustrates examples of C. *tuta* from the Chouteau and lower Burlington limestones of Missouri. Moore (1928) cites the species from Missouri in beds ranging in age from Hannibal to Keokuk. Laudon and Bowsher (1941) list the species in the Caballero formation, Sacramento Mountains, New Mexico. C. *tuta* was found in ***the***

Caloso formation, in the Lemitar and Magdalena Mountains and the Coyote Hills.

Specimens studied. Two complete but exfoliated specimens, 4 incomplete dorsal valves, 1 ventral valve, and partial ventral valve preserved in chert were available for study. New Mexico Bureau of Mines and Mineral Resources, nos. 510, 511, 515.

Genus TETRACAMERA Weller, 1910

Tetracamera subcuneata (Hall)

Pl. 4, fig. 3-7

Rhynchonella subcuneata Hall, 1856, Albany Inst. Trans., v. 4, p. 1 I, (fide S. Weller, 1914, Illinois Geol. Survey Mon. 1, p. 214).
---- Hall and Whitney, 1858, Iowa Geol. Survey, v. I, pt. 2, p. 658; pl. 23, fig. 3a-c.
– -- Keyes, 1894, Missouri Geol. Survey, v. 5, p. 102.
Camarophoria subcuneata Hall and Clarke, 1895, Pal. of New York, v. 8, pt. 2, pl. 62, fig. 34-37.
Tetracamera subcuneata Weller, 191o, Geol. Soc. Am. Bull., V. 21, p. 503; fig. 4.
---- Weller, 1914, Illinois Geol. Survey Mon. 1, p. 214-215; pl. 28, fig. 13-24.

Description. The shell length and width are subequal, the width being somewhat greater than the length; the greatest width is anterior to the middle. The shell is subtriangular in outline. The posterolateral margins are nearly straight, but just perceptibly convex toward the anterior. The anterolateral margins are rounded. The anterior margin is rounded but slightly truncated.

The ventral valve is slightly convex; the posterolateral margins are deflected at right angles to meet a similar deflection of the opposite valve. The anterolateral and anterior margins curve very abruptly to meet the opposite valve. A sinus is not present. The beak is small, very pointed, and incurved. There are 15 to 18 angular, simple plications on each valve. The plications originate at the beak.

The dorsal valve is slightly more convex than the ventral; the greatest convexity is on the beak. The posterolateral, anterolateral, and anterior margins are deflected in a manner like those of the opposite valve. If a fold is present, it may contribute to giving the dorsal valve more lateral convexity than the ventral valve. The plications are like those of the opposite valve.

Fine, very obscure, radiating striae apparently cover the whole surface but usually are best preserved in the furrows.

The dimensions of three disassociated valves, compared with three specimens of Weller (1914, p. 24), are given below:

VENTRAL VALVE

SPECIMEN	WIDTH (mm)	LENGTH (mm)	GREATEST WIDTH FROM ANTERIOR MARGIN (mm)
546	11.5	10.0	6.0
546a	12.5	12.3	6.7
Weller (a)	12.0	11.7	—
Weller (b)	11.5	10.4	—
Weller (c)	15.3	15.3	—
DORSAL VALVE			
546b	10.7	10.8	7.0

Internal structures. The rostral portions of a number of specimens were ground and found to be barren, but several individuals displayed in the ventral valve the dental lamellae and buttress plates which are significant diagnostic characteristics of the genus *Tetracamera.* The dorsal valves of most individuals showed a strong, well-developed, median septum and two lateral lamellae.

Remarks. This rhynchonelliform brachiopod is placed in the genus on the basis of the external form, the buttress plates connecting the dental lamellae, the strong dorsal median septum, and the two lateral lamellae. The external contour of the shell compares very favorably with Weller's illustrations (1914, pl. 28, fig. 13-24) of T. *subcuneata* from the Salem limestone, Indiana, except that the ventral valve of the Kelly formation specimen tends to be slightly less convex.

Horizon. T. *subcuneata* is restricted to beds of Keokuk to Salem age (Moore, 1928; Weller et al., 1948, p. 114). T. *subcuneata* has not been reported previously from New Mexico. The species is present in the Kelly formation in the Ladron, Lemitar, and Magdalena Mountains. It is abundantly present in the upper 20 feet of the Kelly formation in the Lemitar Mountains.

Specimens studied. Ten disassociated valves, 1 complete specimen, and some 20 specimens on small rock slabs were available for study. New Mexico Bureau of Mines and Mineral Resources, no. 546.

Tetracamera cf. *subtrigona* (Meek and Worthen)

P1.3, fig. 31-34

Rhynchonella subtrigona Meek and Worthen, 186o, Acad. Nat. Sci. Philadelphia Proc., v. 17, p. 451.
Camarophoria subtrigona Meek and Worthen, 1866, Illinois Geol. Survey, v. 2, p. 251; pl. 18, fig. *7a-c.*
Rhynchonella subtrigona Keyes, 1894, Missouri Geol. Survey, v. 5, p. 102.
Camarophoria *subtrigona* Hall and Clarke, 1895, Pal. of New York, v. 8, pt. 2, pl. 62, fig. 38-43.
Tetracamera subtrigona Weller, I910, Geol. Soc. Am. Bull., v. 21, p. 504-506; fig. 5.
---- 1914, Illinois Geol. Survey Mon. 1, p. 218-221; pl. 29, fig. I-13.

The specimens studied consisted of two large valves which were completely crushed and broken, two valves that had been crushed and flattened from the anterior margin but which had the rostral portions in their relative positions, and one small, complete dorsal valve.

Description. The dorsal valve is subtrigonal in outline and is slightly truncated on the anterior margin. The dorsal valve is slightly convex and is abruptly deflected to the anterior lateral and anterior margins. The posterolateral margin is deflected abruptly toward the opposite valve. The posterolateral deflection is inflected in a concave manner. A fold is absent except on the anterior quarter of the shell, where the center five plications rise gently and then abruptly deflect at the anterior margin to meet the opposite valve. The valve has 14 strong, simple, rounded plications, which become faint on the posterolateral margin.

The ventral valve appears to have been less convex than the dorsal; its posterolateral margins are deflected in the same manner as the opposite valve.

Dimensions. The only specimen which could be measured was the uncrushed, rather small dorsal valve; width 22.5 mm, length 18.2 mm.

Internal features. The two complete specimens had been crushed and flattened on the anterior end, but the rostral portions were not crushed and remained in their relative positions. By grinding both individuals, internal features were revealed (pl. 3, fig. 31, 34). The ventral valve has in its posterior portion a very strong dental lamella, with supporting buttress plates characteristic of the genus *Tetracamera.* The brachial valve has a high, narrow, median septum, which at the posterior of the shell divides to form a spondylioid hinge plate. In all known species of *Tetracamera* the dorsal valve has two lateral lamellae, except in the species T. *subtrigona.*

Remarks. The presence of spondylium buttress plates is characteristic of *Tetracamera,* and the absence of lateral lamellae in the brachial valve is a specific characteristic of T. *subtrigona* (Meek and Worthen) from the Keokuk limestone of Missouri and Illinois.

Horizon. Moore (1928, p. 23o) found T. *subtrigona* restricted in Missouri, Illinois, and Iowa to beds of Keokuk age. Weller et al. (1948, p. 114) state that the larger species of *Tetracamera,* such as T. *subtrigona,* are known to occur only in beds of Keokuk age. The only known occurrence of the species in New Mexico is in the Kelly formation, in the Ladron, Lemitar, and Magdalena Mountains. New Mexico Bureau of Mines and Mineral Resources, no. 543.

Genus **RHYNCHOPORA** King, 1865

Rhynchopora persinuata

(Winchell) Pl. 3, fig. 24

Rhynchonella persinuata Winchell, 1865, Acad. Nat. Sci. **Philadelphia** Proc., v. 17, p. 121.

Camarophoria occidentalis Miller, 1881_, Cincinnati Soc. Nat. History Jour., V. 4, p. 313; pl. 7, fig. 7a, b.

Camarotoechia persinuata Weller, 1901, St. Louis Acad. Sci. Trans., V. I I, p. 197; **pl.** 19, fig. 5.

–--- Weller, 1909, Geol. Soc. Am. Bull., V. 20, p. 302; pl. 12, fig. 24-25.

Rhynchopora persinuata Weller, 191o, Geol. Soc. Am. Bull., v. 21, p. 515.

---- Weller, 1914, Illinois Geol. Survey Mon. 1, p. 233-235; pl. 3o, fig. 1-6.

–--- Hyde, 1953, Ohio Geol. Survey Bull. 51, p. 282-285; **pl. 18,** fig. 1-41; pl. 19, fig. 1-29.

Only one complete, external ventral valve was available for study.

Description. The shell is subpyramidal in shape, wider than long, and of rhynchonellid form. The posterolateral margins meet at the beak at an obtuse angle. The lateral margins are rounded, the anterior margins straight.

The ventral valve is compressed with a slight convexity in the posterior half. The surface of the valve curves flatly to the posterior lateral margins. The shell along the axial line is flat on the umbo and then sharply curves toward the opposite valve. The sinus originates as a broad, shallow depression near the middle of the valve and becomes deeper anteriorly. The anterior lateral margins are slightly upcurved. The surface of the shell near the anterior margin is abruptly incurved toward the opposite valve. The beak is small, pointed, and slightly incurved. The delthyrium, deltidial plates, and foramen were not observed. The plications are simple and subangular. The furrows are narrow and deep. Seven plications are present in the sinus, and 8 on each lateral slope. The plications originate on the umbo. Internal characters were not observed. The shell structure is densely punctate. Dimensions of a ventral valve are: Width, 18.o mm; length, 10.9 mm; thickness, 7.2 mm; width of sinus at anterior margin, 9.8 mm.

Remarks. The configuration of the ventral valve from the Kelly formation conforms with Weller's (1914, p. 233-234; pl. 3o, fig. 1-2) description of *R. persinuata* from the Kinderhook of Iowa.

The Kelly formation *R. persinuata* is slightly more robust, and has a somewhat more pronounced sinus, than four examples of the same species which were used for comparison from the Nunn member, Lake Valley formation, Lake Valley, New Mexico.

Horizon. The species was described originally from the Marshall group of Ohio. Moore (1928, p. 204) lists a range for the species in Missouri from Pierson to lower Burlington time. Laudon and Bowsher (1941, 1949) cite its occurrence in New Mexico at many localities in the Lake Valley formation. The only known occurrence of the species in the Kelly formation is at the exposures in the southern Ladron Mountains. New Mexico Bureau of Mines and Mineral Resources, no. 536.

Genus **SPIRIFER** Sowerby, 1816, sensu lato

Spirifer centronatus Winchell

Pl. 1, fig. I, 19-21

Spirifer centronata Winchell, 1865, Acad. Nat. Sci. Philadelphia Proc., V. 17, p. 118-119.

Spirifer centronatus White, 1875, U. S. Geog. Geol. Survey West of the 100th Meridian Rept., v. 4, p. 86; pl. 5, fig. 8a-c.

Spirifera centronata Hall and Whitfield, 1877, U. S. Geol. Expl. of the 4oth Par., p. 254-255; pl. 4, fig. 5-6.

Spirifer centronatus Girty, 1899, U. S. Geol. Survey Mon., v. 32, pt. 2, p. 547; pl. 70, fig. 3a-d.

Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 285-286. ---

- Hyde, 1953, Ohio Geol. Survey Bull. 51, p. 258-259.

Winchell's (1865, 118-119) original description :

Spirif era, Sowerby

Spirifera centronata, n. sp. Shell of medium size, with an elongate, cuspidate hinge margin, and, aside from the cardinal extremities, a somewhat semicircular general outline. Ventral valve of medium fulness near the umbo, somewhat depressed between there and the margins; beak elevated above the cardinal line more than one-fifth the whole length of the valve, incurved and overhanging a very narrow area. A distinct and comparatively deep sinus begins at the extremity of the beak, very gradually widening and becoming ill-defined in the middle of the valve and beyond. External surface marked by 36 to 4o ribs, of which from three to five fall in the mesial sinus. The ribs disappear on the alate cardinal expansions. One or two concentric furrows marking the middle region of the valve.

Length along cardinal line, 1 •23 (100); length from beak to anterior margin, • 52 (42); greatest convexity of ventral valve,11 • (9).

Museum of the University of Michigan. Collected by A. Winchell, at Cuyahoga Falls, Ohio, in the flagstones below the conglomerate. Occurs also in Col. Whittlesey's collection from Akron, Ohio, 5o feet below the conglomerate.

This species is distinguished from all other spirifers by the association of cuspidate hinge extremities with a ribbed mesial sinus, and semicircular front margin. When the cuspidations are removed, the shell recalls S. *Marionensis,* Shumard, from the so-called Chemung of Missouri and Iowa; and, in all except semicircular outline it corresponds with S. *cuspidatus,* Hall, (not of Martin,) from the Chemung of New York.

Discussion. Winchell's rather inexact description does not have an illustration of the holotype. The lack of further studies or illustrations by subsequent workers on S. *centronatus* from the Cuyahoga formation of northern Ohio has resulted in much speculation and doubt as to the identification of S. *centronatus* in the Mississippian strata of the western United States. The strongest proponent of the theory that the Eastern and Western forms were distinct species is Stoyanow, who (1948, p. 32o) stated that "the form from Michigan and Iowa described S. *centronatus* by Weller (1901, p. 163, pl. 14, figs. 3-4; 1914, p. 323) is not conspecific with *S. centronatus* Winchell of the southwest, which apparently was autochthonous and does not occur east of Colorado and Arizona." Stoyanow based his opinion on Weller's misidentification of S. *centronatus* from Kinderhookian beds of Michigan and Iowa. Weller (1914, p. 323-324) apparently recognized his mistake and designated a new species *Spirifer biplicoides* Weller, which he placed in synonymy with his 1901 S. *centronatus.*

Because Winchell's holotype (pl. 1, fig. 1) is only a mold (moreover, the posterior portion of the ventral valve), the writer has attempted to locate from the Cuyahoga formation of northern Ohio supplementary material on which to compare the Western forms.

The writer had the privilege of viewing Dr. E. Szmuc's (Kent State University) private collection of S. *centronatus* from the Cuyahoga formation south of Akron, Ohio. The writer made an extensive search of the Cuyahoga formation at Cuyahoga Falls in an attempt to locate topotype material. The section is very sparsely fossiliferous, and only fragmental material was found. Small collections of the species were made in the Cuyahoga formation south of Akron and around Wooster, Ohio.

The present knowledge of the Lower Mississippian *Spirifer* phylogeny, evolution, and distribution indicates that the Western forms listed in the synonymy are conspecific with *S. centronatus* Winchell from the Cuyahoga formation of northern Ohio.

The geologic literature, particularly the more recent studies on Mississippian stratigraphy of the West, has numerous and obvious misidentifications of S. *centronatus.* This has resulted in the species' acquiring in the literature a much higher vertical range than it actually has. Dr. E. Szmuc (personal communication) has found the species in Ohio to have a range roughly from the Chouteau to Fern Glen time. The writer is engaged in a paleontologic and stratigraphic study of the Escabrosa limestone of southern New Mexico and Arizona, in which the attempt will be made to define a precise vertical range for S. *centronatus* in the Southwest.

Spirifer centronatus ladronensis, n. subsp.

Pl. 1, figs. 7-12, 16-18

Description. Shell is subsemicircular to subtriangular in outline. The greatest width is along the hinge line. The hinge line is acute on immature specimens. The hinge line is proportionately shorter, and the extremities more obtuse, with age.

The pedicle valve is convex and very slightly depressed toward the cardinal extremities. The umbo region is prominent. The surface curves abruptly to the cardinal margins. The cardinal area is of moderate height and is arched toward the beak. The anterior margin in ephebic individuals curves without a break to the middle portion of the shell, but in late ephebic and gerontic individuals there is a series of growth lamellae near the anterior margin which correlates with an abrupt curvature to the anterior commissure. Well-preserved specimens demonstrate a mucronated nature, which is more pronounced on immature individuals. A distinct sinus starts as a slight depression between two lateral plications at the extremity of the beak. On the beak at a point slightly behind the origin of the sinus, a median plication appears. The median plication continues to the anterior commissure without bifurcation. The lateral plications bifurcate on the umbo and again near the anterior margin (fig. 12). Each lateral slope bears ix to 14 simple, rounded plications. On some individuals there is a tendency for the plication next to the sinus or the fold to bifurcate. The plications on the cardinal extremities tend to be weaker.

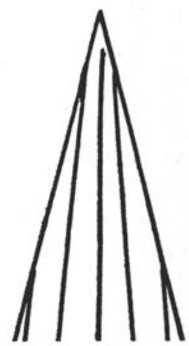


Figure 12

SINAL PLICATIONS IN *Spirifer centronatus ladronensis*

$\times 2$

The brachial valve is slightly less convex than the pedicle valve, with the greatest convexity posterior to the middle. The cardinal area is linear. The fold originates at the beak. On the umbo, the fold is slightly elevated above the surface of the shell. On the anterior commissure, the fold is strong and pronounced. Two plications arise on the incipient fold on the umbonal region. They bifurcate near the middle of the shell to give four plications on the fold at the anterior commissure. The plicae on the lateral slope, adjacent to the fold in some mature individuals, bifurcate on the posterior half of the shell. The remaining i o to 13 plications are simple and similar to those of the opposite valve.

Dimensions. Specimen 506 is an external mold; the rest are internal molds.

SPECIMEN	WIDTH	LENGTH	THICKNESS
506	34.6 mm	24.7 mm	—
507	32.6	23.0	16.0 mm
507a	43.0	29.0	—
507b	45.0	28.8	21.4
507c	33.7	29.4	20.0
507d	37.0	29.0	—
507e	40.0	33.5	20.5

Interior Structure. The ventral valve bears diverging dental lamellae. The teeth point inward and upward to the dental sockets. The tooth-bearing portions converge inside the delthyrium but do not meet, and then diverge again toward the outer margin of the shell (pl. 1, fig. 12). Pronounced thickening occurs inside the apical portion of the delthyrium. Adductor scars are located on a slight raised narrow ridge which extends to the middle of the shell. Each diductor scar has the shape of an elongate ellipse or prolate rhomb. The diductor area is raised above the inner surface of the shell and is bordered by a still more elevated callus. Ovarian pits are well developed on the floor of the beak cavity (pl. 2, fig. 10-12).

The socket plates unite beneath the dorsal umbo as a support for the cardinal process. The cardinal process is a small rectangularly shaped boss attached to the floor of the shell at the apex of the beak on the dorsal valve. A low, very narrow median ridge arises on the umbo and extends past the middle of the valve. This low ridge may represent a median septum or the dorsal adductor scars.

SPECIMEN	LENGTH OF MUSCLE FIELD	WIDTH OF MUSCLE FIELD	WIDTH OF ADDUCTOR SCARS
507	9.3 mm	4.6 mm	1.0 mm
507c	11.3	5.2	1.2
507d	9.0	7.0	1.3
507e	11.6	6.0	1.3
507f	10.0	9.0	1.8

Remarks. Spirifer centronatus was described by Winchell (1865, p. 118-119) from an incomplete specimen collected from the Cuyahoga formation, Cuyahoga Falls, northern Ohio. Dr. E. C. Stumm, of the University of Michigan, kindly sent the writer a latex cast of Winchell's holotype. Dr. E. Szmuc, of Kent State University, permitted casual comparison of his collection of S. *centronatus* from the Cuyahoga formation south of Akron, Ohio, with the New Mexico material. The species is by no means common in northern Ohio, and the collecting trips made by the writer yielded only poor material.

A comparison of S. *centronatus* from the Cuyahoga formation with S. *centronatus ladronensis* from the Caloso formation, New Mexico, discloses the following common characteristics:

x. Both have the same general contour and convexity.
2. Both have the same type of derivation for the lateral plications and the same general range in number of lateral plications (12-16).
3. Both have the same types of inception for the sinus and fold. The fold in both displays the same relative size and elevations above the surface of the shell.
4. The development of plications and their number on the sinus and fold are almost identical for both.
5. Individuals from both localities, when well preserved, demonstrate mucronated cardinal extremities, particularly in neanic individuals.
6. The specimens from Ohio and from New Mexico each show a fairly wide range in morphologic characters, such as height and width of plications, depth and width of the sinus, size and shape of the muscle field, and size of the ephebic individual. However, this generalization is possible: The specimens of maximum size in the Cuyahoga formation are comparable to the smaller ephebic specimens in the Caloso formation.

The observed differences between S. *centronatus*, from Ohio, and *S. centronatus ladronensis*, from New Mexico, are:

1. The umbonal region on the specimens from the Cuyahoga formation tends to be proportionately slightly larger than on the specimens from the Caloso formation.
2. On the Caloso specimens, the bounding furrows next to the fold are deeper in comparison to the furrows on the lateral slopes, whereas on the Cuyahoga specimens, the bounding furrows next to the fold are of about the same depth as those on the lateral slopes.
3. The average specimen from the Caloso formation is much more robust than the average specimen from the Cuyahoga.

The genus Spirifer is divided by most workers into species on the basis of general contour, number of plications, type of plical bifurcation, and particularly the nature and origin of the sinal plications. Since the specimens from both the Cuyahoga and Caloso formations agree with respect to the above criteria, it is believed judicial to consider the larger Caloso examples with their otherwise only slight morphologic differences as a geographical subspecies or possibly an ecotype. The geographic separation of *S. centronatus ladronensis* from the holotype area of S. *centronatus* at Cuyahoga Falls, Ohio, is approximately 1,100 miles. The much more robust size of the Caloso examples is probably due to ecological controls. The Caloso formation is an algal limestone, whereas the Cuyahoga formation is a shale, with lesser amounts of sandstones and conglomerates.

Horizon. S. centronatus ladronensis occurs abundantly in chert nodules in the lower part of the Caloso formation, at the north end of Cerro Colorado. It is sparsely found in various horizons in the limestone in the Caloso formation in the Ladron Mountains. Several poorly preserved and doubtfully identified fragments have been found at the base of the Caloso formation, in the Magdalena Mountains.

Material studied. All specimens are deposited at the New Mexico Bureau of Mines and Mineral Resources. One almost complete specimen (no. 506, holotype), 6 internal molds (no. 507), and some 20 disassociated internal molds of valves were available for study.

Spirifer louisianensis Rowley

PI. 2, fig. 9, 10, 15, 3o

Spirifer louisianensis Rowley, 1900, Am. Geologist, v. 25, p. 262; pl. 5, fig. 18-20, 64.

---- Weller, 1914, Illinois Geol. Survey Mon. I, p. 322; pl. 4o, fig. 1-23.

---- Branson, 5939, Missouri Univ. Studies, v. 8, p. 61-62; pl. 6, fig. 13, 22, 29.

Description. The shell is subtriangular to subsemicircular in outline and is wider than long. The greatest width is along the hinge line. The cardinal extremities are acutely angular.

The ventral valve is strongly convex; it is slightly more convex posterior to the middle. The surface of the valve curves abruptly to the cardinal margins on each side of the beak, and steeply to the anterolateral margins. The beak is small and incurved. The cardinal area is triangular in outline and of moderate height; slightly arched, with curvature greatest toward the beak. The sinus begins at the extremity of the beak as a slight depression between lateral plications, which do not divide and tend to be more prominent than the plications on the lateral slope. The sinus is very slightly elevated at the beak; at the anterior commissure it is subangular. A faint median plication arises on the umbo and continues to the anterior without division. The median plication is faint and depressed as compared with lateral plications. See Figure 13.

Each lateral slope has from 8 to Io round, radiating plications, the first 1 or 2 of which may bifurcate at the beak from the lateral plication.

The dorsal valve is less convex than the ventral, with a narrow linear cardinal area. The fold is obscure except on the anterior portion of the valve, where it is elevated slightly. It is bounded by furrows slightly wider and deeper than those on the lateral slopes. On the umbo a median plication on the fold bifurcates into two obscure rounded plications, with a shallow median furrow (fig. 3).

Internal features were not observed on any specimens.

Figure 13
SINAL AND FOLD PLICATIONS IN *Spirifer louisianensis* Rowley
×5.

Surfaces of all specimens collected from the Magdalena Mountains were exfoliated. Weller (1914, p. 322) observed that the surface of the shell when well preserved is marked by exceedingly fine, regular, concentric striae, about 15 of which occupy the space of r mm. The dimensions (in mm) of six disassociated valves are:

SPECIMEN	LENGTH	WIDTH	SINUS	THICKNESS
VENTRAL VALVE				
517a	19.2	9.1	4.7	5.1
517b	14.0	8.1	3.1	3.5
517c	18.0	9.4	4.8	4.4
517d	20.1	11.4	4.9	5.0
517	19.6	10.0	5.0	4.5
524	13.9	6.5	3.8	3.8
DORSAL VALVE				
516a	15.4	9.2	3.5	4.0
516	16.2	8.2	3.0	—
516b	18.0	8.2	3.3	—

Remarks. Rowley (1900, p. 262) described 15 to 20 plications on each lateral slope on the original material from the lower Burlington limestone, at Louisiana, Missouri. Weller (1914, p. 322) and Branson (1938, p. 6,) found 10 to 13 plications on each lateral slope on their specimens from the Louisiana, Chouteau, and lower Burlington limestones of Missouri. Weller and Branson also observed on their specimens that the sinus had 3 plications anteriorly and 1 posteriorly; also that 2 of the plications in the sinus arise from the lateral plications. The fossils attributed here to Spirifer *louisianensis,* from the Caloso formation of the Magdalena Mountains, have from 8 to 10 plications on each lateral slope, and the sinus has only a faint median plication, with the lateral plication nonbifurcating. The fold divides on the umbo, giving rise to two suppressed plications which continue to the anterior margin without division. The specimens from the Caloso formation compare well in contour and size with Weller's (1914, pl. 40, fig. 1-23) illustrations of S. *louisianensis* from the Chouteau limestone and the lower Burlington limestone of Missouri, except that the Caloso specimens have a less developed beak or umbo. Considering the mid-continent variation in the plical details, and pending a statistical study of the species, the examples from the Caloso formation are classified with some reservation as S. *louisianensis.*

Horizon. Spirifer louisianensis first appears in Missouri in the Louisiana limestone and is present up to and including beds of lower Burlington age. Laudon and Bowsher (1941, 1949) report that the species is present in the Kinderhookian Caballero formation and the lower Osagian Lake Valley formation. S. *louisianensis* is rather abundant in the lowest feet of the Caloso formation, in the Magdalena Mountains.

Specimens studied. Twenty-seven disassociated, exfoliated valves were available for study. New Mexico Bureau of Mines and Mineral Resources, nos. 516, 5r7, 524.

Spirifer tenuicostatus Hall
Pl. 4, fig. 12-13

Spirifer tenuicostatus Hall and Whitney, 1858, Iowa Geol. Survey Rept., v. r, pt. z (Pal.), p. 66z; pl. 23, fig. 8a-c.
---- Weller, 1914, Illinois Geol. Survey Mon. 1, p. 328-330; pl. 52, fig. 4-16.

Description. The shell is wider than long, the greatest width being along the hinge line. The cardinal extremities are angular.

The ventral valve is more convex posterior to the middle. The surface slopes abruptly from the umbonal region to the cardinal margin, and gently to the anterolateral margin. The cardinal extremities are slightly compressed. The beak is small, somewhat pointed, and moderately incurved. Each lateral slope has 28 to 3o rounded plications which, by bifurcation on the umbo, arise from 6 plications on the beak. The sinus originates at the beak, where it is sharply defined, and becomes less pronounced and even evanescent anteriorly.

A median plication originates at the extremity of the beak and progresses to the anterior margin, with bifurcation at a point slightly behind the point of origin of the median plication. The bifurcation continues as is shown in Figure 14. At

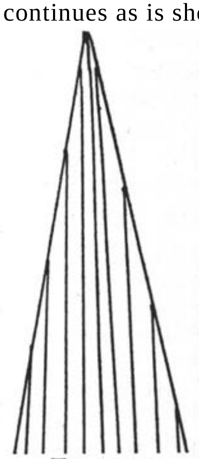


Figure 14
SINAL PLICATIONS IN *Spirifer tenuicostatus*
×3.

the anterior commissure some 9 to I I plications are present in the sinus.

The dorsal valve is less convex than the ventral. The fold originates at the extremity of the beak. It is narrow and slightly elevated above the general contour of the shell on the umbonal region, becoming moderately elevated anteriorly, where it is subrounded to subangular.

The dimensions (in mm) of five disassociated valves are:

DORSAL VALVE

SPECIMEN	LENGTH	WIDTH
550	20.0	41.0
550a	18.0	34.0
550b	20.9	41.6
550c	19.0	40.4
Weller specimen (1914, p. 329)	24.8	41.0

VENTRAL VALVE

SPECIMEN	LENGTH	WIDTH
551	18.7	34.0?
Weller specimen (1914, p. 329)	25.0	41.0

Internal features. Neither the cardinal area nor internal features were preserved on the New Mexico material.

Remarks. All the specimens found were very poorly preserved, having been exfoliated and extremely recrystallized. *S. tenuicostatus* constitutes one of the most characteristic fossils in the Kelly formation in the Ladron, Lemitar, and Magdalena Mountains. It has never been found as a complete specimen but is present generally as fragments in the crinoidal limestone. The New Mexico material compares very closely with Weller's (1914, p. 328-330) description, particularly in the nature of plical bifurcation on the lateral slopes, and in the mode of origin of plications on the sinus and fold. The New Mexico specimens, however, are not quite so long in proportion to width as Weller's examples, and their fold is slightly more pronounced than in typical S. *tenuicostatus.*

Horizon. Weller (1914, P. 33o) and Moore (1928) found the species to range from the Keokuk to Warsaw limestones in the midcontinent region. In New Mexico the species was identified from the Ladron Mountains by G. H. Girty (Dar-ton, 1917, p. 52). The writer has found the species to be abundant in the Kelly formation in the Ladron, Lemitar, and Magdalena Mountains.

Specimens studied. Six incomplete, exfoliated dorsal valves and 3 incomplete, exfoliated ventral valves are the basis for the above analysis. New Mexico Bureau of Mines and Mineral Resources, nos. 55o, 55r.

Spirifer grimesi Hall Pl.
3, fig. 35; pl. 4, fig. 1-2

Spirifer grimesi Hall and Whitney, 1858, Iowa Geol. Survey Rept., v. 1, pt. z (Pal.), p. 604; pl. 14, fig. 1-5.
Spirifera *grimesi* Keyes, 1894, Missouri Geol. Survey, v. 5, p. 79.
Spirifer *Grimesi* Hall and Clarke, 1895, Pal. of New York, v. 8, pt. 2, pl. 35, fig. 8, 16-19.
Spirifer *grimesi* Weller, 1914, Illinois Geol. Survey Mon. 1, p. 361-362; pl. 51, fig. 1-2; pl. 52, fig. 1-4; pl. 53, fig. 1-2.

Description. The shell is subelliptical in outline. The length is usually less than the width. The hinge line is shorter than the greatest width. The cardinal extremities are rounded or obtusely angular. The dimensions of one almost complete, but crushed and broken, specimen are: Width 91.0 mm, length 71.0 mm.

The ventral valve is strongly convex, the greatest convexity being posterior to the middle. The surface curves abruptly from a broad umbonal region to the cardinal margin, and more gently to the anterolateral extremities. The beak is pointed and incurved. The cardinal area is of moderate height and strongly arched, with the curvature strongest toward the beak. The delthyrium is large and broader than it is high. The lateral slopes are depressed toward the cardinal extremities, and each lateral slope is covered by 35 to 42 rounded, bifurcating plications. The sinus originates at the extremity of the beak as a uniplicate, sharply defined, narrow depression, which becomes less distinct anteriorly. At the anterior margin the sinus has 18 to 22 plications, which arise by bifurcation from the lateral plications.

Only one dorsal valve was found; this was badly crushed and broken. It is marked by plications like those of the opposite valve. The fold is broad and rounded, and is marked by plications like those on the sinus.

The surface of each valve bears concentric lines of growth, particularly on the anterior third.

Remarks. This species is the most common fossil in the Kelly formation of west-central New Mexico. However, generally only a fragment of the ventral umbonal region is preserved. Specimens preserving both valves are very rare.

S. *grimesi* belongs to a closely allied group of typically spiriferoid species, including S. *rowleyi* Weller and S. *logani* Hall. Weller (1914, p. 361-364) confessed his inability to distinguish them satisfactorily. S. *rowleyi* generally can be distinguished from S. *grimesi* by its much narrower and much more well-defined sinus, narrower umbonal region, more pointed beak, and smaller size. S. *logani* Hall generally can be distinguished from S. *grimesi* by its proportionately broader shell and greater length of the hinge line. The forms identified as S. *grimesi* from the Kelly formation have most of the gross characteristics of S. *grimesi* Hall as redefined by Weller; some examples, however, have characteristics which are reminiscent of S. *rowleyi,* and others are very strongly suggestive of S. *logani.*

Weller et al. (1948, p. 113-114) assert that the (S. *rowleyi)*S. *grimesi-S. logani* zone is characteristic of the Osagian series, although representatives of this line *(S. rowleyi)* first appear in the upper Kinderhookian. Moore (1928) cites the first appearance of *S. rowleyi* in the Pierson limestone (Kinderhook) and states that it is absent in beds younger than the lower Burlington. *S. grimesi* first appears in the lower Burlington and is present to the Keokuk. S. *logani,* according to Moore, is restricted to the Keokuk.

Horizon. This species is by far the most abundant brachiopod in the Kelly formation and is found throughout the Kelly sections.

Specimens studied. One almost complete but crushed individual and the umbonal region of 25 specimens were available for study. New Mexico Bureau of Mines and Mineral Resources, nos. 544, 545, and the University of Cincinnati Geological Museum, geol. cat., nos. 34526-3453o.

Genus BRACHYTHYRIS McCoy, 1844

Brachythyris suborbicularis (Hall)
P1.3, fig. 10-

Spirifer suborbicularis Hall and Whitney, 1858, Iowa Geol. Survey Rept., v. 1, pt. 2 (Pal.), p. 644.

---- Meek and Worthen, 1875, Illinois Geol. Survey, v. 6, p. 523-524; pl. 3o, fig. ra˜d.
Brachythyris suborbicularis Weller, 1914, Illinois Geol. Survey Mon. p. 374-376; pl. 61, fig. 1-8; pl. 6z, fig. 1˜1 2.

Description. The shell is suborbicular in outline and is wider than it is long. The cardinal extremities are rounded or obtusely angular.

The ventral valve is strongly convex; more so toward the umbo. The surface curves abruptly from the umbo to the cardinal margins; more gently towards the anterior lateral margins and cardinal extremities. The surface is slightly flattened at the cardinal extremities. The delthyrium is large, its width greater than its height. Each lateral slope has about 10 depressed, obscure, simple plications, the 3 or 4 on the lateral extremities being indistinct. The mesial sinus begins on the beak as a subangular depression; anteriorly it is less defined, broad, and shallow. On the anterior half of some shells the sinus bears a faintly depressed plication; on some individuals the lateral plications bifurcate, producing weak sinus plications. The valve is marked by obscure lines of growth which are more pronounced nearer the umbo. No dorsal valves were available for study.

The dimensions of five incomplete ventral valves are:

VENTRAL VALVE

SPECIMEN	WIDTH (mm)	LENGTH (mm)	HEIGHT (mm)
530a	38.0	28.0	11.5
530	30.0	31.0	12.0
531	28.0	26.5	13.0
531a	31.0	26.0	10.0

INTERNAL MOLD, VENTRAL VALVE

SPECIMEN 531b	
Total width of muscle field	7.5 mm
Length of adductor scars	12.5 mm
Length of diductor	12.5 mm

Internal structure. The muscle scars of the ventral valve are on the umbo. The diductor scars are longate-triangular; they are divided by a linear raised surface which bears the adductor scars. Campbell (1957, p. 76), in his studies on the New South Wales species *B. pseudovalis,* which is very closely related to the American *B. suborbicularis* (Hall), points out that there is considerable variation in the shape of the muscle scar.

Remarks. The specimens of B. *suborbicularis* from the Kelly formation agree in contour with Weller's (1914, pl. 61, fig. and pl. 62, fig. 1-12) illustrations. The specimens that have been found in the Kelly formation tend to be a little smaller than most of Weller's examples.

Horizon. B. suborbicularis was first described by Hall (1858, p. 644) from the Keokuk limestone. In the midcontinent it first appears in the lower Burlington and is present through the Warsaw limestone. Weller et al. (1948) cite a similar range for *B. suborbicularis.* The specimens described are from the Kelly formation, Paleozoic hogback, Ladron Mountains. Fragments of ventral valves of this species were collected in the Kelly formation in the Magdalena and Lemitar Mountains. *B. suborbicularis* is rather rare in the Kelly formation of west-central New Mexico.

Specimens studied. One internal mold of a ventral valve and four ventral valves were available for study. New Mexico Bureau of Mines and Mineral Resources, nos. 53o, 531.

Genus ATHYRIS McCoy, 1884

Athyris aff. *lamellosa* (Léveillé)

Pl. 4, fig. 17

Spirifer lamellosus Léveillé, 1835, Soc. geol. France Compte rendu, 1st ser., v. 2, pl. 39, fig. 21-23.
Athyris lamellosus Davidson, 1857, British Carboniferous Brachiopods Palaeont. Soc., p. 79-80; pl. 16, fig. 1, and pl. 17, fig. 6. *Athyris lamellosa* Herrick, 1888, Denison Univ., Sci. Lab., Bull., v. 3 p. 24.
---- Hall and Clarke, 1895, Pal. of New York, v. 8, pt. 2, pl. 46 fig. 16-20.
Girty, 1899, U. S. Geol. Survey Mon. 32, p. 561; pl. 71 fig. 7a.
---- Weller, 1914, Illinois Geol. Survey Mon. I, p. 465-467; pl 78, fig. 1-5, 15-20.
---- Branson, 1938, Missouri Univ. Studies, v. 8, no. 4, p. 28˜29 pl. 21, fig. 16-18.

The only representatives of the genus *Athyris* from the Kelly formation are two poorly preserved, exfoliated ventra valves and a posterior, left lateral fragment of another ex foliated ventral valve.

Description. The ventral valve is transversely subelliptica in outline and concave. The gretaest convexity is posterior to the middle. The surface curves strongly from the umbona region to the cardinal areas, and gently to the anterolatera and cardinal extremities. The umbonal region is large. The beak is large, pointed, and slightly incurved. Posterolatera margins meet at the beak at an angle of about 110 degrees they are almost rectilinear, with a slight convexity toward the(posterior. The cardinal extremities are rounded; likewise the anterolateral extremities. The sinus begins on the umbo as broad ill-defined depression, becoming deeper and more dis tinct anteriorly, and deflected somewhat abruptly as it ap

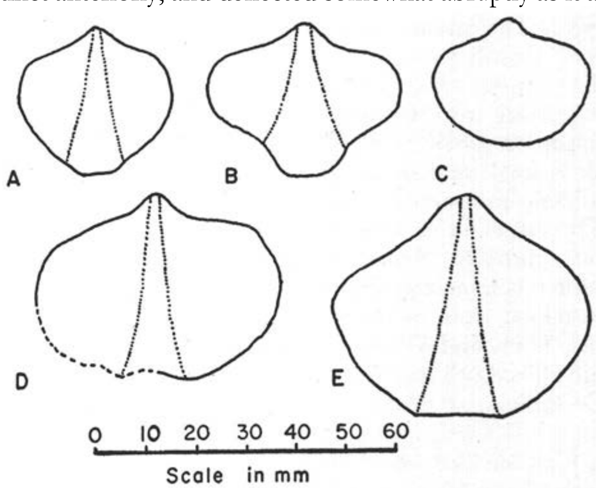


Figure 15

OUTLINES OF THE PEDICLE VALVE OP *A. lamellosa*

A. Davidson (1865).
B. Hall and Clarke (1895).
C. Girty (1899).
D. Weller (1914).
E. *A.* aff. *lamellosa,* Kelly formation.

proaches the opposite valve. The surface is marked by subparallel concentric lamellae.

Remarks. This *Athyris* from the Kelly formation differs from the *A. lamellosa* illustrated by Weller (1914, pl. 78, fig. 1) from the Keokuk limestone, Warsaw, Illinois, by having a much larger umbonal region and beak. Moreover, the beak of the New Mexico material is more pointed, and the posterior lateral margins are more linear. The specimens from the Kelly formation more closely resemble in contour Davidson's (1857, pl. 17, fig. 6a) *A. lamellosa*, but again the beak and umbo are much larger in the New Mexico specimens.

Weller (1914, p. 467) maintained that *A. lamellosa* is only moderately variable in its contour. Thus, it appears, on the basis of the larger umbonal region, larger, pointed beak, and somewhat rectilinear posterolateral margins, that the *A.* aff. *A. lamellosa* from the Kelly formation of west-central New Mexico represents a new species of *Athyris.* At this time, however, adequate material is not available upon which to base a description.

Horizon. Specimens studied were collected from the Kelly formation at the south end of the Paleozoic hogback, Ladron Mountains. New Mexico Bureau of Mines and Mineral Resources, no. 555. Fragments of this species also were observed in the Kelly formation in the Lemitar and Magdalena Mountains.

Genus CLEIOTHYRIDINA Buckman, 1906

Cleiothyridina hirsuta (Hall)

Pl. 3, fig. 12-13

Spirigera hirsuta Hall, 1857, Albany Inst. Trans., V. 4, p. 8.
Athyris hirsute Hall, 1883, Indiana Geol. Survey Ann. Rept., 12th Ann. Rept., p. 328; pl. 29, fig. 18-21.
---- Walcott, 1884, U. S. Geol. Survey Mon. 8, p. 222; pl. 18, fig. 5.
Cliothyris Roysii Hall and Clarke, 1895, Introduction to the Study of Brachiopods, pt. 2, pl. 46, fig. 23 (not fig. 24), Albany, N. Y.
Cliothyridina hirsuta Weller, 1914, Illinois Geol. Survey Mon. I, p. 479-480; pl. 8o, fig. 13-24.

Description. The shell is subpentagonal in outline and lenticular; its greatest width is at the middle of the shell. The cardinal extremities are rounded; the posterolateral margins are straight, meeting at the beak at an angle of 90 to 100 degrees. The anterolateral margins are curved, and the anterior is slightly truncated.

The ventral valve is more convex posterior to the middle. The surface curves abruptly to the cardinal margins and much more gently to the lateral and anterior margins. The beak is small and incurved. A very obscure broad sinus is detectable on some specimens.

The dorsal valve is as convex as the ventral; the surface curves abruptly from the umbo to the cardinal margins, sloping much more gently to the lateral and anterior margins. The mesial sinus is present on some specimens as a very broad, faint, and ill-defined depression. The dorsal beak is incurved beneath the beak of the opposite valve.

On individuals which have not been completely exfoliated, there are flat imbricating lamellose extensions of the shell, which are divided into flattened spines. Four of these spines occupy the space of I mm. When exfoliated, the shell is marked by fine concentric markings.

The dimensions of two specimens are:

SPECIMEN	WIDTH (mm)	LENGTH (mm)	THICKNESS (mm)
529	6.5	7.5	3.5
529a	8.0	7.3	4.0

Remarks. In contour, the presence of flat spines, and concentric markings, the specimens from the Kelly formation of west-central New Mexico resemble the examples of C. *hirsuta* illustrated by Weller (1914, pl. 8o, fig. 13-24).

Horizon. This species is present in the midcontinent in beds from Warsaw to Ste. Genevieve age (Weller, 1914, p. 480). A form which is very closely allied to, if not conspecific with, C. *hirsuta is Cleiothyridina tenuilineata* (Rowley), which ranges from Kinderhook through Burlington time. In southern New Mexico, Laudon and Bowsher report C. *tenuilineata* from the Kinderhookian Caballero formation and the Lower Osagian Lake Valley formation. The only known occurrence of C. *hirsuta* in New Mexico is in the upper half of the Kelly formation, in the Ladron, Lemitar, and Magdalena Mountains.

Specimens studied. Two complete, partly exfoliated individuals and some 20 disassociated individuals on small rock slabs were available for study. New Mexico Bureau of Mines and Mineral Resources, no. 529.

Cleiothyridina obmaxima (McChesney)

P1.4, fig. 8

Athyris obmaxima McChesney, 1861, Chicago Acad. Sci. Extract n. 2, p. 8o (fide S. Weller, Illinois Geol. Survey Mon. 1, 1914, p. 475).
Spirigera obmaxima White, 1877, U. S. Geol. Survey West of the 100th Mer., v. 4, p. 92; pl. 5, fig. 12.
Cleiothyris incrassata Weller, 1909, Geol. Soc. Am. Bull., v. 20, p. 313; pl. 14, fig. 8-1o.
Cliothyridina obmaxima Weller, 1914, Illinois Geol. Survey Mon. 1, P. 475-478; pl. 79, fig. 1.

Description. The shell is transversely subelliptical in outline. The greatest width is near the midlength. The cardinal extremities are rounded. The posterolateral margins are short and slightly curved. The ventral valve is strongly convex. The shell is strongly arched from the middle to the beak. The shell surface curves abruptly from the umbo to the cardinal area; the surface is more gently sloped to the cardinal extremities and anterior. The sinus is strongly developed on the anterior half of the shell and obsolete toward the beak. The sinus produces a weak lingual extension on the anterior margin. The beak is small, pointed, and incurved.

The surfaces of some well-preserved individuals have lamellae which are divided into flat spines, of which 3 or 4 occupy I mm.

DIMENSIONS OF TWO VENTRAL VALVES

SPECIMEN	WIDTH (mm)	LENGTH (mm)
547	62.0	46.0
547a	40.0	29.0

Remarks. Only two exfoliated and recrystallized ventral valves were found. Their characteristic subelliptical outline, size, strong and characteristic sinus, small beaks, and divided flat spines are all typical of C. *obmaxima.* According to Moore (1928), C. *obmaxima* ranges from the Fern Glen to the Warsaw in the midcontinent.

Horizon. Specimens described are from the Kelly formation, Paleozoic hogback, Ladron Mountains. Numerous fragments of C. *obmaxima* were observed in the Kelly formation, in the Lemitar and Magdalena Mountains. New Mexico Bureau of Mines and Mineral Resources, no. 547.

Genus DIELASMA King, 1859

Dielasma chouteauensis Weller

Pl. 2, figs. 1-7, 11-14, 17-28, 31

Dielasma formosa Hall and Clarke, 1895, Pal. of New York, v. 8, pt. z, pl. 8x, fig. 24 (not fig. 12-23 or 25-26).

Dielasma chouteauensis Weller, 1914, Illinois Geol. Survey Mon. r, p. 257-259; pl. 32, fig. 1-17.
---- Branson, 1938, Missouri Univ. Studies, v. 8, n. 3, p. 55-56; pl. 5, fig. 28-30.

Description. The shell is of medium size, subovate to obscurely subpentagonal in outline. The greatest width is near the middle. The anterior commissure is rounded to slightly subtruncate.

The pedicle valve is more convex posterior to the middle and is arched from beak to front along the median line, with the curvature progressively greater posteriorly. The mesial portion of the valve generally is slightly flattened between ill-defined lines, but in some specimens a slight sinus is present. The median sinus starts as a faint shallow depression behind the beak and widens to a very shallow concave depression at the anterior margin of the shell. The beak is prominent, pointed, and incurved, and pierced by an ovate foramen, which encroaches upon the umbonal region.

The dorsal valve is less convex than the pedicle. The valve is slightly flattened in the middle, becoming markedly more convex toward anterior and posterior margins. The brachial valve surface curves abruptly to the posterolateral margin and less abruptly to the anterior and anterolateral margins. The median portion of the valve is not differentiated as a fold or sinus. The beak is acutely pointed and incurved beneath that of the opposite valve.

Faint concentric lines of growth are present, becoming more obvious and crowded toward the anterior margin of large individuals. Weller (1914, p. 258) states that on well-preserved individuals the surfaces of both valves are marked toward the lateral and anterior margins by exceedingly faint, depressed radiating costae, about three of which occupy the space of I mm. Because of the poor nature of preservation of shell material, costae were not seen on the specimens taken from the Ladron Mountains.

There is the suggestion of a pattern of quincunx punctae on specimens which had some original shell material remaining. The dimensions of 12 nearly complete examples are:

muscular area concave; between the crural plate and the sockets are thin, narrow triangular grooves.

Remarks. Some of specimens of *Dielasma chouteauensis* from the Ladron Mountains have a shallow concave sinus on the ventral valve. The sinus begins as a faint impression on the umbo and is broad and conspicuous on the anterior margins. Weller (1914, p. 258) states that typical D. *chouteauensis* from the Chouteau limestone of Missouri has the mesial portion of the ventral valve slightly flattened between ill-defined lines, but that it is not depressed in a median sinus. Weller's illustrations of a specimen (1914, pl. 32, fig. 4) show the anterior commissure, which may indicate a very low, rounded sinus.

All the dorsal valves on the specimens studied from the Ladron Mountains were much more inflated than those illustrated by Weller. The most marked difference was on the anterior lateral margin. Weller's illustrated types are very gently curved to flat from the middle to the anterior margin of the shell. On all the examples of *D. chouteauensis* from the Ladron Mountains, the surface curves abruptly from the middle to the anterior margin.

The anterior margins of Weller's types are rounded; the majority of the examples of D. *chouteauensis* from the Ladron Mountains have slightly subtruncate anterior margins.

Horizon. Dielasma chouteauensis first appears in Missouri in the Chouteau limestone and is present throughout beds of lower Burlington age. The known occurrence of the species in New Mexico is in the Caloso formation, at the northwest end of the Cerro Colorado, southern Ladron Mountains. Scraps of a brachiopod which may be D. *chouteauensis* have been found in the basal dolomitic limestone of the Caloso formation, on the north side of Corkscrew Canyon, Lemitar Mountains.

Specimens studied. The study collection consisted of 12 ephebic internal molds, to which small amounts of original shell adhered, 2 neanic individuals, and 20 incomplete specimens. New Mexico Bureau of Mines and Mineral Resources, nos. 513, 518, 521, 522.

SPECIMEN	LENGTH (mm)	WIDTH (mm)	GREATEST WIDTH FROM ANTERIOR (mm)	THICKNESS (mm)	ANTERIOR COMMISSURE SINUS	COMPARISON WITH WELLER'S TYPES (DORSAL VALVE ONLY)
513	31.0	21.5	14.5	13.3	very weak	inflated
521	33.9	24.2	19.2	14.7	pronounced	strongly inflated
521a	31.4	21.8	—	15.4	absent	slightly inflated
518	35.2	22.2	15.2	17.3	absent	inflated
518a	33.9	21.8	14.7	15.4	absent	inflated
522	29.2	21.0	15.5	19.6	absent	slightly inflated
518c	30.3	20.5	14.0	—	absent	——
518d	30.3	21.1	—	14.8	——	inflated
518e	35.3	25.0	16.0	18.2	absent	strongly inflated
518f	35.1	24.5	13.6	18.0	absent	strongly inflated
518g	35.8	24.0	15.0	17.5	weak	strongly inflated
518h	38.8	25.5	16.3	20.0	weak	very strongly inflated

Internal structures. In the interior of the ventral valve the dental lamellae are very well developed. Adductor muscular scars are very obscure, originating at the beak between the dental lamellae and extending beyond the middle of the valve. The interior of the dorsal valve is marked by socket plates distinct from the crural plates. At the apex of the valve the crura originate as a V-shaped platform, with the center

Genus DIMEGELASMA Cooper, 1942

Dimegelasma neglectum (Hall)

Pl. 4, fig. 9-11

Spirifer neglectus Hall and Whitney, 1858, Iowa Geol. Survey Rept., v. r, pt. 2 (Pal.), p. 643; pl. 20, fig. 5.
---- St. John Meek and Worthen, 1875, Illinois Geol. Survey, v. 6, p. 523; pl. 3o, fig. 1c, 2a.

Spirifer pl. *neglecta* fig. Walcott, 1884, U. S. Geol. Survey Mon. 8, p. 217; 18, 10.
Spiriferella neglecta Weller, 1914, Illinois Geol. Survey Mon. 1, P. 415-416; pl. 64, fig. 5-9; pl. 65, fig. 1-4.
Dimegelasma neglectum Cooper, 1942, Washington Acad. Sci. Jour., v. 32, p. 232.
---- Cooper, 1943, in Shimer, H. W., and Shrock, R. R., Index Fossils of North America, p. 359; pl. 141, fig. 1-5.

Description. The width of the dorsal valve is much greater than its length, the maximum width being a little anterior to the hinge line. The dimensions of the dorsal valve are: Width, 62.o mm; length, 42.0 mm; thickness, 20.0 mm. The valve is very strongly convex, the surface being convex from the cardinal area to the anterolateral and anterior margins. The greatest curvature is from the anterior third of the valve to the commissure. The posterior cardinal extremities are slightly compressed, and the posterolateral margins are straight and meet at the beak at an angle of about 14o degrees. The cardinal extremities are rounded. The subangular, nonplicated fold is depressed progressively posteriorly on the umbo and becomes more rounded, broader, and very pronounced anteriorly. The cardinal area is very small. The beak is short and slightly incurved. Six simple, broad, and fiat plications are present on each lateral slope. The plicae arise at the beak and become stronger anteriorly. The furrows are narrow and shallow, becoming (as do the plications) less distinct toward the cardinal extremities.

The specimen studied is exfoliated, but obscure concentric lines (fine, about four per millimeter) of growth are observable on the shell. Regular "twilled cloth" endopunctae are present (see pl. 4, fig. 9).

Remarks. The only examples of this species available were two exfoliated dorsal valves. The distinctive contour of the shell, the unplicated fold, the 12 simple plications, and the "twilled cloth" endopunctate shell are characteristic of *Dimegelasma neglectum.* The contour of the Kelly formation specimen is very similar to Cooper's illustration (1943, pl. 141, fig.) of *Dimegelasma neglectum.* Figure 16 is a comparison, by means of outline drawings of the Kelly formation specimen, with Hall's (1858, pl. 20, fig. 5) type specimen of *Dimegelasma neglectum* from the Keokuk limestone. *Dimegelasma neglectum* is reported from the midcontinent of the United States only from beds of Keokuk and Warsaw age (Moore, 1928; Cooper 1943, p. 359).

Horizon. Kelly formation, south end of the Paleozoic hogback, Ladron Mountains, and Corkscrew Canyon, Lemitar Mountains.

Specimens studied. The only examples of this beautiful brachiopod were a dorsal valve of an ephebic individual found in the upper half of the Kelly formation, Ladron Mountains, and a neanic individual from the Kelly formation, Corkscrew Canyon, Lemitar Mountains. New Mexico Bureau of Mines and Mineral Resources, nos. 548, 549.

Genus PENTREMITES Say, 182o

Pentremites conoideus Hall

Pl. 3, fig. 1-9

Pentremites conoideus Hall and Whitney, 1858, Iowa Geol. Survey Rept., v. r, pt. 2 (Pal.), p. 655-656; pl. 22, fig. 8, 9, 10. ---- Ulrich, 1905, U. S. Geol. Survey Prof. Paper 36, p. 57; pl. 6, fig. 1-6.
---- Galloway and Kaska, 1957, Geol. Soc. Am. Mem. 69, p. 4243; pl. z, fig. 8-15; pl. 11, fig. 1-19; pl. 13, fig. 8.

For a more complete bibliography of the species, the reader is referred to Bassler and Moodey (1943, p. 238) and Galloway and Kaska (1957, p. 42).

Description. The calyx is conoidal, gradually contracting upwards from the radial lips. The ratio of length to width is 1.3 to 1.4. The summit is contracted; the base is subpyramidal; the horizontal section is pentagonal. The pelvis is about 3.4 mm long and is cup shaped. The basal angle (pelvic angle) is about 100 degrees. The ambulacra are 2.8 to 3.2 mm wide and strongly convex, with scarcely any rims. There are about 9 transverse ridges in 3 mm. The interambulacra are deeply concave. The deltoids are about 3.2 mm long, ending about 1.2 mm below the summit. Spiracles are triangular ovate, closely placed around the mouth. Hydrospire fold and ornamentation were not preserved on the specimens studied. The dimensions of the specimens studied are:

SPECIMEN	LENGTH (mm)	WIDTH (mm)	WIDTH OF AMBULACRA (mm)
526	11.4	8.7	3.4
527	11.7	8.4	3.0
528	5.9	5.1	2.5

Remarks. The examples of *Pentremites* from the Kelly formation are one nepionic individual, with a pelvic angle of about 6o degrees, and two late neanic specimens, with a pelvic angle of about loo degrees. Galloway and Kaska (1957) have given excellent descriptions and illustrations of the ontogenetic development of *Pentremites.* The Kelly formation

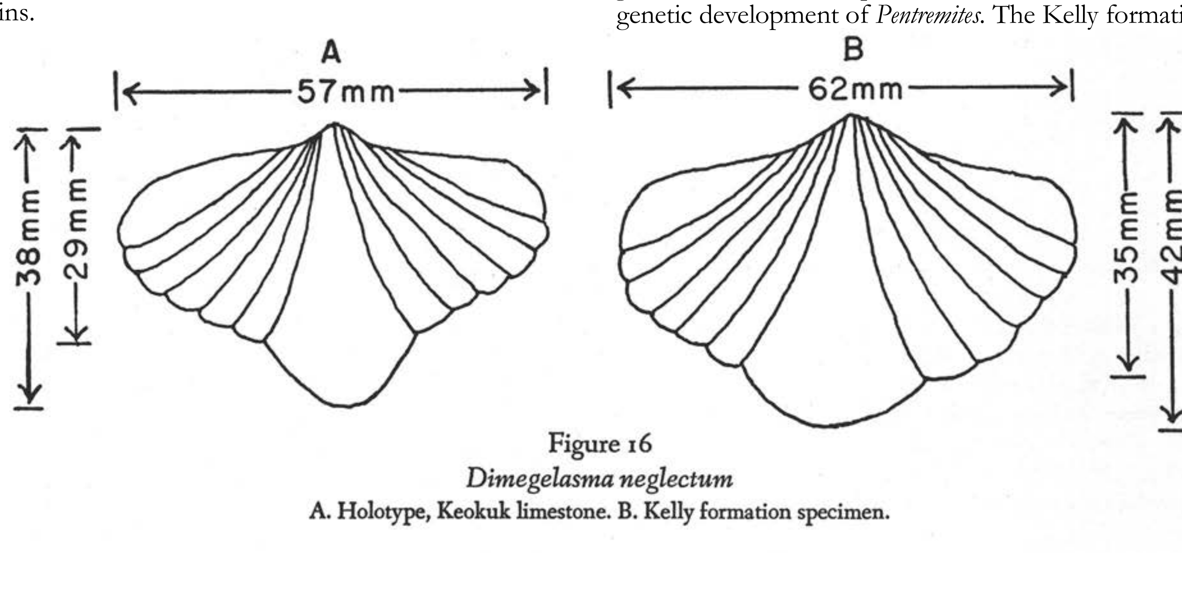


Figure 16

Dimegelasma neglectum

A. Holotype, Keokuk limestone. B. Kelly formation specimen.

specimens conform very well to the description of *Pentremites conoideus* Hall given by Galloway and Kaska (1957, p. 13-44; pl. 11, fig. 1-19). The Kelly formation specimens differ in that the ambulacra tend to be slightly wider than those figured by Galloway and Kaska. The latter remark (1957, p. 17-18) that the width of the ambulacrum varies with the ontogenetic stage and is not a reliable specific character.

Horizon. Although the apogee of *Pentremites conoideus* was apparently in beds of Harrodsburg and Salem age, the species is recorded from the Keokuk of Missouri (Galloway and Kaska, 1957, p. 43).

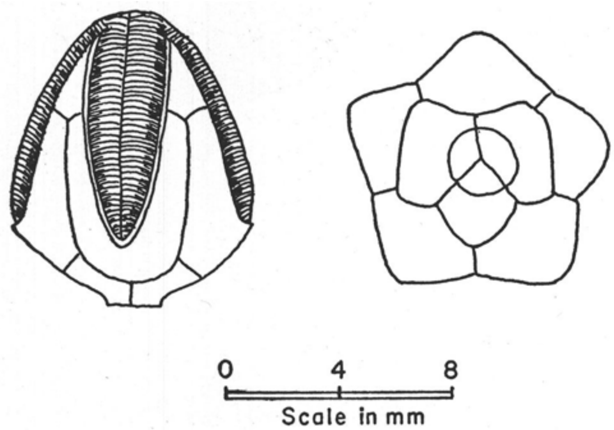


Figure 17

Pentremites conoideus

Diagrammatic representation of the plates of a specimen from the Kelly formation.

Neither the species nor the genus has been reported previously from New Mexico. *P. conoideus* occurs abundantly as broken and crushed thecae in the highest beds of fine-crystalline limestone in the Kelly formation in exposures in the Ladron, Lemitar, and Magdalena Mountains. Individuals do not weather free of the limestone but have to be broken out; therefore, a complete calyx is very difficult to obtain.

Specimens studied. Two ephebic and one neanic individual were available for study. New Mexico Bureau of Mines and Mineral Resources, nos. 526-528.

Genus ORBITREMITES Austin and Austin, 1840

Genotype. Pentremites derbiensis Sowerby (Zool. Jour. for 1825-1826, n. 7, pl. I 1, fig. 3).

The following is taken from a discussion of *Orbitremites* by Conkin (1957, p. 133):

> *Diagnosis.* [The characters of the genus are:] a deep basal concavity, two hydrospire folds under each ambulacrum, hydrospire pores throughout the entire length of the ambulacrum, radials longer than deltoids and five spiracles with one spiracle piercing the apex of each deltoid.

Orbitremites floweri, n. sp.

Pl.3, fig. 16-23

Description. The calyx is melon shaped (prolate); its greatest length is 12.2 its greatest width, 11.1 mm. The cross-section is circular. The basal plates are completely hidden in the columnar cavity. The size and shape of the stem column are unknown. Deltoids are 5.0 mm long and 5.0 mm wide at the radial deltoid suture. Radials are 8.2 mm high, 6.2 mm wide at the radial deltoid suture, and 2.5 mm wide at the base. The ambulacra are long and narrow, and extend the full length of the calyx. The width of the ambulacrum at the radial deltoid suture is 2.0 mm. Side plates are present, about 14 in 5 mm. Hydrospire pores are present the full length of the ambulacra. Hydrospire folds are present, two under each ambulacrum. The hydrospire fold is stalked, and the sac almost circular in horizontal section (fig. 18). The mouth is small. Spiracles are not well preserved but appear to perforate the deltoid plates. The anal spiracle is large and oval and is projected above the summit of the calyx toward the mouth. The anal projection is a hoodlike solid extension of the deltoid plate. Surface ornamentation is obliterated by

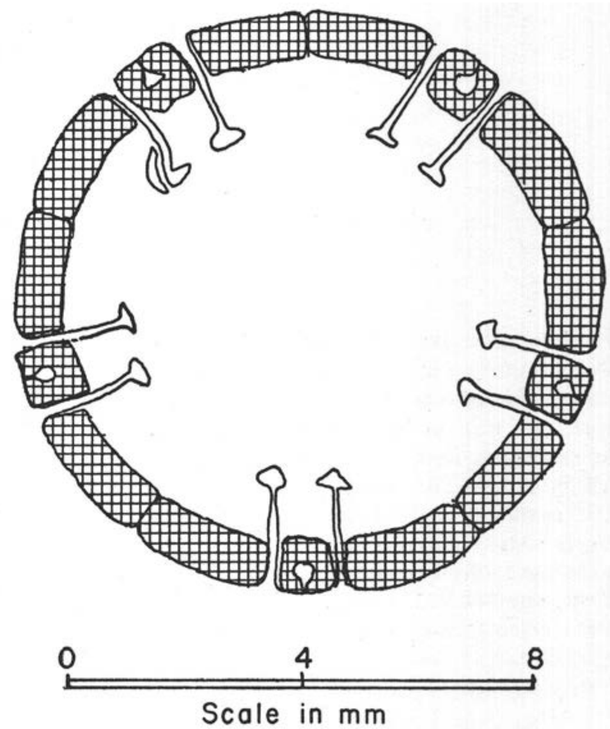


Figure 18

Orbitremites floweri

Diagrammatic representation of the hydrospire folds at midsection.

coarse recrystallization, although faint vestiges of chevron ornamentation were observed on the deltoids of some individuals.

Remarks. Some 20 specimens of *Orbitremites floweri* were collected for laboratory study. Also, a large number of broken and incomplete individuals were observed in the field. It is evident from the material examined that the holotype from the Kelly formation, Ladron Mountains, is a metaephebic individual.

The Kelly formation *Orbitremites floweri* shows closest affinity to the described species *Orbitremites granulatus* (Roemer) from the New Providence shale. *Orbitremites floweri* differs from *Orbitremites granulatus* in being one-half to one-third as large, in being much less gibbous, in having an anal hood or extension, and in apparently lacking the granulated surface. *Orbitremites granulatus*, when compared with *Orbitremites floweri*, displays a much more concave interambulacral area toward the distal portion of the calyx, and deltoids that are proportionately larger in relation to the calyx.

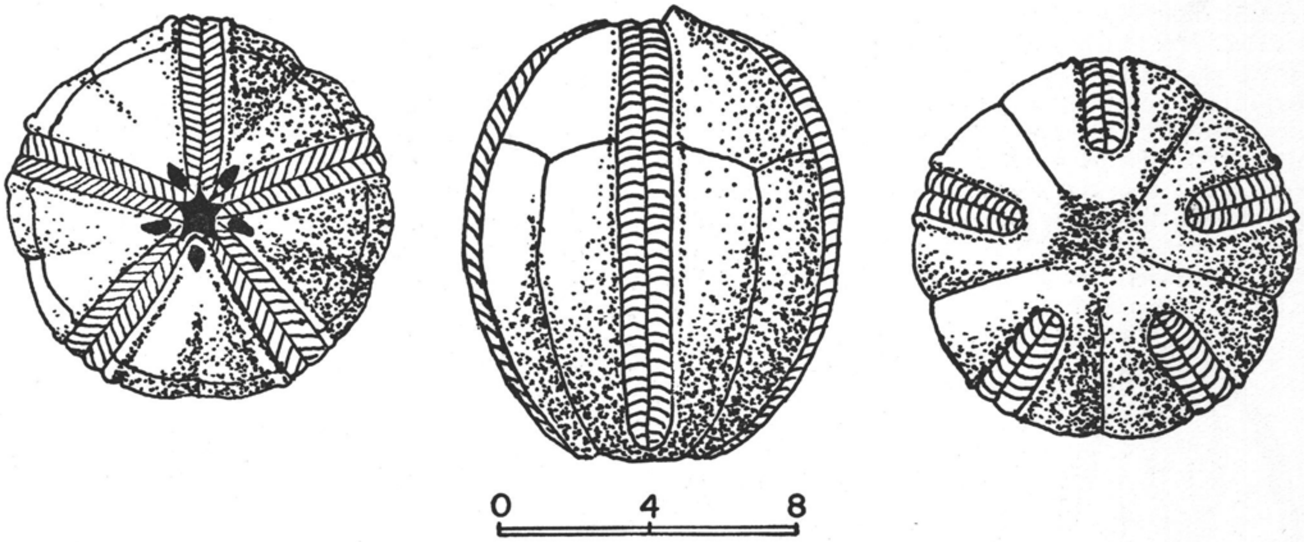


Figure 19
Orbitremites floweri
Diagrammatic representation of the plates.

Horizon. The genus *Orbitremites* appears to be restricted in North America to beds of Kinderhook and Osage age, with the exception of one very doubtful identification by Rowley (1900a, p. 69) in the St. Louis limestone of Illinois. The maximum development of the genus was in strata of Burlington age. The presence of *Orbitremites floweri* in the Kelly formation is the first known occurrence of the genus in New Mexico. 0. *floweri* occurs throughout the Kelly section in the Ladron, Lemitar, and Magdalena Mountains.

Specimens studied. Ten specimens were available for study. New Mexico Bureau of Mines and Mineral Resources, nos.
534, 535.

Genus ZAPHRIPHYLLUM Sutherland, 1954

Zaphriphyllum Sutherland, 1954, Geol. Mag., v. 91, n. 5, p. 363-365. ---- Hill, 1956, Treatise on Invertebrate Paleontology, pt. F (Coelenterata), p. F267.

Genotype. Zaphriphyllum disseptum Sutherland, Geol. Mag., v. 9,, n. 5, p. 364-365.

The following generic description is taken from Sutherland (1954, p. 363-364):

> Solitary trochoid corals which have numerous long major septa which tend toward a radial symmetry; a prominent well-developed cardinal fossula; tabulae arched periaxially and down-turned into the fossula; well-developed dissepimentarium, at least in ephebic stage.

Remarks. Sutherland (1954, p. 363-364) proposed the genus *Zaphriphyllum* for those zaphrentids which still possess a trochoid shape and pronounced cardinal fossula and consistently have dissepiments. These forms usually also show *a* tendency toward a radial arrangement of the septa in the immediate area of the cardinal fossula. *Zaphriphyllum* closely resembles *Amplexizaphrentis* Vaughan; except that, as Sutherland (personal communication) has pointed out, the latter is characterized by the absence, or very sparse and discontinuous development, of dissepiments.

Zaphriphyllum casteri, n. sp.

Pl. 5, fig. 1-7

The corallum is trochoid; epitheca is thin with rugae and striae. Oral surface or calice was not preserved on specimens studied. Calyx diameters in two paratypes are 36 by 34 mm and z8 by 26 mm. Cardinal fossula is on the concave side of the coral.

The late ephebic transverse section of the holotype (diameter 4o by 39 mm) shows 54 major septa which tend toward a radial symmetry. Minor septa are very short and rudimentary. Dissepiments are common. Tabulae are present. Right and left counter quadrants have 14 major septa, of which the first adjacent to each alar pseudofossula is much reduced. Alar pseudofossulae are obscure in the later ephebic stages but progressively more pronounced in earlier stages. A prominent, well-developed cardinal fossula is present.

In the early ephebic stage of the holotype (diameter 34 by 31 mm), there are 44 major septa. Minor septa are very short. Alar pseudofossulae are obvious. Dissepiments are common. Septal stereozones are well developed in the cardinal quadrants, where the septa are withdrawn from the axis.

The material available for study generally did not have the apical end present. Thus we are largely ignorant of the very early ephebic and neanic stages. The few specimens which had this part of the corallum were sectioned but, because of coarse recrystallization, generally lacked internal structure.

Remarks. Zaphriphyllum casteri, except for its consistently higher septa count and greater number of dissepiments, resembles Sutherland's (1954, p. 364-365) Z. *disseptum.*

Horizon. Sutherland (1954, p. 364) describes the genus *Zaphriphyllum* from interbedded shales and limestones of possible Middle Mississippian age from the Liard Range, Northwest Territory, Canada. Z. *casteri* is a very abundant fossil in the Kelly formation.

Specimens studied. Some 4o specimens were available for study, of which the vast majority were extensively recrystallized and broken. The specimens had apparently suffered

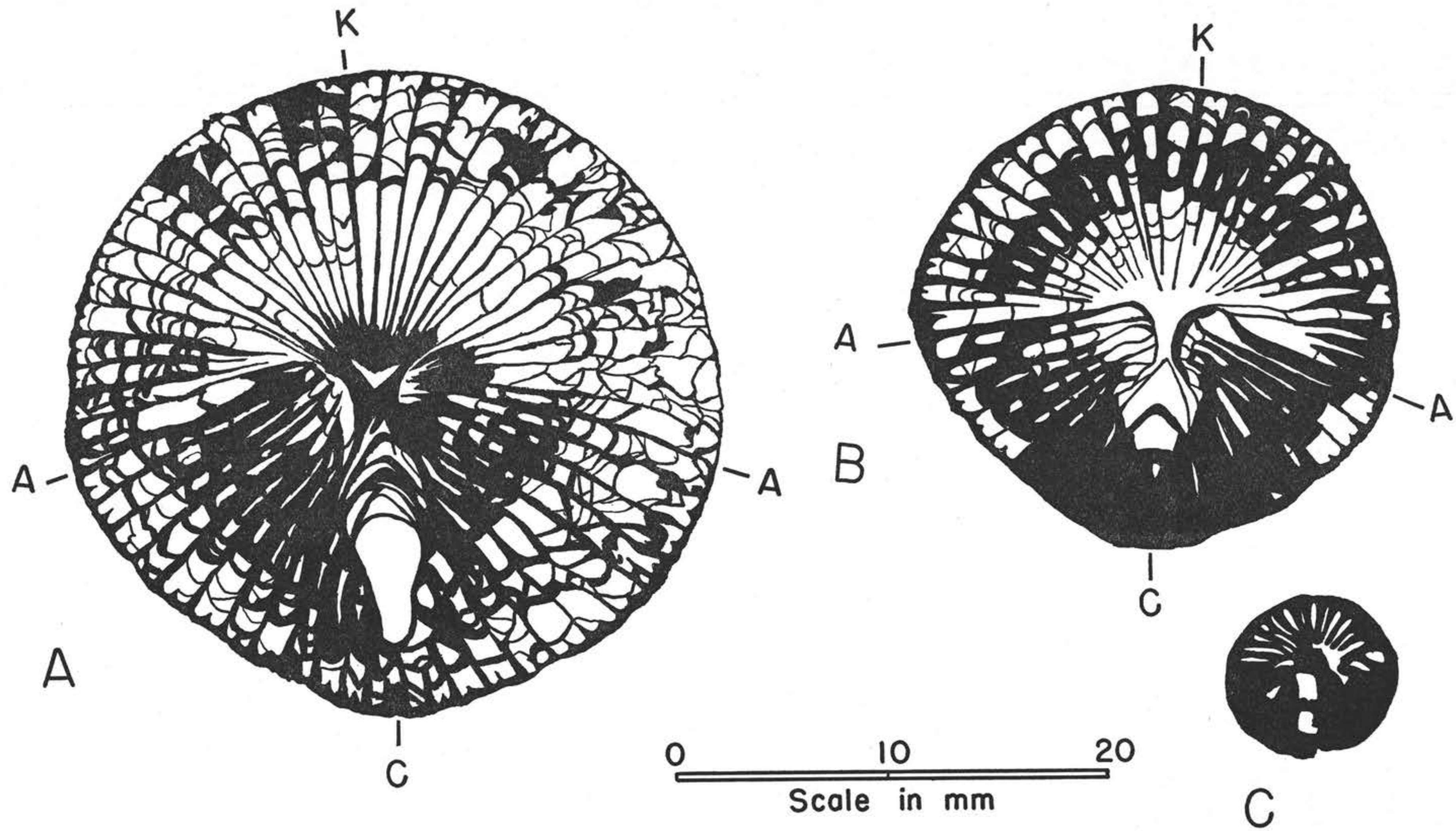


Figure 20

Zaphriphyllum casteri

Bleached inked photograph of thinsection. A. Late ephebic stage, illustrating (a) stereozones in cardinal quadrants and (b) numerous dissepiments. B. Early ephebic stage with extensive stereozones in cardinal quadrants; withdrawal of septa from center in counterquadrants. C. Very early ephebic stage. Extensive stereozones; lack of apparent dissepiment. [A, alar septum; C, cardinal septum; K, counterseptum.]

abrasion and breaking before burial and lithification. New Mexico Bureau of Mines and Mineral Resources, nos. 558 (holotype), 559-56o (paratypes).

Genus **PLECTOGYRA** Zeller, 1950

Plectogyra sp.

Description. The shell is from 0.4 to 0.5 mm in diameter. The coiling is plectogyroid; total angular distortion is moderate. The last two chambers are collapsed. The septa are directed anteriorly. A hamulus or hook is present in the last chamber. This same structure is reabsorbed partially in the next to last chamber. The aperture is low and is situated at the base of the apertural face. The tumuli do not appear to show positive evidence of reabsorption. Adult shells show 3 to 4 volutions.

Remarks. Crinoidal limestones, as pointed out by Zeller (1951), are an unfavorable environment for endothyrids. In about 40 thinsections from the Kelly limestones, only 5 poorly preserved and unoriented individuals could be found. The specimens, although too poor for specific identification, possess a distinct trait of stratigraphic value. In all specimens a collapsed structure is present in the final two chambers. Zeller (1951, p. 12) observed, with reference to the endothyrids, that the collapse of the final chambers is a specific trait of the majority of Keokuk forms in the midcontinent region. This phenomenon was not observed in horizons above or below the Keokuk.

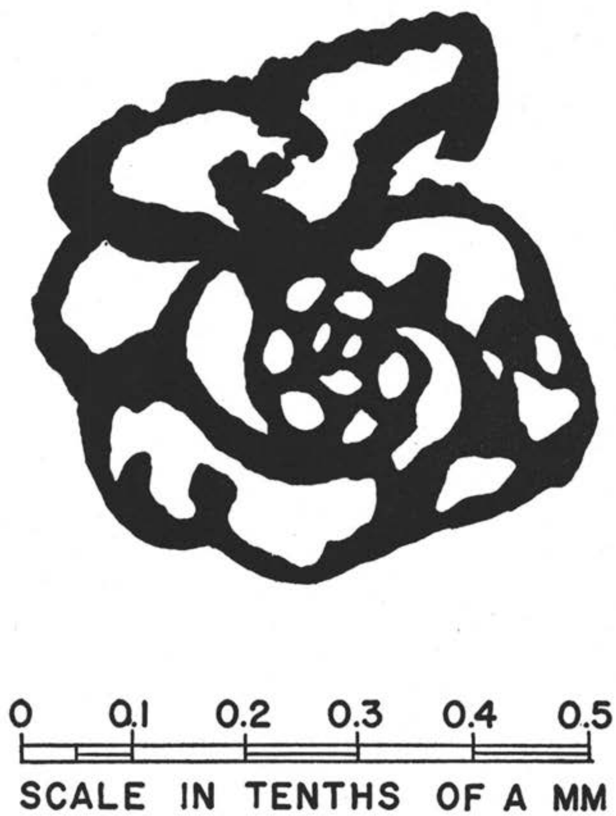


Figure 21

Plectogyra sp.

Slightly oblique horizontal section of a specimen from the middle of the Kelly formation, Magdalena Mountains. Final two chambers distorted or collapsed.

References

Armstrong, A. K. (1955) *Preliminary observations on the Mississippian system of* northern *New Mexico,* N. Mex. Inst. Min. and Technology, State Bur. Mines and Mineral Res. Circ. 39, 4z p.

---- (1958) *Meramecian (Mississippian) endothyrid fauna from the Arroyo Peñasco formation, northern and central New Mexico,* Jour. Paleontology, v. 3z, n. 5, 970-976.

Bassler, R. S., and Moodey, M. W. (1943) *Bibliographic and faunal index of Paleozoic pelmatozoan echinoderms,* Geol. Soc. Am. Spec. Paper 45, 733 p.

Branson, E. B., et al. (1938) *Stratigraphy and paleontology of the Lower Mississippian of Missouri,* pt. I-II, Missouri Univ. Studies, v. 13, n. 13-14.

Campbell, K. S. W. (1957) *Lower Carboniferous brachiopod-coral fauna* from *New South Wales,* Jour. Paleontology, v. 31, n. 34-98.

Conkin, J. E. (1957) *Stratigraphy of the New Providence formation (Mississippian) in Jefferson and Bullitt Counties, Kentucky,* and *fauna of the Coral Ridge member,* Bull. Am. Paleontology, v. 38,n. 168, 1-152.

Cooper, G. A. (1944) *"Phylum brachiopoda,"* in Shimer, H. W., and Shrock, R. R., Index fossils of North America, New York, John Wiley & Sons, Inc., 277-365, pl. 105-543.

Darton, N. H. (191 *7) A comparison of Paleozoic sections in southern New Mexico,* U. S. Geol. Survey Prof. Paper 108-C, 31-55.

Davidson, T (1857) *British Carboniferous brachiopoda,* Paleont. Soc. (London) Pub., 1-288.

Dunbar, C. 0., and Condra, G. E. (1932) *Brachiopoda of the Pennsylvanian system in Nebraska,* Nebraska Geol. Survey Bull. 5, d ser.

Fenneman, N. M. (193r) *Physiography of western United States,* New York, McGraw-Hill Book Co., 534 p.

Fitzsimmons, J. P., Armstrong, A. K., and Gordon, M. (1956) *Arroyo Peñasco formation, Mississippian, north-central New Mexico,* Am. Assoc. Petrol. Geol. Bull., v. 40, 1935-1944.

Galloway, J. J., and Kaska, H. V. (1957) *Genus* Pentremites *and its species,* Geol. Soc. Am. Mem. 69, 1-104, pl. 1-13.

Gordon, C. H. (1907) *Mississippian formations in the Rio Grande valley, New Mexico,* Am. Jour. Sci., 4th ser., v. 24, 58-64.

Hall, J. (1893) *Thirteenth annual report of the State Geologist of New York, v. z* (Paleontology).

----, and Whitney, J. D. (1858) *Report of the Geological Survey of the State of Iowa,* Iowa Geol. Survey Rept., v. 1, pt. 2 (Paleontology).

Hill, Dorothy (1956) *Treatise on invertebrate paleontology,* edited by Moore, R. C., pt. F (Coelenterata), F233-F322.

Herrick, C. L. (1904) *Laws of formation of New Mexico mountain ranges,* Am. Geologist, v. 33, 301-312, 393.

Kelley, V. C., and Silver, Caswell (r952) *Geology of the Caballo Mountains, etc.,* New Mexico Univ. Pub., geol. ser., n. 4, 286 p.

King, William (1850) A *monograph of the Permian fossils* of England, Paleont. Soc. (London) Pub., 248 p., 38 pl.

Laudon, L. R. (1948) *Osage-Meramec contact,* Jour. Geology, v. 56, 288-302.

----, and Bowsher, A. L. (1940 *Mississippian formations of Sacramento Mountains, New Mexico,* Am. Assoc. Petrol. Geol. Bull., v. 25, 2107-2160.

----, and ---- (1949) *Mississippian formations of southwestern New Mexico,* Geol. Soc. Am. Bull., v. 6o, 1-87.

Loughlin, G. F., and Koschmann, A. H. (1942) *Geology and ore deposits of the Magdalena mining district, New Mexico,* U. S. Geol. Survey Prof. Paper 20o, 168 p., 38 pl.

Moore, R. C. (1928) *Early Mississippian formations in Missouri,* Missouri Bur. Geology and Mines, v. 21, 2d ser., 1-283.

Noble, E. A. (1950) *Geology of* the southern *Ladron* Mountains, *Socorro County, New Mexico, N.* Mex. Univ., unpublished M. S. thesis.

Palmer, A. R., Williams, J. S., and Reeside, J. B. (5956) *General geology of central Cochise* County, *Arizona,* U. S. Geol. Survey Prof. Paper 281.

Rowley, R. R. (1900a) *New species of crinoids, blastoids and cystoids from Missouri,* Am. Geologist, v. 25, 65-75.

– (1900b) *Descriptions of new species of fossils* from *the Devonian and Subcarboniferous rocks of Missouri,* Am. Geologist, v. 25, 261-273.

Stoyanow, A. (1948) *Some problems of Mississippian stratigraphy* in *southwestern United States,* Jour. Geology, v. 56, 313-326.

Sutherland, P. K. (1954) *New genera of Carboniferous tetracorals from western Canada,* Geol. Mag., v. 91, 361-37r.

Weller, J. M., et al. (1948) *Correlation of the Mississippian formations of North America,* Geol. Soc. Am. Bull., v. 59, 91-196.

Weller, S. (190i) *Kinderhook faunal studies. III. The faunas of bed no.* 3 to *no.* 7 at *Burlington, Iowa,* Acad. Sci. St. Louis Trans., v. II, 197-222.

– (1914) *Mississippian brachiopoda of the Mississippi Valley Basin,* Illinois Geol. Survey Mon. r, pt. r, 1-508; pt. 2,pl. 1-83.

Winchell, A. (1865) *Description of new species of fossils, from the Marshall group of Michigan and its supposed equivalent,* in other *States; with notes* on *some fossils of the same age previously described,* Acad. Nat. Sci. Philadelphia Proc., v. 17, 109-133.

Zeller, E. J. (195o) *Stratigraphic significance of Mississippian endothyroid* foraminifera, Kansas Univ. Contr. 7, art 4 (Protozoa).

Index

Numbers **in** *italics* indicate figures and plates; **boldface** indicates main references.

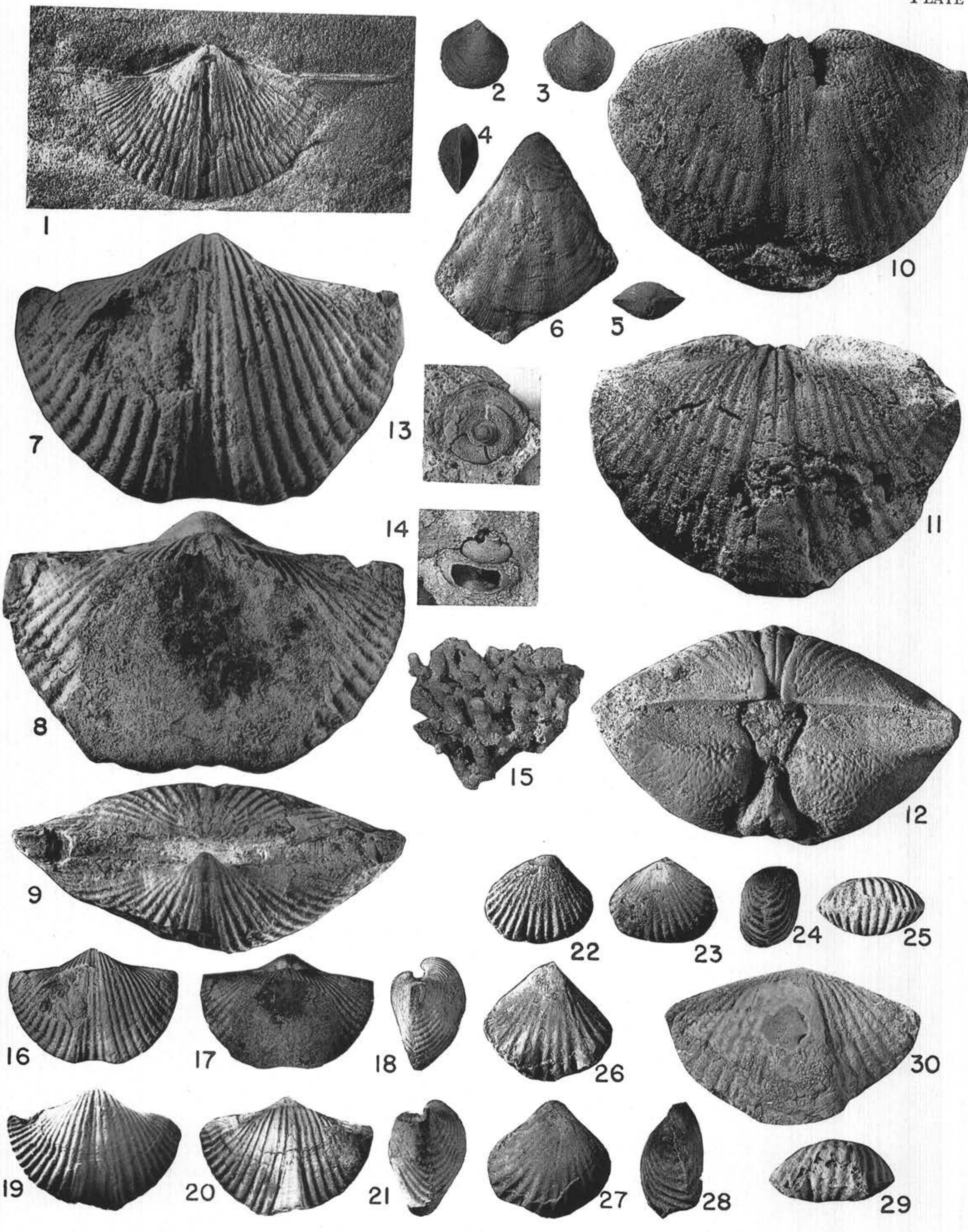
PLATES 1 - 6

WITH EXPLANATIONS

(Specimen numbers refer to the collection of the New Mexico Bureau of Mines and Mineral **Resources,** Socorro, New Mexico.)

PLATE 1

Figures		Page
1.	*Spirifer centronatus* Winchell . . . . Latex mold of the holotype. Ventral valve; the anterior and lateral extremities are not preserved. × 2. Holotype, University of Michigan Museum; latex mold, No. 503; from the Cuyahoga formation, Cuyahoga Falls, Ohio.	20
2-5.	*Composita?* sp. . . . . 2. Ventral valve. 3. Dorsal valve. 4. Lateral view, ventral valve on the right. 5. Anterior view, ventral valve on bottom. × 3. No. 504; from the Caloso formation, southeast side of Tip Top Mountain, Magdalena Mountains, New Mexico.	5, 6
6.	*Rhynchotreta?* sp. . . . . Ventral valve; note small plications on the posterior fifth of shell which radiate toward posterior lateral margins; surface of shell covered by fine radiating striae and concentric lines of growth. × 2.5. No. 505; from the Caloso formation, southeast side of Tip Top Mountain, Magdalena Mountains, New Mexico.	5
7-9.	*Spirifer centronatus ladronensis* . . . . 7. Ventral valve; note nature of sinual plications and the nonbifurcating plications on the lateral slopes. 8. Dorsal valve, with fold and adjacent areas eroded off. 9. Posterior view, illustrating cardinal area and origin of the sinus on the beak. × 2. No. 506; from the Caloso formation, southern Ladron Mountains, New Mexico.	21
10-12.	*Spirifer centronatus ladronensis* . . . . Internal mold of a typical specimen. 10. Ventral valve; note diductor muscle scars and two thin ridges for attachment of adductor muscles. Ovarian "pits" can be seen at front of valve. 11. Dorsal valve; note median septum. 12. Posterior view, with ventral valve oriented below dorsal. Note ovarian pits on ventral valve and median septum on dorsal valve. No. 507; from the Caloso formation, southern Ladron Mountains, New Mexico.	21
13-14.	*Straparolus luxus* (White) . . . . Two views of a typical example preserved in chert. × 1. No. 508; from the Caloso formation, southern Ladron Mountains, New Mexico.	5, 11
15.	*Aulopora* sp. . . . . A silicified individual which was etched from limestone. × 2. No. 509; from the Caloso formation, Lemitar Mountains, New Mexico.	5, 11
16-18.	*Spirifer centronatus ladronensis* . . . . Same individual as in figures 7-9. 16. Ventral valve. 17. Dorsal valve. 18. Lateral view. × 1. No. 506; from the Caloso formation, southern Ladron Mountains, New Mexico.	21
19-21.	*Spirifer centronatus* Winchell . . . . Photographs of the topotype, from Dr. E. Szmuc. 19. Ventral valve. 20. Dorsal valve. 21. Lateral view. × 1. Collection of Dr. E. Szmuc, Kent State University; from the Cuyahoga formation, Ohio.	20
22-25.	*Camarotoechia tuta* (Miller) . . . . 22. Ventral valve; note three plications in the sinus. 23. Dorsal valve. 24. Lateral view, with ventral valve to the left. 25. Ventral valve beneath dorsal valve; on anterior commissure, note development of sinus. × 3. No. 510; from the Caloso formation, Magdalena Mountains, New Mexico.	18
26-29.	*Camarotoechia tuta* (Miller) . . . . 26. Ventral valve. 27. Dorsal valve; note trace of median septum. 28. Lateral view, ventral valve on the right. 29. Posterior view, ventral valve beneath dorsal; note depth of fold. × 3. No. 511; from the Caloso formation, Magdalena Mountains, New Mexico.	18
30.	*Syringothyris?* sp. . . . . Dorsal valve, large nonplicated fold; specimen very poorly preserved. × 1.8. No. 512; from the Caloso formation, Coyote Hills, west of Bosque del Apache Fish and Wildlife Refuge, New Mexico.	5


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

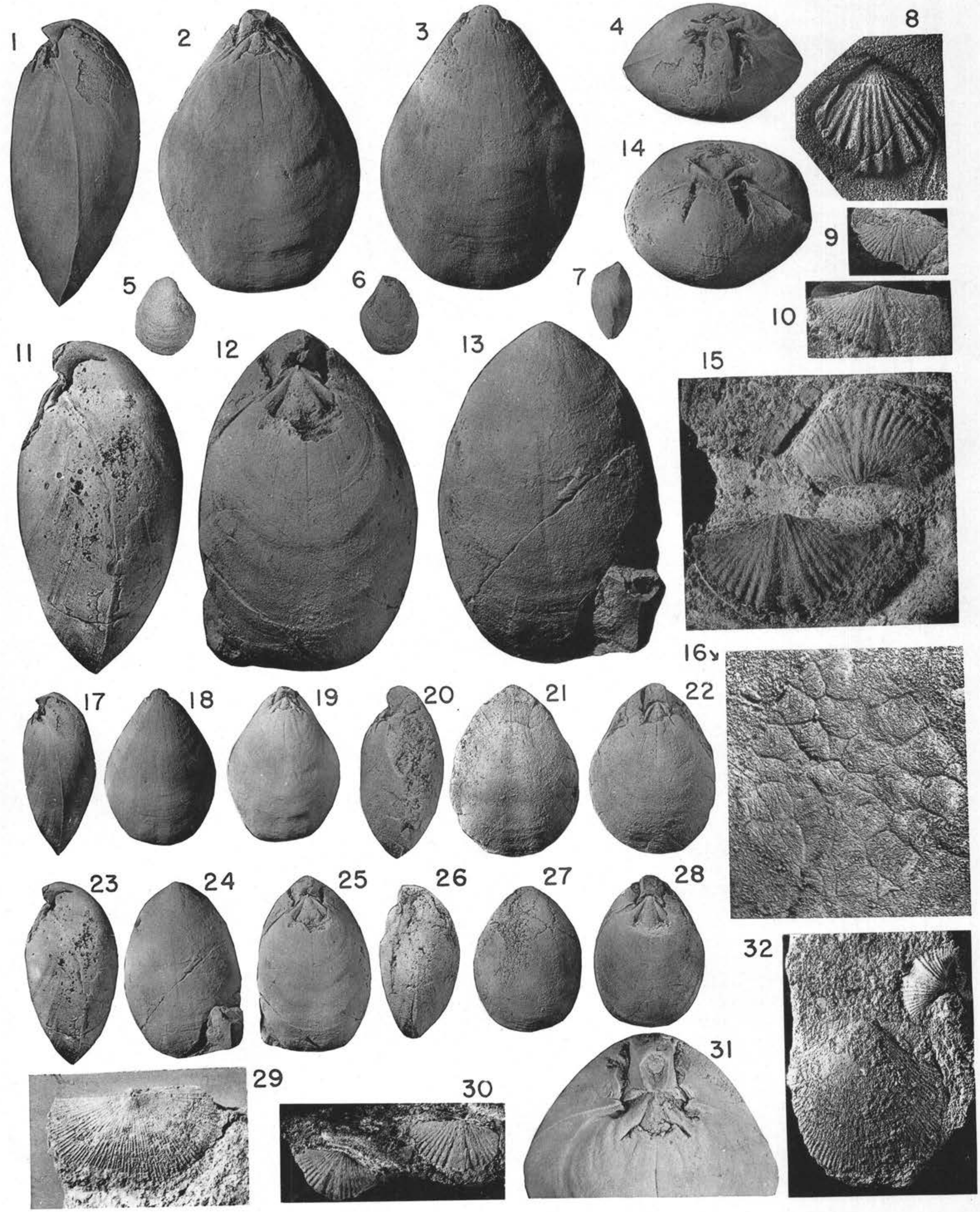

1
2
3
4
8
14
9
5
6
7
10
11
12
13
15
16
17
18
19
20
21
22
23
24
25
26
27
28
32
29
30
31

PLATE 2

Figures		Page
1-4.	*Dielasma chouteauensis* Weller . . . . Internal mold. 1. Lateral view, with ventral valve to the right; note the curvature of the commissure. 2. Dorsal valve, showing the crural (hinge) plate separate from the socket walls; also concentric lines of growth. 3. Dorsal valve. 4. Posterior view, with ventral valve beneath dorsal; note foramen. × 2. No. 513; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
5-7.	*Dielasma chouteauensis* Weller . . . . A neanic individual with an incomplete beak. 5. Ventral valve. 6. Dorsal valve. 7. Lateral view, with ventral valve to the right. × 1. No. 514; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
8.	*Camarotoechia tuta* (Miller) . . . . Individual preserved in chert. Ventral valve. × 3. No. 515; from the Caloso formation, Corkscrew Canyon, Lemitar Mountains, New Mexico.	18
9.	*Spirifer louisianensis* Rowley . . . . Dorsal valve, showing nature of the fold and plications. × 1.3. No. 516; from the Caloso formation, Magdalena Mountains, New Mexico.	22
10.	*Spirifer louisianensis?* Rowley . . . . Ventral valve of a large individual. × 1.3. No. 517; from the Caloso formation, Magdalena Mountains, New Mexico.	22
11-14.	*Dielasma chouteauensis* Weller . . . . Internal mold of a large individual. 11. Lateral view, with the ventral valve to the right; note lines of growth on both valves. 12. Dorsal valve, illustrating the separation of the dental sockets and the hinge plate. 13. Ventral valve. 14. Posterior view, with ventral valve beneath dorsal; note convergence of dental lamellae. × 2. No. 518; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
15.	*Spirifer louisianensis* Rowley . . . . Two disassociated ventral valves. × 2. No. 519; from the Caloso formation, Magdalena Mountains, New Mexico.	22
16.	*Michelinia* sp. . . . . Natural section of an individual. × 1. No. 520; from the Caloso formation, Magdalena Mountains, New Mexico.	5
17-19.	*Dielasma chouteauensis* Weller . . . . Internal mold. 17. Lateral view, ventral valve to the right. 18. Ventral valve. 19. Dorsal valve. × 1. No. 513; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
20-22.	*Dielasma chouteauensis* Weller . . . . Internal mold. 20. Lateral view, ventral valve to the right. 21. Dorsal valve; note development of a median sinus. 22. Dorsal valve. × 1. No. 521; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
23-25.	*Dielasma chouteauensis* Weller . . . . Internal mold. 23. Lateral view, ventral valve to the right. 24. Ventral valve. 25. Dorsal valve. × 1. No. 518; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
26-28.	*Dielasma chouteauensis* Weller . . . . Internal mold. 26. Lateral view, with ventral valve to the right. 27. Ventral valve. 28. Dorsal valve. × 1. No. 522; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
29.	*Schuchertella?* sp. . . . . An exfoliated and poorly preserved valve. × 2.2. No. 523; from the Caloso formation, Magdalena Mountains, New Mexico.	5
30.	*Spirifer louisianensis* Rowley . . . . The specimen to the right is a ventral valve with a well-developed median plication in the sinus. The specimen to the left is a dorsal valve. × 1.3. No. 524; from the Caloso formation, Magdalena Mountains, New Mexico.	22
31.	*Dielasma chouteauensis* Weller . . . . An oblique view of the dorsal valve, showing that crural plate is separate from the socket wells; note dental lamellae and foramen. × 3. No. 513; from the Caloso formation, southern Ladron Mountains, New Mexico.	26
32.	Pelecypod . . . . An exfoliated valve. To the right of the pelecypod is a ventral valve of *Spirifer louisianensis* Rowley. × 1.2. No. 525; from the Caloso formation, Magdalena Mountains, New Mexico.	5

PLATE 3

Figures		Page
1-3.	*Pentremites conoideus* Hall . . . . 1-2. Side views. 3. Ventral view. × 3.5. No. 526; from the Kelly formation, southern Ladron Mountains, New Mexico.	28
4-6.	*Pentremites conoideus* Hall . . . . 4-5. Side views. 6. Ventral view. × 3.5. No. 527; from the Kelly formation, Lemitar Mountains, New Mexico.	28
7-9.	*Pentremites conoideus* Hall . . . . 7-8. Side views. 9. Ventral view. × 3.5. No. 528; from the Kelly formation, Lemitar Mountains, New Mexico.	28
10-11.	*Brachythyris suborbicularis* (Hall) . . . . Ventral valve of two poorly preserved individuals; note weak development of plications on the lateral slopes and their absence in the sinus. × 1. Nos. 530, 531; from the Kelly formation, southern Ladron Mountains, New Mexico.	24
12-13.	*Cleiothyridina hirsuta* (Hall) . . . . 12. Ventral valve; note flattened spines on surface of valve. 13. Dorsal valve; this specimen illustrates a subpentagonal outline. × 2.5. No. 529; from the Kelly formation, southern Ladron Mountains, New Mexico.	26
14.	*Chonetes* cf. *illinoisensis* Worthen . . . . Ventral valve, which has been exfoliated, exposing the papillae "pits" on the cardinal extremities and anterior margin. × 2. No. 532; from the Kelly formation, southern Ladron Mountains, New Mexico.	17
15.	*"Phillipsia"* sp. . . . . × 3. No. 533; from the Kelly formation, southern Ladron Mountains, New Mexico.	4, 11
16-19.	*Orbitremites floweri*, n. sp. . . . . Holotype. 16-17. Side views; note ambulacra extending full length of calyx; radial plates slightly longer than the deltoid. 18. Ventral view. 19. Dorsal view, illustrating basal concavity. × 3.2. No. 534; from the Kelly formation, southern Ladron Mountains, New Mexico.	29
20-23.	*Orbitremites floweri*, n. sp. . . . . 20-21. Side views. 22. Ventral view. 23. Dorsal view. × 3.2. No. 535; from the Kelly formation, southern Ladron Mountains, New Mexico.	29
24.	*Rhynchopora persinuata* (Winchell) . . . . Ventral valve. × 1. No. 536; from the Kelly formation, southern Ladron Mountains, New Mexico.	20
25-27.	*Rhipidomella* sp. . . . . Ventral valves of three disassociated individuals; specimens exfoliated and poorly preserved. × 1. Nos. 537-539; from the Kelly formation, southern Ladron Mountains, New Mexico.	17
28-29.	*Spirifer?* sp. . . . . Disassociated valves of a common form. 28. Ventral valve; note angular plications and furrows. 29. Dorsal valve, with strong simple fold. × 1. Nos. 540, 541; from the Kelly formation, southern Ladron Mountains, New Mexico.	4
30.	*Spirifer?* sp. . . . . Dorsal valve. × 1. No. 542; from the Kelly formation, Lemitar Mountains, New Mexico.	4
31, 34.	*Tetracamera* cf. *subtrigona* (Meek and Worthen) . . . . Rostral section, showing the internal characters of the shell. 31. Section with the ventral valve above the dorsal; left third of ventral valve missing. Right side of ventral valve has dental lamellae with a buttress plate. The dorsal valve shows the absence of lamellae and the presence of a median septum with a subquadrangular hinge plate. × 2. 34. An enlargement showing the nature of the dental lamellae and the buttress plate. × 4.5. No. 543; from the Kelly formation, Magdalena Mountains, New Mexico.	19
32-33.	*Tetracamera* cf. *subtrigona* (Meek and Worthen) . . . . A large but crushed and distorted individual; flattened from the anterior, but with rostral portion intact. 32. Posterior view, showing median septum. 33. Anterior view, illustrating nature of commissure and plications. × 1.3. No. 543; from the Kelly formation, Magdalena Mountains, New Mexico.	19
35.	*Spirifer grimesi* Hall . . . . Ventral valve of an incomplete individual, illustrating an angular sinus characteristic of some *S. grimesi* and *S. rowleyi*. × 1. No. 544; from the Kelly formation, southern Ladron Mountains, New Mexico.	24

PLATE 3

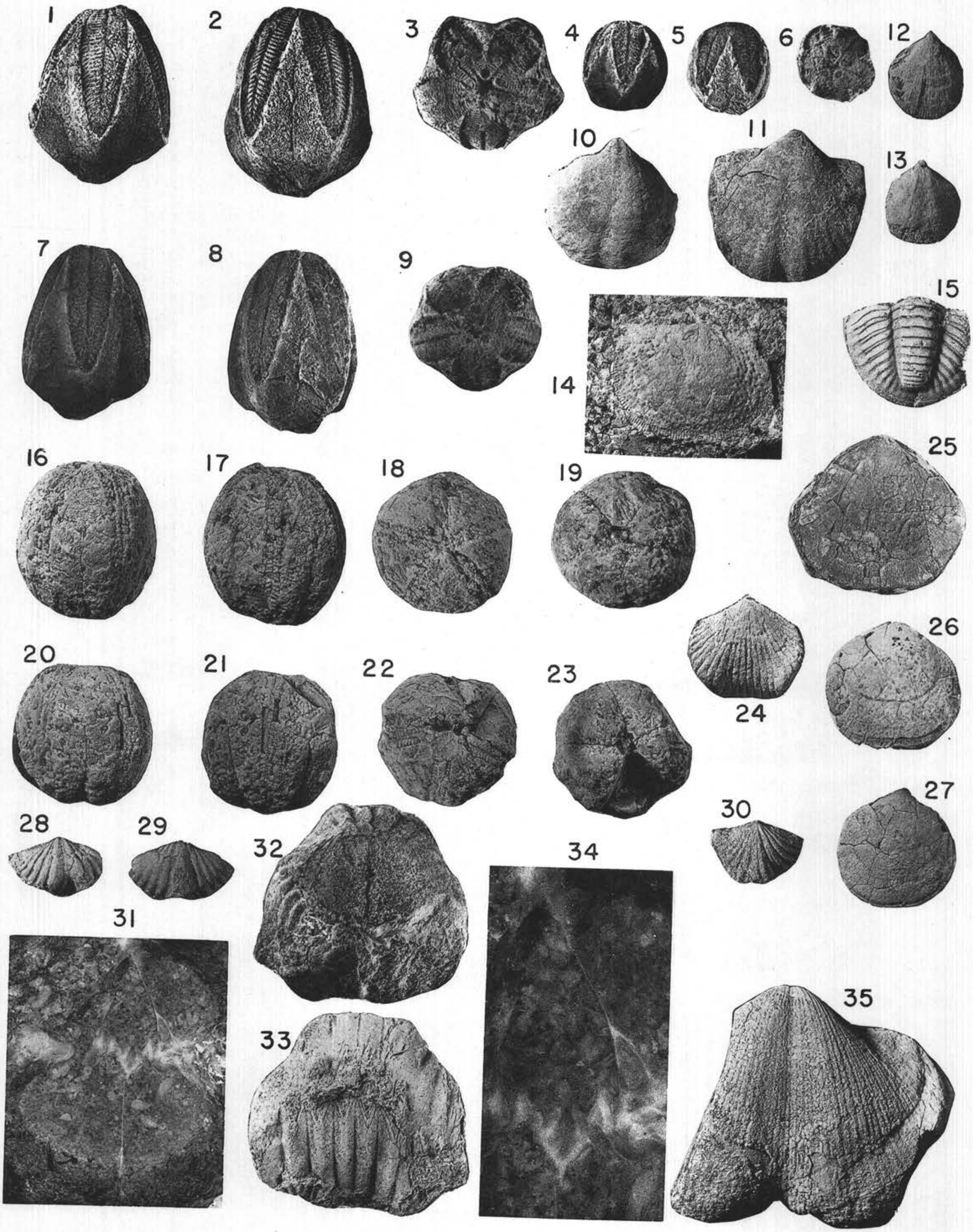

1
2
3
4
5
6
12
10
11
13
7
8
9
14
15
16
17
18
19
25
20
21
22
23
24
26
28
29
32
34
30
27
31
33
35

PLATE 4

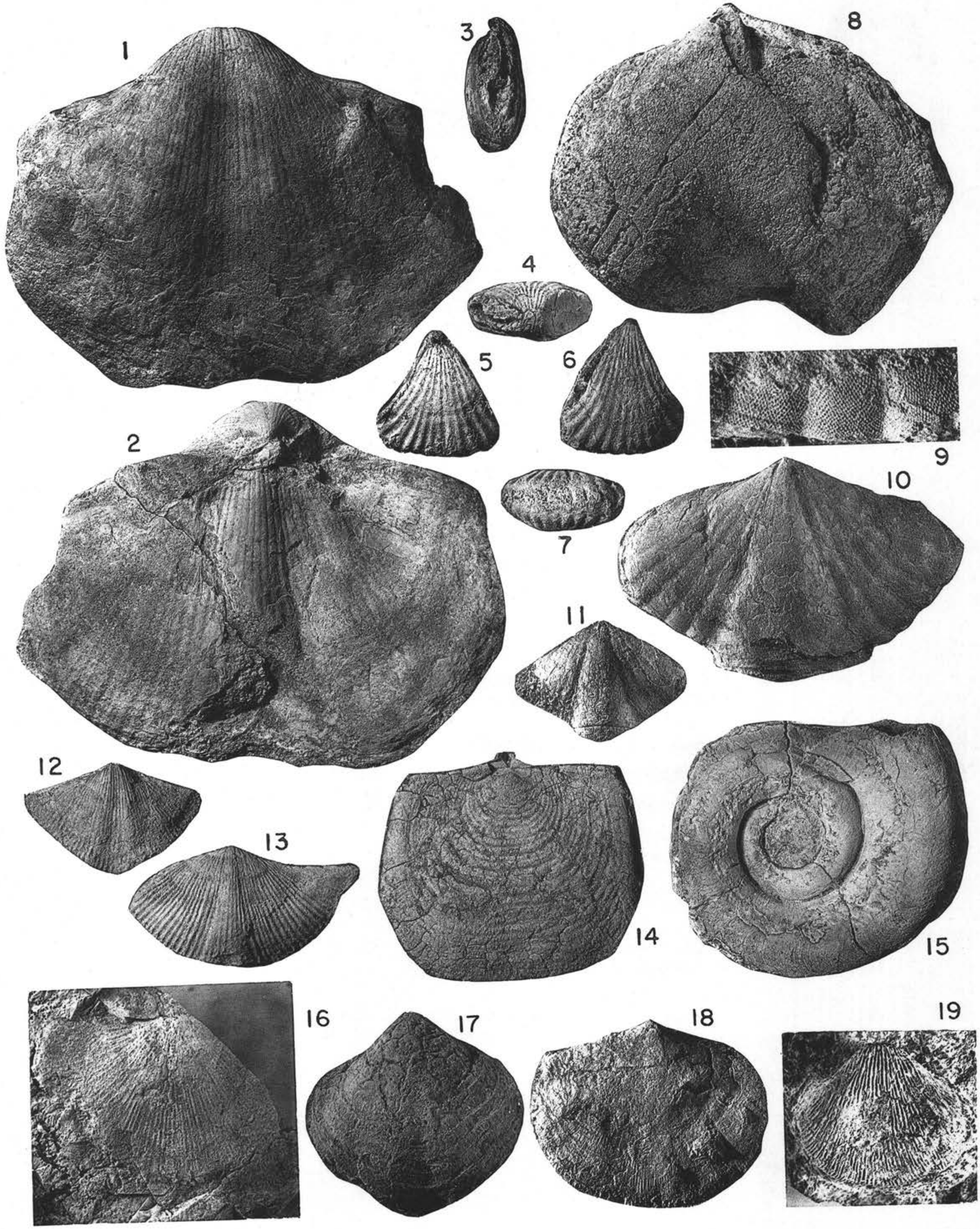


PLATE 4

Figures | Page

1-2. *Spirifer grimesi* Hall 24
A large, almost complete, specimen, but crushed; has the general proportions of *S. logani* Hall. 1. Ventral valve, with broad shallow sinus. 2. Dorsal valve, crushed; concentric lines of growth still present on the anterior portion of the shell. × 1. No. 545; from the Kelly formation, Magdalena Mountains, New Mexico.

3-7. *Tetracamera subcuneata* (Hall) 19
3. Lateral view, with the ventral valve to the right. 4. Posterior view, with the ventral valve beneath the dorsal. 5. Dorsal valve. 6. Ventral valve. 7. Anterior view, illustrating the absence of a fold and sinus. × 2.8. No. 546; from the Kelly formation, Lemitar Mountains, New Mexico.

8. *Cleiothyridina obmaxima* (McChesney) 26
Incomplete ventral valve. × 1. No. 547; from the Kelly formation, southern Ladron Mountains, New Mexico.

9-10. *Dimegelasma neglectum* (Hall) 27
9. Enlargement of the exfoliated shell surface, illustrating the "twilled cloth" endopunctae. × 3. 10. Dorsal valve of a mature individual. × 1. No. 548; from the Kelly formation, southern Ladron Mountains, New Mexico.

11. *Dimegelasma neglectum* (Hall) 27
Dorsal valve of a neanic individual. × 1. No. 549; from the Kelly formation, Lemitar Mountains, New Mexico.

12-13. *Spirifer tenuicostatus* Hall 23
12. Incomplete and exfoliated ventral valve. 13. Incomplete and exfoliated dorsal valve. Nos. 550, 551; from the Kelly formation, Magdalena Mountains, New Mexico.

14. *Productus*, sensu lato 4
Dorsal valve of a large individual. × 1. No. 552; from the Kelly formation, Magdalena Mountains, New Mexico.

15. *Straparolus?* sp. 4
Average-size individual. × 1. No. 553; from the Kelly formation, Magdalena Mountains, New Mexico.

16. "*Orthotetes?*" sp. 4
Incomplete individual preserved in chert; fragments of this type are common in the Kelly formation. × 1. No. 554; from the Kelly formation, southern Ladron Mountains, New Mexico.

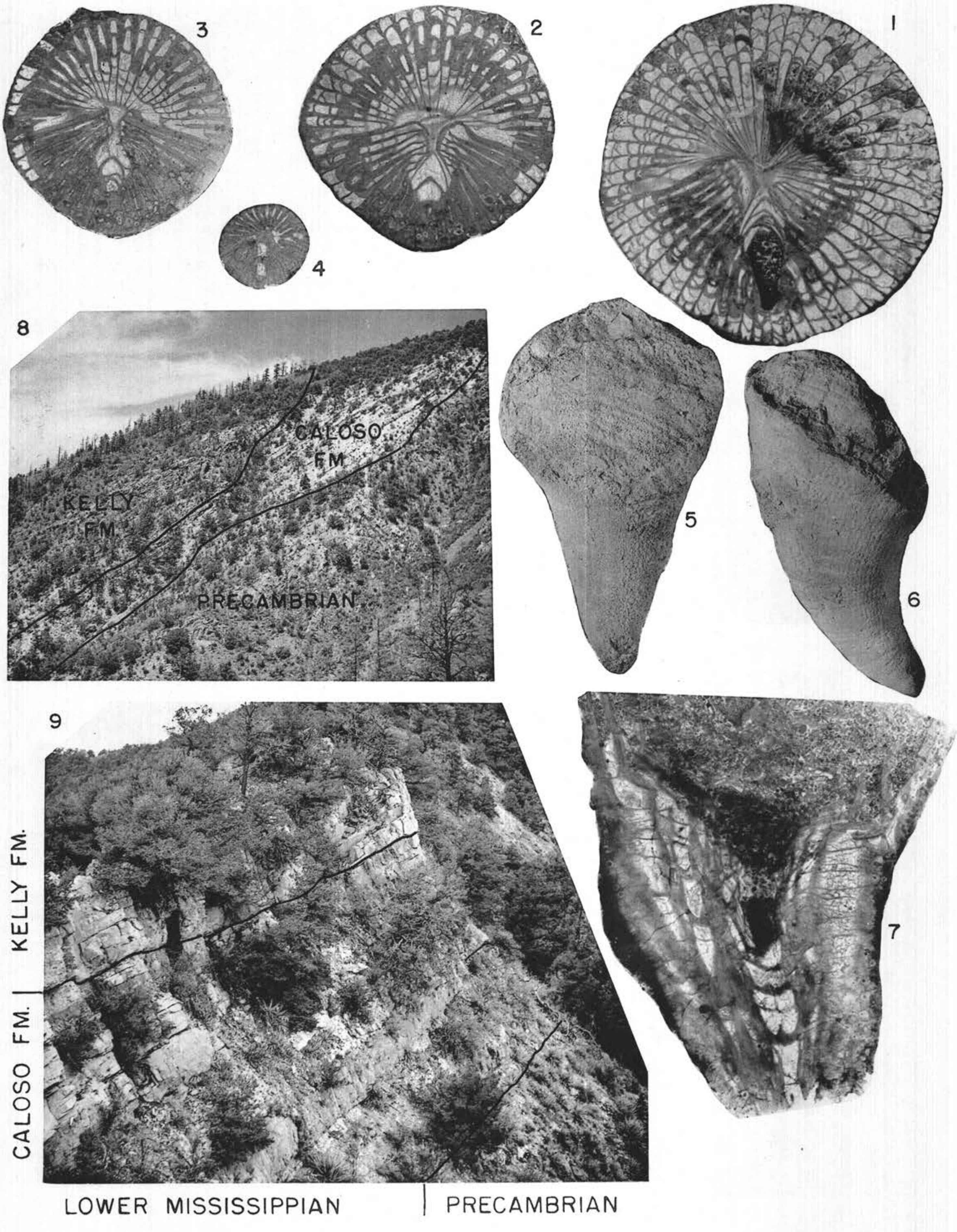
17. *Athyris* aff. *lamellosa* (Léveillé) 25
Exfoliated, but almost complete, ventral valve. × 1. No. 555; from the Kelly formation, southern Ladron Mountains, New Mexico.

18. *Streptorhynchus?* sp. 5
Exfoliated ventral valve. × 1. No. 556; from the Kelly formation, Magdalena Mountains, New Mexico.

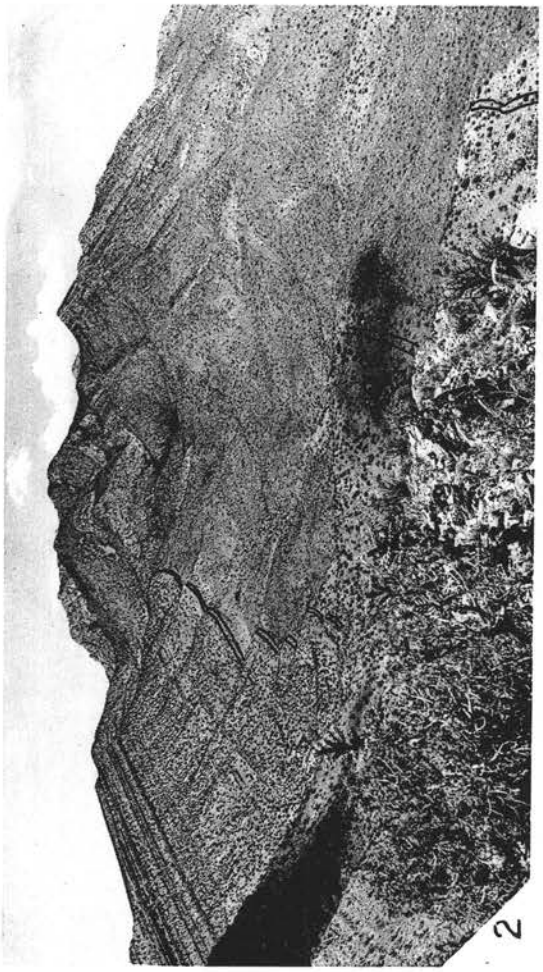
19. *Linoproductus* sp. 17
Incomplete ventral valve. × 1.2. No. 557; from the Kelly formation, southern Ladron Mountains, New Mexico.

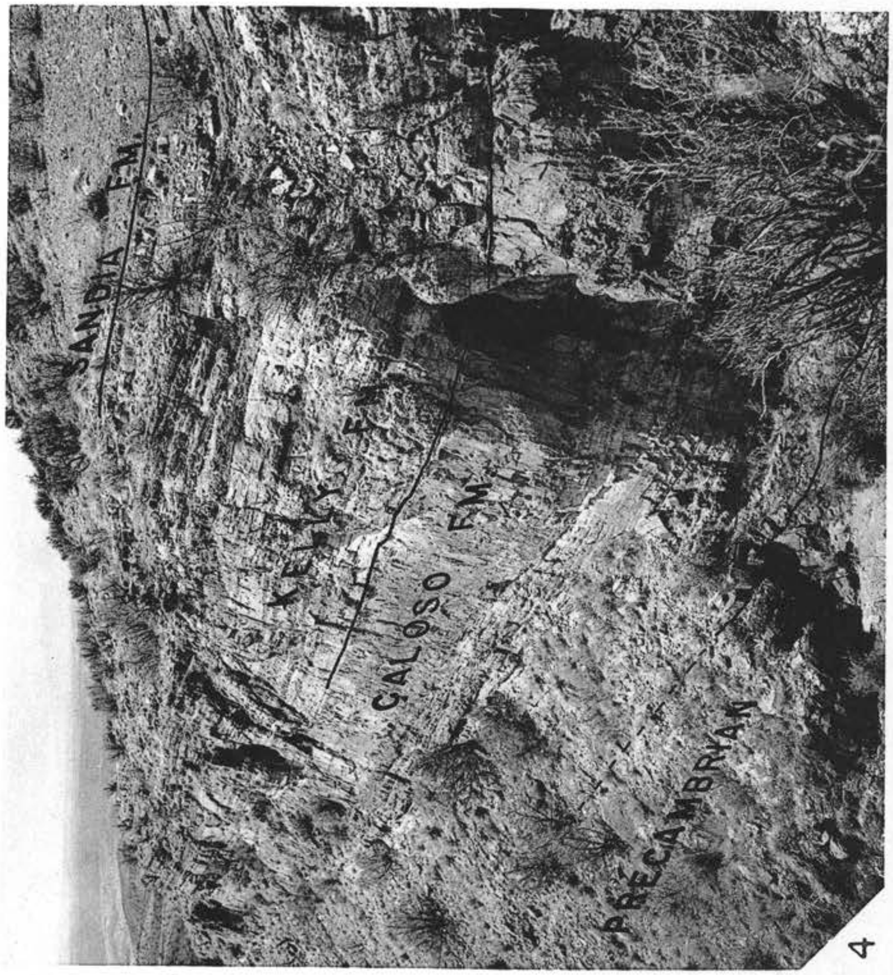
PLATE 5

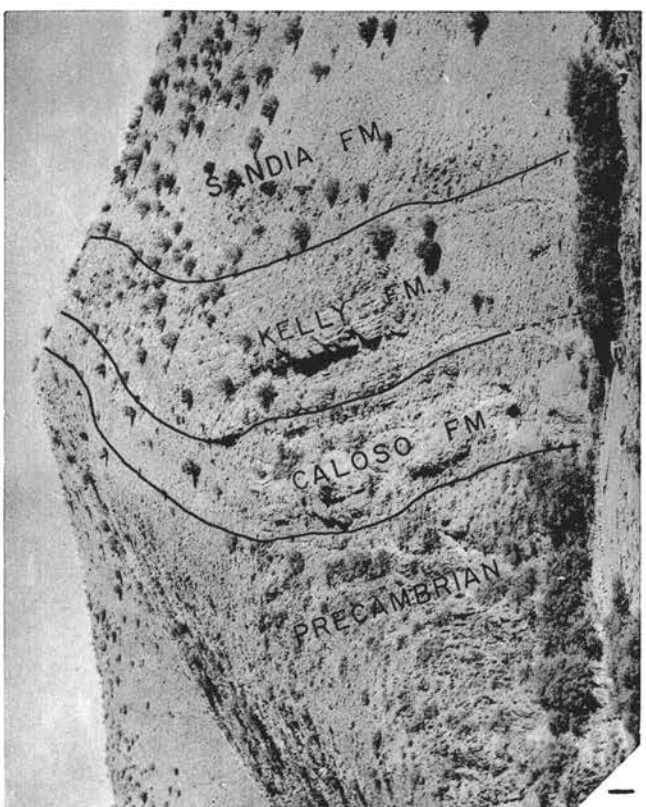
Figures		Page
1-7.	*Zaphriphyllum casteri*, n. sp. . . . . 1. Late ephebic stage; note rather abundant dissepiments, also indistinct alar pseudofossula. × 2. 2-3. Sections of an earlier ephebic stage; note more pronounced development of an alar pseudofossula and the well-developed stereozones in the cardinal quadrant. × 2. 4. Early ephebic stage, illustrating the compact stereozones in the cardinal quadrants and thick nature of the septa in the counterquadrants. × 2. Figures 1-4 are of the holotype. No. 558. 5. Cardinal side. 6. Left alar side. × 1. Paratype. No. 559. 7. Longitudinal section; note tabula. × 2. Paratype. No. 560. All specimens are from the Kelly formation, Ladron Mountains, New Mexico.	30
8.	View of the Kelly and Caloso formations on the north side of Chihuahua Gulch, Magdalena Mountains. Photograph taken on the opposite side of the gulch at an altitude of about 8,500 feet.	6
9.	East-facing Mississippian rock on the crest of the Magdalena Mountains, some 2,000 yards south of Tip Top Mountain. At this location, the upper portion of the Kelly formation is eroded and is exposed at progressively lower elevations on the western dip slope of the Magdalena Mountains.	6



1
2
3
4
5
6
7
8
CALOSO FM
KELLY FM.
PRECAMBRIAN
9
CALOSO FM.
KELLY FM.
LOWER MISSISSIPPIAN
PRECAMBRIAN


2


SANDIA FM.
KELLY FM.
CALOSO FM.
PRECAMBRIAN
4


SANDIA FM.
KELLY FM.
CALOSO FM.
PRECAMBRIAN
1

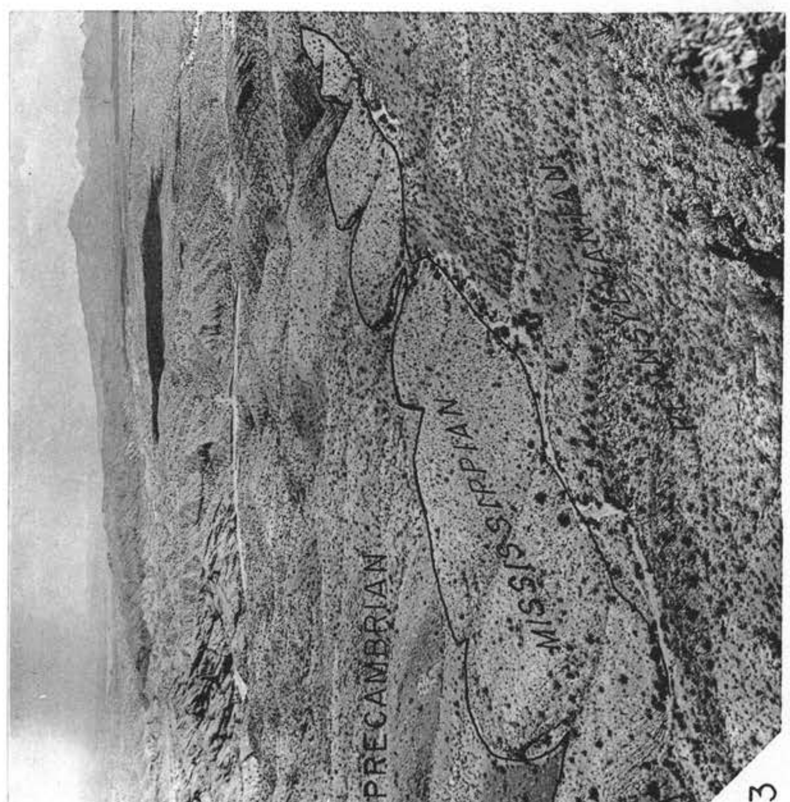

PRECAMBRIAN
MISSISSIPPIAN
PENNSYLVANIAN
3

PLATE 6

Figure 1

Correlation diagram of the Mississippian strata of west-central New Mexico