

MEMOIR 8

Stratigraphy and Paleontology
of the Mississippian System
in Southwestern New Mexico and
Adjacent Southeastern Arizona

By AUGUSTUS K. ARMSTRONG

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Abstract

The Mississippian system was studied in western Cochise County, Arizona, and in Luna, Hidalgo, and Grant Counties, New Mexico. The primary concern was with the Osage through Meramec Escabrosa limestone, its stratigraphy, paleoecology, and biologic contents. The Escabrosa limestone is regarded as a group and has been divided into two formations. These are, in ascending order, the Keating formation (Fern Glen to Burlington Osage), and the Hachita formation (Burlington Osage to St. Louis Meramec). The Escabrosa group has a minimum thickness of 650 feet in the Peloncillo Mountains and a maximum thickness of 1,000 feet in the Big Hatchet Mountains of New Mexico. In the area of this report, it is primarily an encrinite with minor amounts of micro-crystalline limestone. These sediments represent almost continuous deposition through all of Osage and Meramec time. The strata were deposited over a slowly sinking shelf area in shallow normal-marine waters.

The corals, brachiopods, blastoids, and endothyrids collected from the Escabrosa group are described and illustrated. The following new species were found: *Chonetes klondikia*, *Unispirifer balki*, *Amplexizaphrentis sonoraensis*, *Amplexizaphrentis northropi*, *Vesiculophyllum sutherlandi*, *Lithostrotionella lochmanae*, and *Michelinia leptosphragma*.

The late Meramec to middle Chester Paradise formation was studied and part of its brachiopod fauna described. The Paradise formation is an alternating series of medium-bedded limestones and shales, with a maximum thickness of 220 feet in the Big Hatchet Mountains. It thins rapidly to the north and to the west, and is only about 80 feet thick in the eastern Chiricahua Mountains of Arizona. The Helms formation of Chester age was studied in the Franklin Mountains and its coral fauna, including the new coral species *Koninickphyllum elpasoensis*, described.

Introduction

The Mississippian system in southwestern New Mexico and southeastern Arizona is represented by the Escabrosa limestone and by the locally present Paradise formation.

Previous published material on the Escabrosa limestone was lithostratigraphic studies done primarily in central Cochise County, Arizona. The extent and thickness of the Escabrosa limestone in New Mexico was an enigma.

The Escabrosa limestone is part of the extensive Cordilleran Osage-Meramec sequence. The fossil contents of these strata are little known. In the past these rocks have been correlated in broad generalities with the Mississippian type sections of the Midcontinent region. This generalized attitude was expressed for the sections in central Cochise County, Arizona, by Williams (in Gilluly, Cooper, and Williams, 1954, p. 12,) who "doubted that success would be obtained were attempts made to zone the Escabrosa."

The biostratigrapher is confronted with two problems when he attempts to zone the Escabrosa limestone and related formations in the Cordilleran region. The first problem is the poor preservation and fragmentary nature of the fossils within these rocks. Fossils are not abundant and are generally difficult to extract from the outcrop. The majority of the specimens are so poorly preserved that when they are studied in the laboratory, generic-level identification is difficult.

The second problem is that the fauna consists of two elements apparently derived from two biologic provinces. The brachiopod fauna consists of a large number of forms which are conspecific with described species from the Midcontinent region. In the Cordilleran region there is no assurance yet that these species have exactly the same stratigraphic range as they have in the Mississippi Valley. Furthermore, in many areas in the Cordilleran region there was continuous deposi-

tion and a stable environment throughout Osage and Meramec time. Within these sections, the generic lineages are vertically a series of intergrading species.

In marked contrast, the Midcontinent Osage and Meramec rock column is marked by a series of hiatuses. Each succeeding formation had a distinct environment and a distinctive fauna.

This study suggests that the Cordilleran Mississippian coral fauna is primarily indigenous to the area and is not represented in the Midcontinent region. Only a small part of this fauna has been described, and the stratigraphic range of the various species and genera is little known.

In an effort to correlate the Midcontinent and Cordilleran rocks, a systematic paleontologic study was made of the brachiopods (exclusive of productids), corals, blastoids, and endothyrids from the Escabrosa limestone. These paleontologic studies were combined with petrographic and insoluble-residue studies to deduce the depositional environment of the Escabrosa throughout Osage and Meramec time.

The investigation was conducted primarily in southeastern Arizona in Cochise County and in southwestern New Mexico in Luna, Hidalgo, and Grant Counties. Those strata which are adjacent to and a facies of the Escabrosa group were studied in considerable detail to ascertain their biologic and lithic relationships to the Escabrosa.

The Escabrosa limestone in this area is elevated to group status and subdivided into two new formations (fig. 1). They are, in ascending order, the Keating formation and the Hachita formation. The Keating formation consists of calcilitites and crinoidal limestones which range from Fern Glen (Osage) to Burlington (Osage) in age. The Hachita formation overlies the Keating formation without a discernible hiatus. The Hachita formation is a massive encrinite with a

maximum thickness of 360 feet and represents continuous sedimentation from Burlington (Osage) to St. Louis (Meramec) age.

Comparison is made between the brachiopod faunas of the Osage Lake Valley and Kelly formations of west-central New Mexico and the Escabrosa group. Part of the coral fauna from the Lake Valley formation west of the Rio Grande is systematically described.

The Meramec Black Prince limestone of central Cochise County, Arizona, is classified as an upper member of the Hachita formation, and its coral fauna is described.

PREVIOUS WORK

The first detailed investigations of the Mississippian system in southern New Mexico were done by Laudon and Bowsher (1941, 1949), in their studies of the Lake Valley and Rancheria formations. They did not extend these studies into extreme southwestern New Mexico to include the Escabrosa group. To the west, in central Cochise County, Arizona, Gilluly, Cooper, and Williams (1954) published a lithostratigraphic study on the Escabrosa and Black Prince limestones. The readily accessible section at Blue Mountain, Chiricahua Mountains, in extreme eastern Cochise County, Arizona, has received considerable attention. Hernon (1935) defined the age, paleontology, and stratigraphy of his Paradise formation at Blue Mountain. Sabins (1957b) demonstrated at the same section the precise boundary between the Devonian-Mississippian strata and named the Devonian rocks the Portal formation. E. J. Zeller (1957) described Mississippian species of *Endothyra* and *Millerella* from the upper part of the section at Blue Mountain. R. A. Zeller, Jr. (1958) described the thick, fossiliferous Mississippian section in the Big Hatchet Mountains as part of his detailed mapping and stratigraphic study.

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TERMINOLOGY OF LIMESTONE

LITHOLOGIES

Anyone who attempts to describe a thick sequence of limestones, such as the Escabrosa group, is immediately faced with the perplexing problem of limestone lithologic nomenclature. The terminology proposed by Pettijohn (1949), which is based primarily on description and origin, is used in a modified sense. These lithic terms, used in this report, are defined below. One of the most useful papers in deciphering limestone lithologies is that of Folk (1959). He convincingly demonstrated the origin of the various limestone petrofabrics. He also proposed an elaborate limestone nomenclature which does not seem to be any improvement on systems widely in use. Folk suggested that limestones are made of three carbonate-rock end members: (1) allochems, evidently transported or otherwise differentiated carbonate-rock bodies;

(2) 1 to 4 micron microcrystalline calcite-ooze matrix, and
(3) coarser grained and clearer sparry calcite, which in most rock forms as a simple pore-filling cement and only uncommonly forms by recrystallization. He recognized only four types of allochems as volumetrically important in limestones: (a) intraclasts, reworked fragments of penecontemporaneous carbonate-rock sediments, (b) oolites, (c) fossils, and (d) pellets (rounded aggregates of microcrystalline calcite, averaging .04 to .10 mm). Allochems provide the structural framework of carbonate-rock "sandstones"; microcrystalline calcite and sparry calcite are analogous with the clay matrix and chemical cement of sandstones.

Folk recognized three major families of limestone which he set up as the vertices of a triangle. Family 1 consists of abundant allochems cemented by sparry calcite; these are the cleanly washed limestones, analogous with well-sorted, clay-free sandstones and similarly formed in loci of vigorous currents. Family 2 consists of variable amounts of allochems embedded in a microcrystalline calcite matrix; these are the poorly-washed limestones that are analogous with clayey, poorly-sorted sandstones, and form in loci of ineffective currents. Family 3 limestones consist almost entirely of calcite ooze, hence are analogous with claystones.

GLOSSARY OF LITHOLOGIC TERMS

Most technical geologic terms convey different shades of meaning to different geologists. Terms are defined herein as the writer has applied them in this study, in order to clarify the geologic jargon for both professional geologists and laymen.

Arenaceous. Rock contains appreciable (but less than 50 percent) sand-sized grains of quartz.

Argillaceous. Rock contains appreciable (but less than 50 percent) clay.

- Arkosic.* Rock contains 10-to-25 percent elastic feldspar grains.
- Band.* Laminae or thin beds that differ in color rather than in grain size.
- Bedding.* Classification follows that of Maher and Lukert (1955, p. 1662):
 fissile—less than $\frac{1}{16}$ inch
 platy— $\frac{1}{16}$ to $\frac{1}{2}$ inch
 very thin-bedded— $\frac{1}{2}$ to 2 inches
 thin-bedded—2 to 4 inches
 medium-bedded—4 to 12 inches
 thick-bedded—12 to 36 inches
 massive-bedded—more than 36 inches
- Bioherm.* Moundlike, lenslike, domelike, or otherwise circumscribed mass, built mainly by sedentary organisms and enclosed in normal rock of different lithologic character.
- Biostrone.* Laterally extensive-bedded structures consisting of, and mainly built by, sedentary organisms.
- Calcarenite.* Limestones made up of elastic calcite grains and fragments of fossils that are at least in part sorted; fragments average larger than silt-size and would be called sandstone if the grains were predominantly quartz.
- Calclutite.* Even-laminated to crosslaminated limestone composed of silt or clay-size, apparently detrital, calcite grains; results from lithification of calcium carbonate muds.
- Calcirudite.* Rock resulting from lithification of detrital calcium carbonate materials predominantly larger than 4 mm in diameter.
- Cherty.* Sparse to abundant nodules, lenses, stringers, and/or flakes of chert. Chert may be subdivided into chalcedonic, smooth, porcelaneous, fine-granular, coarse-granular, and chalky.
- Coquina.* More or less cemented fossil-shell debris that has been transported some distance.
- Coquinoid.* Indurated fossil debris accumulated more or less in place.
- Crossbedded.* Beds characterized by included minor beds that are oblique and inclined to the main stratification.
- Dense.* Tightly cemented elastic rocks or crystalline rocks with very little pore space; used to indicate lack of porosity rather than aphanitic, microcrystalline, or lithographic texture.
- Dolomitic.* Crystalline carbonate rock containing appreciable (but less than 50 percent) dolomite, as estimated from action of dilute HCl.
- Encrinite.* Crinoidal limestones or crinoidal coquinas composed primarily of sorted and washed crinoid fragments.
- Facies.* Sedimentary facies, as defined by Moore (1949, p. 8), are really segregated parts of differing nature belonging to any genetically related body of sedimentary deposits.
- Intraclasts.* Fragments of penecontemporaneous, usually weakly consolidated carbonate-rock sediments that have been eroded from adjoining parts of the sea bottom and redeposited to form a new sediment.
- Marl.* Intimate mixture of incoherent clay and carbonates, ranging from limy shale to very argillaceous limestone; may be relatively compact.
- Microcrystalline calcite.* Calcite grains 1-4 microns in diameter, generally subtranslucent with a faint brownish cast in thinsection. In hand specimen, this is the dull and opaque ultra-fine-grained material that forms the bulk of "lithographic" limestones and the matrix of chalk, and may vary in color from white through gray, bluish and brownish gray, to nearly black.
- Quartzite.* Hard siliceous sandstone which, when broken, breaks across individual grains.
- Pellets.* These bodies are rounded, spherical to elliptical or ovoid aggregates of microcrystalline calcite ooze, devoid of any internal structure. They are probably invertebrate fecal pellets.
- Sandy.* Rock contains appreciable (but less than 50 percent) sand-sized grains of minerals, usually a mixture of quartz, calcite and others; contrasted with *arenaceous*, which is applied when elastic fragments are chiefly quartz.
- Shaly.* Rock contains appreciable (but less than 50 percent) clay and very fine silt, with fissile bedding.
- Siliceous.* Rock with cement of, or intimate replacement by, silica.
- Sparry calcite.* Usually simple pore-filling cement, precipitated in place within the sediments; usually forms grains or crystals 10 microns or more in diameter and is distinguished from microcrystalline calcite by its clarity and its coarser crystal size.

Stratigraphy

ESCABROSA GROUP

The Escabrosa limestone of Mississippian age (Kinderhook—Osage boundary through Meramec time) was named by Girty (1904, p. 42) for the Lower Carboniferous section in the Escabrosa Cliffs west of Bisbee, Arizona. It is separated by a paraconformity from the underlying late Devonian and by an unconformity from the overlying Pennsylvanian Naco formation. The name Escabrosa limestone was extended through Cochise County, Arizona, by the U.S. Geological Survey in reports dealing with various mining areas. Girty's (1904, p. 42-44) type section of the Escabrosa is in an area of considerable post-Paleozoic tectonic activity and is probably one of the poorest Escabrosa exposures in Cochise County. As a result of the complex structure, Girty found it impossible to determine the exact thickness of the Mississippian strata within the Bisbee quadrangle.

The Escabrosa limestone in western Cochise County, Arizona, and Luna, Hidalgo, and Grant Counties, New Mexico, is a thick sequence of carbonate rocks which represents a major portion of the Mississippian period. The Escabrosa limestone is elevated in this report to group status and is divided into two formations. These formations are, in ascending order, the Keating formation from the Kinderhook—Osage boundary through middle Osage age, and the Hachita formation of middle Osage through upper Meramec age (fig. 2, 3).

The Keating formation is a sequence of calcilitites and encrinites varying in thickness from 350 to 590 feet. The Keating formation ranges from highest Kinderhook—Fern Glen (Osage) to Burlington (Osage) in age. The Hachita formation conformably overlies the Keating formation and is a massive encrinite 250 to 350 feet thick. This sequence represents continuous sedimentation from Burlington (Osage) to St. Louis (Meramec) time. The type sections for these two new formations are the excellent exposures at the south end of Blue Mountain, Chiricahua Mountains, Arizona (SW¹, 4, sec. 20, T. 26 S., R. 30 E.).

KEATING

FORMATION Lithology

The name Keating is proposed for the basal formation of the Escabrosa group. The formation bears a fauna of Osage age and is divided by lithology into two members, which are called members A and B for simplicity. The name is derived from Keating Canyon, a few miles north of Blue Mountain in the Chiricahua Mountains, Arizona. The type section is on the southeast side of Blue Mountain (sec. 20, T. 26 S., R. 30 E.), Arizona. The thickest known section of the Keating formation is in the Big Hatchet Mountains of New Mexico, where some 590 feet are exposed. It thins to the west in the Chiricahua Mountains, north in the Peloncillo Mountains, and east in the Klondike Hills as a result of original deposition. South of Ajax Hill in the Tombstone Hills of Arizona it is some 360 feet thick and in the Klondike Hills of New Mexico it is 395 feet thick. From the Chiricahua Mountains of Arizona eastward, the Keating formation is readily divisible into two members.

Member A, stratigraphically the lowest, rests with a para

conformity on Upper Devonian strata. The basal unit of this member in most places is 50 feet thick and consists primarily of encrinite. Thinsections (pl. 10, fig. i) show a breccia of crinoidal remains which range in size from 0.2 mm to 9 mm. The larger fragments are worn crinoid columnals; the smaller ones appear to be broken crinoid columnals and plates. The pore space between the echinoderm fragments is filled primarily with microcrystalline ooze and, to a lesser degree, by sparry calcite. Some thinsections from this unit show large crinoid fragments suspended in microcrystalline ooze. The latter may comprise as much as 30 to 40 percent of the thinsection.

Insoluble residues show that the lower 20 feet of the Keating formation may contain a relatively high percentage of clay and fine-grained quartz sand. The sand grains average about 0.05 mm to 0.1 mm in diameter. The clay apparently is derived from the soil which existed upon the argillaceous Devonian limestones previous to the advance of Mississippian marine waters. At a horizon some 50 to 60 feet above the Devonian—Mississippian paraconformity, the crinoidal limestones contain very little argillaceous material but still have traces of fine-grained (0.01 mm) quartz sand.

A zone 20 to 50 feet thick in the upper part of member A is characterized by a prolific, diversified coral fauna. This horizon, which is very persistent over a wide area, is called in this report the "coral zone." The coral zone is typically a massive, dark-gray limestone with only minor amounts of nodular chert. It contains a megafauna of brachiopods and corals imperfectly silicified to brown chert on the surface of the rock. Thinsections from this horizon show a wide range of microlithologies. In the Klondike Hills the most characteristic rock is a limestone composed of bioclastic fragments which range in size from 0.3 mm to 0.5 mm. The bioclastic fragments are primarily broken crinoid plates and brachiopod shells, with lesser amounts of coral fragments and pellets. This material is cemented with microcrystalline ooze, and the small amount of original pore space is filled with sparry calcite. Some of the thinsections examined showed the microcrystalline ooze to be recrystallized, leaving the bioclastic material suspended in a matrix of sparry calcite.

The coral zone, from Blue Mountain eastward to the Klondike Hills, has highly oolitic microfacies within the massive limestones. A typical example (pl. 10, fig. 4) contains up to 75 percent oolites. They are generally spherical, show concentric lines of growth, and are between 0.5 mm to 1 mm in diameter. The average size is about 0.6 mm. The majority of oolites have as a nucleus a fragment of an echinoderm plate or a broken brachiopod shell. The space between the oolites is frequently filled with microcrystalline ooze and small fecal pellets about 0.2 mm in size. Sparry calcite composes less than 2 percent of the total rock, but in local patches all of the pore space is filled with this material.

A third type of limestone, which is common in the coral zone at Blue Mountain and present in most of the sections to the east, is a microcrystalline ooze in which occasional crinoid or brachiopod fragments are suspended. The microcrystalline ooze typically has microbedding planes which are caused by repeated layers of material with a slightly increased concentration of shale and organic matter. The microcrystalline ooze

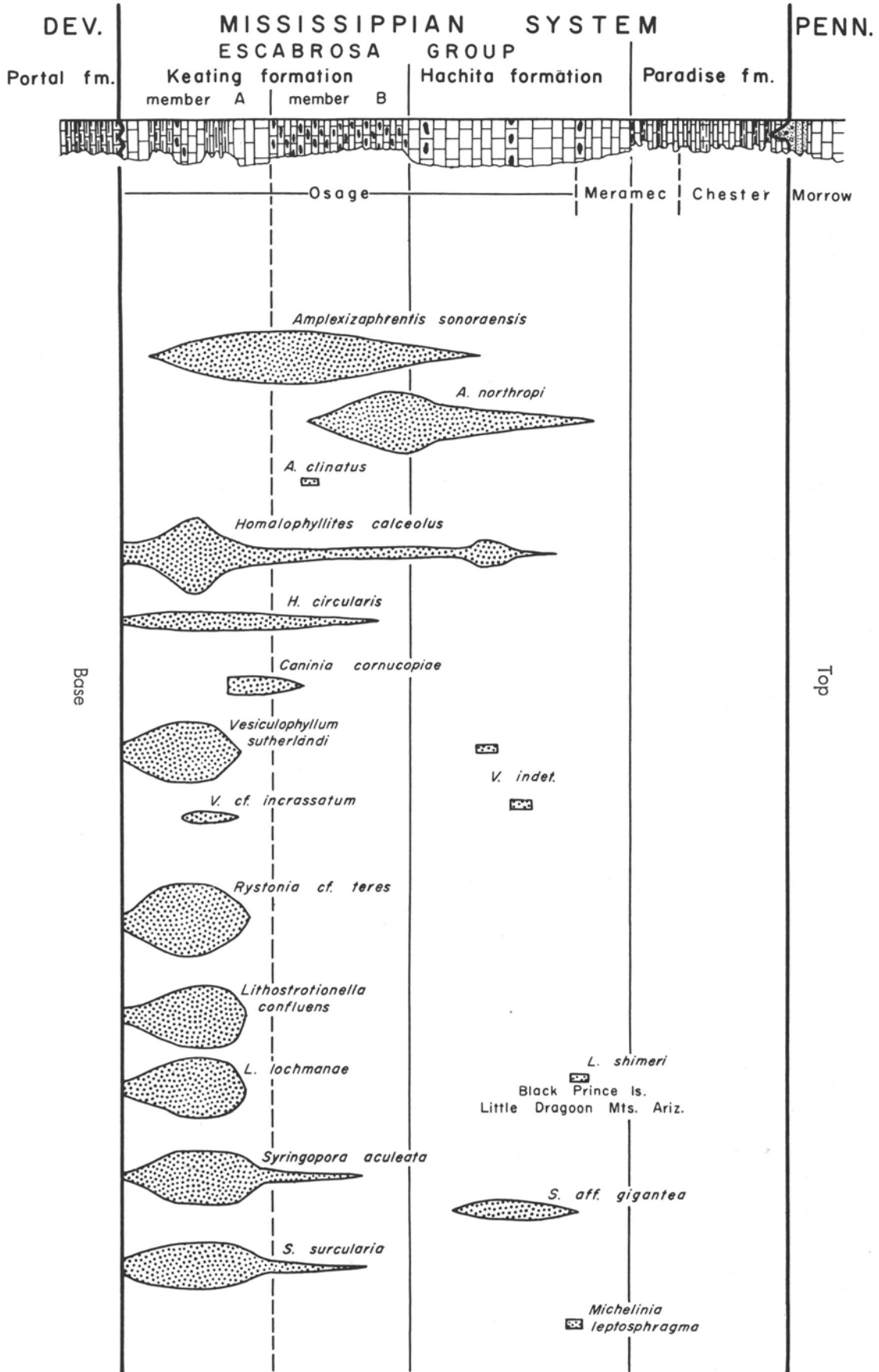


Figure 2

APPARENT VERTICAL RANGE OF THE TABULATE AND RUGOSE CORALS WITHIN THE ESCABROSA GROUP IN THE BIG HATCHET MOUNTAINS, NEW MEXICO

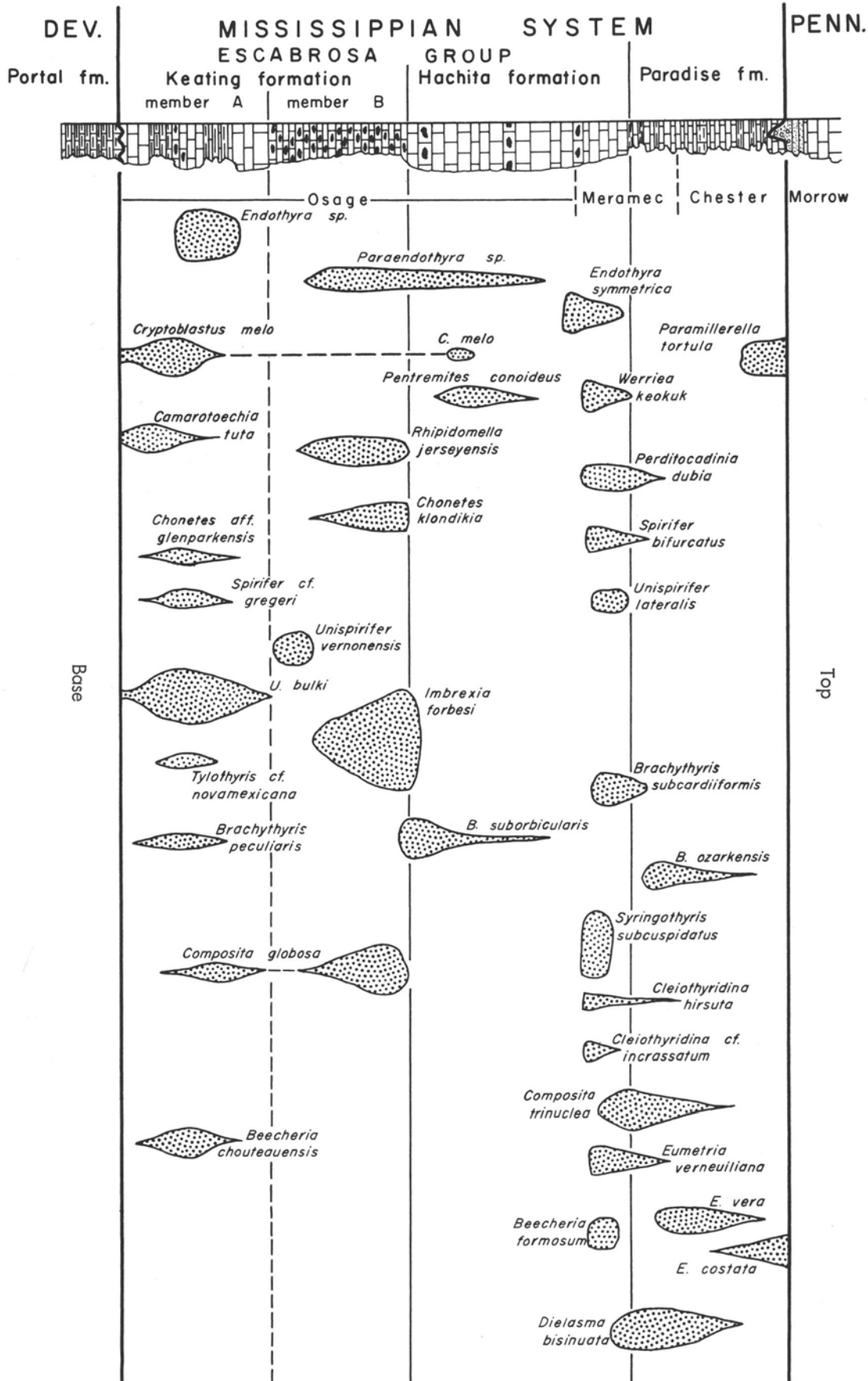


Figure 3

APPARENT VERTICAL DISTRIBUTION OF FORAMINIFERA, BLASTOIDS, AND BRACHIOPODS IN THE ESCABROSA GROUP IN THE BIG HATCHET MOUNTAINS, NEW MEXICO

grades imperceptibly horizontally and vertically into oolites and encrinites with microcrystalline ooze filling the pore spaces.

Member A forms cliffs above the less resistant Devonian argillaceous limestones and below the thin-bedded limestones of member B of the Keating formation. The most diagnostic feature of member A is the almost complete absence of nodular chert.

Member B is thin bedded and highly cherty. Twenty to 40 percent of the rock is composed of chert in long, lenticular bodies which frequently coalesce above and below with adjacent chert masses. The contact between members A and B is a zone 10 to 30 feet thick in which the bedding becomes thinner and the percentage of chert increases. The contact of member B with the overlying white to light-gray, crinoidal limestones of the Hachita formation is very sharp and suggests a paraconformity at Blue Mountain.

The chert in member B is well developed at Blue Mountain, Arizona, and the Peloncillo, Animas, and Big Hatchet Mountains of New Mexico. In the lower part of member B in the Klondike Hills, the chert is composed of brown, primarily ill-defined, disseminated masses parallel to the bedding. The chert is scarce in the sections south of Warren, in the Tombstone and Dragoon Mountains, so that members A and B are not readily recognized.

The lower limestones of member B are gray to dark gray and lithographic. Thinsection studies reveal that they are of a microcrystalline calcite matrix rich in fecal pellets. The fecal pellet limestones (pl. 1 o, fig. 5) are composed of small (0.2 mm) brown pellets surrounded by and, in part, suspended in microcrystalline ooze. Fossils in the calcilutite usually consist of isolated brachiopods and corals, which are disposed in the limestone like plums in a pudding.

These lower calcilutites grade up into calcarenites and coquina limestones. These are dark gray and in thinsections are composed primarily of broken crinoid plates with lesser amounts of brachiopod, coral, and bryozoan fragments. The fragments of the shell hash range in diameter from about 0.4 mm to 10 mm. The pore space between the fossil fragments is filled with brown pellets, some being as large as 0.3 mm. The remaining space is filled with microcrystalline calcite and minor amounts of clay. In some thinsections the pore spaces are filled with sparry calcite. The higher beds of member B frequently contain angular interclasts composed of similar material. These interclasts tend to have their long axes parallel to the bedding, and are generally composed of pelletic and coquina limestones typical of the adjacent horizons.

Insoluble residue studies reveal that the calcilutites in the lower part of member B contain only traces of clay and no detrital quartz sand. The higher beds of member B are also devoid of detrital quartz and contain only small quantities of clay. All of the limestones from member B which were dissolved in hydrochloric acid produced a thick layer of hydrocarbons at the top of the beaker. This relatively high amount of organic material is believed to be responsible for the dark color of member B.

The nodular chert, which comprises a large part of member B, has the textural features of the surrounding limestones and of tens contains silicified remains of invertebrates. Crinoid stems were observed both in the limestone and in chert. The part of the crinoid stem within the chert was silicified, whereas the part in the limestone was not. Where the limestone was composed of crinoid remains and other organic hash, the chert

was nodular and composed primarily of silicified crinoid remains.

Throughout member B secondary silicification has affected most of the brachiopods and corals which are exposed on the surface of the rock. The silicification of most of these fossils does not extend far beneath the surface; for instance, some large corals are completely silicified above the surface of the rock, whereas in thinsections only incipient silicification is demonstrated beneath the surface. Weathering processes account for the selective silicification of fossils on the surface of limestone.

Fauna of Member A

The fauna of member A of the Keating formation throughout the area of study indicates an age which transgresses the Kinderhook—Osage boundary. This fauna is equivalent to those of the Andrecito and Alamogordo members of the Lake Valley formation to the east in the Cooks Range and Black Range. It seems to be of about the same age as that of the Represo limestone of northwestern Sonora, Mexico. The fauna of member A consists of brachiopods, corals, endothyrids, blastoids, bryozoans, crinoids, and occasional trilobites and gastropods. The preservation of the gastropods, trilobites, and bryozoans is so poor that specific or generic identification could not be made. A large variety and number of brachiopods were collected. The preservation of the brachiopods was generally very poor, and only a small percentage could be identified specifically.

The coral fauna is large, relatively well preserved, and very persistent over a wide area in both member A of the Keating formation and in the lower part of the Lake Valley formation. This coral fauna of member A seems to be part of a widespread fauna unique to the lower Mississippian of the Cordilleran region. The corals have not proved to be of direct value in correlating with the standard Midcontinent section, but are very valuable in intraregional correlation for the western half of the United States and Canada. The brachiopods give some indication of the relationship with the standard Midcontinent type sections.

The lower part of member A is in most places an encrinite and varies between 50 feet thick in the Klondike Hills and at Blue Mountain, to 150 feet thick in the Big Hatchet Mountains. This zone contains a sparse fauna characterized by *Cryptoblastus melo* (Owen and Schumard), *Camarotoechia tuta* Miller, and *Homalophyllites calceolus* (White and Whitfield). In the Midcontinent region, Cline (1937, p. 635-637) found abundant *Cryptoblastus melo* in the lower part of the Burlington formation, but none in the Chouteau (Kinderhook) limestone.* Weller and Sutton (1940, p. 806) believed *C. melo* to be restricted to the Burlington formation. *Camarotoechia tuta* is a long-ranging species which is found both in the upper Kinderhook and the lower Osage. *Homalophyllites calceolus* is, according to Easton (1944a, 1958), primarily a lower Osage species. The dating of the basal limestone of member A is admittedly on tenuous ground because of the small fauna. The age assignment is near the Kinderhook—Osage boundary.

A Kinderhook age has been repeatedly cited by many

* D. B. Macurda, Jr. (personal communication), who studied the Keating formation *Cryptoblastus* specimens, states they are most likely a new species but compare very favorably with an undescribed species of *Cryptoblastus* from the Hampton formation (upper Kinderhook) at La Grande, Iowa.

authors for the lower part of the Escabrosa group. No conclusive and substantial paleontologic evidence has been presented by these authors to support their assignment, however. The first study of Escabrosa fossils was made by Girty (1904) of a few specimens collected by Ransome near Bisbee, Arizona. Girty thought that the lower part of the Escabrosa was of Kinderhook age, but at that time the Kinderhook series at the type section in Illinois embraced all Mississippian strata up to the base of the Burlington limestone. Weller et al. (1948) on the Mississippian correlation chart assigned at least half of the Escabrosa group to the Kinderhook series. Stoyanow (1936, 1948), largely influenced by Girty's earlier studies, considered the Escabrosa to be in part of Kinderhook age. Williams (in Gilluly, Cooper, and Williams, 1954, p. 12; Gilluly, 1956) viewed the Escabrosa fauna as existing through both Kinderhook and Osage time. He gave no faunal evidence to support his conclusions. The assignment by most authors of parts of the Escabrosa group to the Kinderhook is based on the *Spirifer centronatus* fauna. No one has, as yet, described this fauna. *Spirifer centronatus* s. l., mentioned in several works concerning the Escabrosa group of extreme southwestern Arizona, is probably *Unispirifer vernonensis* (Swallow) and *Spirifer latior* Swallow. The collections made by the writer from the Escabrosa group failed to show any *S. centronatus* Winchell s.s. (see Armstrong, 1958b).

The mythical *Spirifer centronatus* of the Escabrosa has become entrenched in the stratigraphic literature of the west, and has become a catch-all term for various species of spiriferoids.

The coral zone in the upper half of member A at Blue Mountain, and in all of the Escabrosa group exposures to the east in New Mexico, contains a relatively rich fauna characterized by large rugose corals. Brachiopods identified from this zone in the upper half of member A include *Leptaena analoga* Phillips, which is a conspicuous member of the fauna. The species is characteristic of Kinderhook and lower Osage strata of North America. *Chonetes* cf. *glenparkensis* Weller occurs both in the upper Kinderhook and in the lower Osage, and is also abundant in the Nunn and Alamogordo members of the Lake Valley formation. *Brachythyris peculiaris* (Schumard) and *Tylothyris novamexicana* (Miller) are also present and occur in late Kinderhook and early Osage strata, as well as in the Lake Valley formation of south-central New Mexico. *Beecheria* cf. *chouteauensis* (Weller), which is characteristic of both the highest Kinderhook and the lowest Osage in the Midcontinent region, is present in the upper half of member A of the Keating formation. *B. chouteauensis* has not been reported from the Lake Valley formation but occurs in the lower Osage Caloso formation of west-central New Mexico (Armstrong, 1958b). *Spirifer louisianaensis* Rowley is a very common spirifer in strata of Chouteau and Burlington age and is also abundant in the Kinderhook Caballero and lower Osage Lake Valley formations of south-central New Mexico. *Spirifer* cf. *gregeri* Weller is also present and indicates both an upper Kinderhook and a lower Osage age. *Unispirifer balki* n. sp. is one of the most abundant brachiopods in member A. It is an alate form and is closely related to *Unispirifer platynotus* (Weller). Spiriferoids of this type are characteristic of lower Mississippian. In general, the brachiopod fauna is represented by forms which are found both in upper Kinderhook and lower Osage faunas of the Midcontinent region. It is important to note that none of the species from member A

is known to be restricted to Kinderhook strata, and that the majority of the brachiopods are found in the Lake Valley formation to the east, which is Fern Glen (lowest Osage) in age.

Rylstonia teres (Girty) is a very conspicuous coral in the coral zone. *Rylstonia* aff. *R. teres* has been reported from the Madison limestone of the Williston basin by Sando (1960, p. 172-173), from the Joana limestone of Nevada by Duncan (in Nolan, Merriam, and Williams, 1956, p. 55-56) and from the Tin Mountain limestone of Inyo County, California, by Langenheim and Tischler (1960, p. 128-130). All of these strata are believed to be of lower Mississippian age and to be near, or to straddle, the Kinderhook—Osage boundary.

The lithostrotionid corals are represented in member A by *Lithostrotionella confluens* Easton. This species is present in the Represo limestone of northwestern Sonora. *L. confluens* is closely related, if not conspecific, with *Lithostrotionella jasperensis* Kelly from the Kinderhook—Osage Banff formation of western Canada. *Lithostrotionella lochmanae* n. sp. occurs with *L. confluens* in member A. *L. lochmanae* is similar, except for the lack of a well-developed zone of dissepiments, to *Lithostrotionella micra* Kelly from the Osage Banff formation of Canada. It is interesting to note that both *L. confluens* and *L. lochmanae* occur in the Andrecito and Alamogordo members of the Lake Valley formation at Lone Mountain, south of Silver City, and in the Andrecito member north of the Santa Rita mining district and in the Cooks Range.

In the Midcontinent region, *Homalophyllites calceolus* (Whitfield) is most frequently found in the lower Osage but occurs also in the younger Kinderhook. This species is very abundant in member A, and is also found in the lower members of the Lake Valley formation. *Homalophyllites circularis* Easton, the only representative of the genus in the Represo limestone of Sonora, Mexico, is occasionally found in member A. A new species *Vesiculophyllum sutherlandi* n. sp., is a large, solitary, caninid coral common to member A; but apparently it is restricted to the upper half of this unit.

Fragments of very rare caninid coral were found in member A, and appear to be the same species as *Vesiculophyllum incrassatum* (Easton and Gutschick) from the Represo limestone of northwestern Sonora and the Redwall limestone of Arizona. Langenheim and Tischler (1960, p. 126) report *V. incrassatum* from the lower Mississippian Tin Mountain formation of Inyo County, California. In member A the genus *Amygdalophyllum* is represented by occasional fragments of a new and very distinctive species. Sufficient material was not available for detailed, specific determination.

The tabulate corals are represented in member A by two species of *Syringopora*, *S. aculeata* Girty and *S. surcularis* Girty. Both species are abundant in member A Keating formation, and the Andrecito and Alamogordo members of the Lake Valley formation.

In member A, foraminifera are represented by a sporadically occurring *Endothyra*, which is thin walled and very large (up to 1.2 mm in diameter). A species of *Endothyra* of such large size has not been reported in the literature in horizons older than Meramec. This species, if taken by itself and compared with present knowledge of endothyrids, would indicate a Meramec age. Zeller (1950, 1957) and Woodland (1958) reported endothyrids of Osage age with a maximum diameter of 0.4 mm. The writer suspects that Mississippian and endo-

thyrid species are not critical indices of time, but are probably in reality very sensitive indicators of specific environmental conditions. Before endothyrids can be used as a narrow time index with any assurance of accuracy, detailed regional studies comparing stratigraphic distributions against rock types must be made on this group.

Fauna of Member B

The highest unit of the Keating formation, member B, contains a fauna which is distinct in comparison with the assemblage found in member A. The difference is believed to be due primarily to ecological conditions and evolutionary changes. The lowest cherty beds of member B are characterized by such lower Osage brachiopods as *Unispirifer vernonensis* (Swallow), *Leptaena analoga* Phillips, and *Athyris lamellosa* (Léveillé). *Unispirifer vernonensis* is characteristic of the lower half of member B. The writer considers it to be the *Spirifer centronatus* which various authors have reported from the Escabrosa group. Weller and Sutton (1940, p. 806) considered *U. vernonensis* to be typical of Fern Glen faunas. This species is also very abundant in the lower part of the Lake Valley formation in south-central New Mexico. The coral fauna of member B is represented by *Amplexizaphrentis sonoraensis* n. sp. from the Lake Valley formation. *Homalophyllites calceolus* (Whitfield) is occasionally found in the lower part of member B.

The middle and upper part of member B is of a more pronounced bioclastic rock produced by many crinoid fragments in the limestone. These two units contain a fauna unlike the lower part of this member. The index fossil of this zone is the Burlington fossil, *Imbrexia forbesi* (Norwood and Pratten). It is abundant in the higher horizons, but is always found as broken and disassociated valves. It is a highly diagnostic guide fossil to the top of the Keating formation, and has been observed in every major outcrop of the Keating formation from the Little Dragoon Mountains of Arizona, eastward into the Klondike Hills of New Mexico. The remainder of the brachiopod fauna also has a distinct Osage character, which consists of the following determined species: *Brachythyris suborbicularis* (Hall), *Rhipidomella jerseyensis* Weller, *Chonetes klondikia* n. sp., and *Composita globosa* Weller. The corals are presented in the middle of member B by *Amplexizaphrentis sonoraensis* n. sp., and in the higher beds by abundant specimens of *Amplexizaphrentis northropi* n. sp.

The higher beds of the Keating formation yielded *Syringothyris*, *Schuchertella*, various species of *Spirifer*, and other specifically unidentifiable fragments. In the stratigraphically higher beds, some of the more argillaceous partings between the massive limestones contain abundant bryozoans. At the same horizons at Blue Mountain, and eastward to the Klondike Hills, the bedding planes of the limestones commonly display the problematical annelid fossil *Taonorus*. Endothyrids were absent from the thinsections studied from member B.

The basal part of member B of the Keating formation, as indicated by the fossils, is of Fern Glen or lowest Burlington age. From the faunal and field evidence, it appears that sedimentation continued without a major hiatus from the basal beds of member A (earliest Fern Glen), which rests on the post-Devonian unconformity, to the highest strata of member B (Burlington).

HACHITA FORMATION

Lithology

The type section of the Hachita formation is at the south end of Blue Mountain, Chiricahua Mountains, Arizona; S1/2, sec. 20, T. 26 S., R. 30 E. The Hachita formation is lithologically and topographically the most characteristic part of the Escabrosa group. It forms a persistent cliff throughout its area of exposure. This cliff is due primarily to the massive nature of the encrinities, in part to the weak Devonian argillaceous limestone and shale below, and in part to the thinner-bedded, less resistant Paradise formation (Chester age) above. The lower two-thirds of the Hachita formation is almost devoid of bedding and is composed of crinoid fragments to the virtual exclusion of other organic remains. The upper third of the formation is darker gray, has persistent massive bedding, and is composed to a large extent of crinoid remains, although it also contains appreciable amounts of brachiopod and bryozoan remains.

The thickest known section of the Hachita formation is at the northern end of the Big Hatchet Mountains, SE1/4, sec. 30, T. 30 S., R. 15 W., with a maximum thickness of 380 feet. Because of original deposition, the Hachita formation thins to the north and west (see correlation diagram). West of the Chiricahua Mountains in Arizona, where the Chester-age Paradise formation is absent, the Hachita formation thins, partly because of erosion during the pre-Pennsylvanian and early Pennsylvanian time (Kottowski, 1960). To the east, because of the sparseness of exposures, the complexity of Cenozoic faulting and thrusting, and, in the Klondike Hills, the presence on some of the Hachita exposures of extensive late-Cenozoic pediment surfaces, the exact thickness of the formation is not known. In the Klondike Hills northeast of the Big Hatchet Mountains, the Hachita formation is at least 350 feet thick and may be considerably thicker.

Laudon (1948), Laudon and Bowsher (1949), and A. L. Bowsher (personal communication, 1960) maintain that the Rancheria formation of the southern San Andres Mountains (Kottowski et al., 1956), southern Sacramento Mountains (Pray, 1961), and the Franklin Mountains form a lower Meramec overlap northward onto an eroded Lake Valley formation surface. This concept would necessitate an uplift in late Burlington or Keokuk time in the Rio Grande and Trans-Pecos region of southern New Mexico and eastward. This would result in the stripping off of earlier Mississippian sediments down to (at least) the Devonian surface and in regional submergence again in earliest Meramec time.

Preliminary field studies by the writer indicate that such a simple explanation is not totally true. There is strong evidence that part of the Rancheria formation represents lower and middle Osage time. The field relations, petrographic data, and some paleontologic evidence now seem to indicate that the Rancheria formation was deposited in a starved basin and represents a siliceous limestone facies of the Escabrosa group and the Lake Valley formation. The relationship of the Escabrosa group to the Lake Valley, Kelly, and Rancheria formations is discussed in greater detail under Paleogeology and Paleogeography. Graphic representation of the relationships of the Escabrosa group to these formations is shown in the lithofacies maps and the regional correlation charts.

Within the area of Escabrosa deposition there is some question as to the nature of the contact of the Hachita formation

with the underlying Keating formation. The lower part of the Hachita is an almost pure, very massive, white to light-gray encrinite limestone with occasional nodules of white chert. In contrast, the upper part of the Keating is a medium-bedded, dark-gray, in part encrinite limestone with zones of abundant lenticular and bedded dark-gray chert. In the Klondike Hills and Big Hatchet Mountains there is a gradational zone, 10 to 20 feet thick, between these two distinct lithologies. The contact between the two formations at Blue Mountain can be observed almost continuously for a distance of three-fourths of a mile. Here the contact is very sharp and in many places suggests a disconformity. The base of the Hachita formation at Blue Mountain frequently contains angular, irregularly arranged fragments (up to 6 inches in diameter) of gray limestone and black chert derived from the top of the Keating formation. Paleontologic evidence, although not conclusive, indicates that if a hiatus does exist between the two formations, it is of short duration. The top of the Keating formation does contain a numerically large fauna dominated by the Osage fossil, *Imbrescia forbesi*, and the very base of the Hachita formation contains a very meager fauna of Osage species typified by *Brachythyris suborbicularis*.

The higher beds of the Keating formation were deposited in very shallow water, as indicated by sedimentary evidence. The transition zone between the two formations, at many locations such as the Big Hatchet Mountains, Klondike Hills, and Tombstone Hills, would suggest continuous deposition in shallow water. The section at Blue Mountain, with its numerous interclasts and abrupt lithologic change between the two formations, would suggest that the region stood at or just below sea level at the end of Keating deposition. During exposure, the calcite muds had time to become partly lithified before shallow waters again flooded the area with accompanying tidal currents and waves. These energy sources dislodged fragments of the partly lithified lime muds, transporting and redepositing them into newly forming calcarenites and calcite ooze. The sharp contact between the Keating and Hachita formations at Blue Mountain appears to be the product of one of these localized short erosion episodes occurring at the beginning of a widespread regional ecological change. This relatively sudden ecological and depositional change resulted in the marked contrast between the limestone lithologies of the Keating and Hachita formations.

The lower two-thirds of the Hachita formation is, in all of the exposures east of Blue Mountain, a massive encrinite limestone almost devoid of distinct bedding. These lower and middle units of the Hachita formation contain some white to light-gray nodular chert. Detailed examination of a number of Hachita exposures failed to reveal any biohermal or biostromal buildup within the formation.

The formation is composed almost entirely of crinoid fragments, nearly to the exclusion of other detrital and organic remains. When an occasional brachiopod was found, it was inevitably a broken and diassociated valve. The crinoid remains were almost always broken and the plates abraded. Very rarely an incomplete crinoid calyx was found and, more often, segments of articulated stems up to 6 inches long were observed. As has been stated, the lower two-thirds of the Hachita formation is almost devoid of bedding, but within this massive crinoidal debris there are interfingering and gradational bodies of encrinite limestone with different textures. Some lenses are composed of coarse-grained crinoid fragments which grade

into zones of very fine-grained abraded crinoid fragments and microcrystalline calcite (see pl. I I, fig. 8).

Study of thinsections revealed that the lower two-thirds of the Hachita formation does not contain any appreciable number of fenestrate bryozoans. This is in marked contrast to Pray's (1958) petrographic conclusions concerning the lower Osage crinoidal bioherms of the Sacramento Mountains, New Mexico. He reported the framework of these bioherms to be fenestrate bryozoans. The Hachita limestone is composed primarily of broken crinoid plates, cemented by either sparry calcite or microcrystalline ooze or a combination of the two (see pl. Io, fig. 9). In thinsections the crinoid fragments are more tightly packed than they could have been before diagenesis. This tight packing is probably the result of solution at points of contact between grains, resulting in numerous microstylolites between the crinoid fragments. A limestone type of minor importance is microcrystalline calcite with suspended fragments of crinoids.

Insoluble residue studies from this part of the section reveal the almost complete absence of detrital quartz, and very minor amounts of clay and organic residue. Some of the limestone beds have small amounts of tiny (o. 0.1 mm—0.3 mm) doubly terminated quartz crystals.

The upper third of the Hachita formation from Blue Mountain eastward is primarily an encrinite; but it does contain a higher proportion of brachiopod, bryozoan, and endothyrid fragments than the lower parts.

The higher beds of the Hachita formation show in thinsections a wider variety of limestone types. The base of the Meramec at both the Big Hatchet Mountains and Blue Mountain is composed of limestone which contains endothyrids (pl. 0, fig. 8). The endothyrids are from 0.5 mm to 0.7 mm in diameter and have formed the nucleus of oolites. About 20 to 40 percent of the rock is composed of rounded fragments of brachiopods and echinoderms, some of which are also the nuclei of oolites. The pore space is filled with sparry calcite and minor amounts of microcrystalline ooze. One of the more common types in the Meramec sequence is a fine-grained, relatively unfossiliferous, light-gray limestone which in thinsection (pl. 11; fig. 3) is primarily composed of fragments of brachiopods, echinoderms, and bryozoans. These fragments are up to 3 mm in diameter, but are present as ghosts, as the rock has been almost completely recrystallized into fine-grained sparry calcite. The highest beds of the Hachita formation, both at Blue Mountain and the Big Hatchet Mountains, are composed of a coquinite and calcarenite containing crinoids, brachiopods, and bryozoans, ranging from 0.5 mm to 1.5 mm in diameter. This material is also tightly packed and the pore space is filled with sparry calcite.

Insoluble residue studies of the higher beds of the Hachita formation show a slightly larger amount of insoluble residues than do studies of the lower encrinites. Although detrital quartz is still rare here, there is a noticeable increase in the clay fraction and organic residue. The upper third of the Hachita formation has a noticeable increase in chert. Appreciable amounts of pink to salmon nodular chert are present in the *Syringothyris subcuspidatus* zone. The remainder of the Meramec zone contains varying amounts of brown and gray chert. The highest limestones contain zones of very thin-bedded brown chert.

The evidence now available indicates that continuous deposition existed from the Osage into the Meramec series. If a

hiatus is present between Osage and Meramec strata, it is completely masked and has not been discovered in the field.

Gilluly, Cooper, and Williams (1954) and Gilluly (1956) found a very sparsely fossiliferous, medium-bedded, fine-grained limestone of middle Mississippian age above their Escabrosa limestone beneath the Pennsylvanian Horquilla limestone in Cochise County, Arizona. They named this limestone the Black Prince limestone. Although they mapped it primarily in the Dragoon and Little Dragoon Mountains, they suggested it might be present further south in Arizona. Beds considered to be the equivalent of the Black Prince limestone have been found in the hills south of Bisbee near Warren and in the Tombstone Hills, Arizona. Gilluly et al. (1954, p. 14-16) placed considerable importance on a zone, 10 to 20 feet thick, of interbedded shales and limestones at the base of the Black Prince limestone in the Big and Little Dragoon Mountains and Gunnison Hill areas. This may represent in part a reworked residual soil and a hiatus which gains a longer time span northward, but probably becomes less and vanishes as it is traced southward and eastward into the thicker sections of Escabrosa deposition. The Black Prince was not studied adequately, but it contains the Canadian Cordilleran index fossil, *Lithostrotionella shimeri* (Crickmay), suggesting that this limestone is a western facies of the Meramec part of the Hachita group. The Black Prince limestone in thinsection is apparently devoid of foraminifera, and is composed primarily of microcrystalline ooze with minor amounts of calcarenite.

Gilluly et al. (1954) noted that the Black Prince limestone was difficult to distinguish from the underlying Escabrosa limestone. The author believes that the Black Prince limestone should be considered as a member of the Hachita formation of the Escabrosa group.

To the east, where the Paradise formation is present, the top of the Hachita formation and the bottom of the Paradise formation form an arbitrary plane. There appears to have been essentially continuous deposition from Meramec to Chester time. Herson (1935, p. 656), at Blue Mountain, separated the Paradise formation from the Escabrosa limestone (here considered the Hachita formation of the Escabrosa group) by the "first marked evidence of shallowing of the waters, where the moderately bedded limestones overlying the typical Escabrosa gives place to shales and thinner bedded limestones carrying limestone conglomerates at their base." Field observations and paleontologic evidence show that the bottom of Herson's Paradise formation extends into the upper part of the Hachita formation as defined in this paper. The base of the Paradise formation is defined at Blue Mountain and in exposures in southwestern New Mexico as the base of the first 18-inch shale zone which occurs on top of the massive limestone of the Hachita formation. The Hachita formation is readily separated from the Paradise formation by the marked differences in topographic expression, although the limestones in the upper third of the Hachita formation are darker in color and possess progressively better-defined bedding planes than does the lower part of the formation. These higher horizons are topographically less resistant than the lower massive crinoidal limestones, and form less precipitous cliffs. The Hachita formation is overlain by the Paradise formation at Blue Mountain and in the Peloncillo, Animas, and Big Hatchet Mountains and Klondike Hills. It is easily weathered and forms gentle, covered slopes beneath the massive Pennsylvanian limestone. The Paradise formation usually is eroded back from the Hachita cliff and rests on a

bench formed by the highest limestone of the Hachita formation.

Fauna

Of the two formations which comprise the Escabrosa group, the Hachita formation is the more sparsely fossiliferous. The lower two-thirds of the Hachita formation is a massive encrinite which is essentially devoid of identifiable fossils. Intensive search of the lower hundred feet of the Hachita formation yielded a small and poorly preserved fauna consisting of *Pentremites conoideus* Hall, *Cryptoblastus?* aff. *melo* (Owen and Schumard), *Brachythyris suborbicularis* (Hall), *Amplexizaphrentis northropi* n. sp., and occasional specimens of *Parandothyra* sp.

Pentremites conoideus is primarily a Meramec fossil, but it is reported (Armstrong, 1958b) from the Kelly formation, Keokuk (Osage) age, from west-central New Mexico.

The genus *Cryptoblastus* is restricted to Osage rocks in North America. *Brachythyris suborbicularis* is a typical representative of the Osage. The only identifiable fossils in the middle part of the Hachita formation are corals, the most frequent form being *Amplexizaphrentis northropi*. This species is abundant in the upper half of member B of the Keating formation and sparsely present in the lower two-thirds of the Hachita formation. Occasional specimens of *Vesiculophyllum* sp. and large colonies of *Syringopora* aff. *S. gigantea* Thompson are also found in the midportion of the Hachita formation.

The Osage—Meramec boundary occurs in a 00-foot-thick zone in the upper two-thirds of the Hachita formation. There is no physical evidence of a hiatus between the two series, the rocks being massive encrinites which show no noticeable change in lithology. Because identifiable fossils are rare, they cannot be used to determine either the presence or absence of a hiatus or even the general location within a few score feet of the boundary between the two series. Apparently in the area of Escabrosa deposition, in extreme southwestern New Mexico and in the Chiricahua Mountains of Arizona, encrinite sedimentation continued from Osage into Meramec time. Undoubtedly there exists within the Hachita formation, as in most epicontinental marine deposits, small local diastems. These were caused by short periods of nondeposition, changes in currents, by-passing, or very short periods of sea-level fluctuations. The physical evidence almost precludes any long period of emergence and erosion within the Hachita formation.

The first bed that appears to be of definite Meramec age is marked by *Endothyra symmetrica* Zeller. This zone has been detected in the Big Hatchet and Chiricahua Mountains. About 30 to 40 feet above the *E. symmetrica* zone a very diagnostic zone occurs which is persistent over a wide area. This fauna consists of the following: *Syringothyris subcuspidatus* (Hall), *Unispirifer latoralis* (Hall), *Spirifer bifurcatus* Hall, *Werriera keokuk* (Hall), *Beecheria formosum* (Hall), *Cleiothyridina incrassata* (Hall), *Cleiothyridina hirsuta* (Hall), *Brachythyris subcardiiformis* (Hall), and *Endothyra symmetrica* Zeller. This fauna is suggestive of Warsaw or Salem age. It has been observed as far south and west as the hills south of Bisbee but reaches its maximum development in the Chiricahua, Animas, and Big Hatchet Mountains. The zone is also believed to be present in the Klondike Hills, but definite identification is obscured by selective dolomitization of the brachiopods.

The highest beds of the Hachita formation, which are 20 to

30 feet below the lowest shale of the Paradise formation at Blue Mountain and in the Big Hatchet Mountains, contain a sparse fauna consisting of *Perditocardina dubia* (Hall), *Beecheria formosum* (Hall), *Eumetria verneuilana* Hall, *Dielasma bisinuatus* (Weller) and *Werreria keokuk* (Hall). This fauna, as was pointed out by Hernon (1935, p. 660) in discussing the section at Blue Mountain, is Meramec in age.

One of the most interesting features of the zones which carry Meramec brachiopods of very distinct Midcontinent aspects is the lack of a coral fauna. A few scraps of unidentifiable rugose corals and specimens of the tabulate coral *Micelinia leptosphragma* n. sp., have been found. Neither *Lithostrotion* nor *Lithostrotionella* has been observed in the Meramec part of the Hachita formation at Blue Mountain nor in any of the sections to the east. Hernon (1935) in his studies at Blue Mountain also commented on the absence of these corals, and believed it was due to some kind of barrier that prevented the migration of lithostrotionids into the area. This "barrier" was probably some regional environmental factor, which prohibited the growth of these organisms. The only known occurrence of lithostrotionids in Meramec rocks of southern Arizona and New Mexico is west of the area of this study. *Lithostrotionella shimeri* (Crickmay) has been found at the base of the Black Prince limestone in the Gunnison Hills. This species is characteristic of Meramec strata in western Canada (Nelson, 1960).

The highest fossiliferous beds of the Escabrosa group in the hills south of Warren, Arizona, contain fauna characterized

by *Syringothyris subcuspidatus* (Hall). These beds are overlain by an unfossiliferous sequence of fine-grained limestones. These limestones, above the *S. subcuspidatus* zone and beneath the Pennsylvanian Horquilla limestone, appear to be lithologically and stratigraphically equivalent to the Black Prince limestone of Gilluly et al. (1954, p. 13), found at the top of the Escabrosa group in the Little Dragoon Mountains. Similar limestones are present in the top of the Hachita formation south of Ajax Hill in the Tombstone Hills. The Black Prince limestone has not yielded a large or diagnostic fauna. The writer has collected a few poorly-preserved specimens of *Eumetria verneuilana* Hall from the lower part of the Black Prince limestone in the Ajax Hills. Gilluly et al. (1954, p. 6) reported from the Black Prince limestone of the Gunnison Hills a fauna composed of *Spirifer* cf. *S. pellaenis* Weller, *Composita humilus* Girty, and a *Lithostrotionella*, which the present author identified as *L. shimeri* (Crickmay). The Black Prince limestone which is exposed on the western periphery of the area of this study was not studied in the detail it deserves. In thinsections it is a fine-grained microcrystalline limestone, which is apparently almost devoid of fossils. Its exact age is uncertain, but it appears to represent a western facies of the Meramec part of the Hachita formation. The bedding, texture, and color of the Black Prince limestone in the Dragoon Mountains, Tombstone Hills, and Warren area are lithologically similar to the Meramec-age horizons at Blue Mountain. The writer regards the Black Prince as a localized member of the Hachita formation.

Paleogeography and Regional Correlations

To discuss the paleogeography of a geologic period for a large geographic area is very hazardous, particularly since most of the field studies were of a reconnaissance nature. Besides, at the present time we have a limited knowledge as to how to interpret lithologies and fossils. Thus the statements made here on paleogeography must be regarded as tentative.

The writer's interpretation of Mississippian sedimentation, paleogeography, and paleoecology has been influenced by the studies of Illing (1954), Newell and Rigby (1957), and Cloud and Barnes (1957) on recent limestone sedimentation and ecology on the Bahama Banks. The concepts and term analogies of Folk's (1959) limestone classifications are used with only slight modification.

PENASCO DOME

The name, Penasco dome, is proposed for the roughly circular, positive area centered in northern New Mexico, southwestern Colorado, northeastern Arizona, and adjacent parts of Utah, that persisted from Cambrian through Mississippian time. The Penasco dome, through the early and middle Paleozoic, stood as a low island in the various epeiric seas or was barely awash. It subsided at a slower rate than any of the surrounding shelf areas. The Penasco dome is graphically illustrated by Clarke and Steam (1960, p. 60) as a southernmost unnamed circular extension of the Transcontinental arch. The northern boundaries of the Penasco dome as separated from the main axis of the Transcontinental arch are indicated by the sag in central Colorado onto which Sloss, Dapples, and Krumbein (1960, p. 1, 4, 14) indicated embayments or crossings of Cambrian, Ordovician, and Devonian seas. Apparently the Penasco dome contributed significant quantities of elastic material to the surrounding epeiric seas only in late Cambrian time. There is little or no stratigraphic evidence that it contributed any quantity of elastic material to the epeiric seas of Ordovician, Silurian, Devonian, and Mississippian time. Kelley and Silver (1952) and Kottowski et al. (1956) demonstrated that in southern and south-central New Mexico little or no evidence of a shoreward facies exists in the northward thinning strata of Ordovician, Silurian, and Devonian age. The writer also found this to be true of the Mississippian strata (Armstrong, 1958b). These various early and middle Paleozoic units are separated from each other by major systemic hiatuses which increase in magnitude northward. Furthermore, within each system are numerous minor hiatuses which also increase in magnitude and number northward toward the dome. Most workers concede that several of these systems, in particular the Ordovician, Devonian, and Mississippian, once extended far onto the flanks or even across the Penasco dome but were stripped back during periods of erosion before each succeeding marine advance. On the eastern side of the Penasco dome a similar relationship has been shown by Maher and Collins (1949) for the Ordovician and Mississippian strata from southwestern Kansas and northwestern Texas westward to the Sangre de Cristo Mountains of northern New Mexico and south-central Colorado. The author has observed the same relationship in the Ordovician, Devonian, and Mississippian strata in the Sangre de Cristo Mountains of south-central Colorado.

UPPER DEVONIAN

The upper Devonian sea, which extended over southern and central New Mexico and Arizona and which may have overlapped the Precambrian rocks on the Penasco dome, retreated southward at the close of the period. The nature of the paraconformity beneath the Mississippian limestone and the outline of the Devonian outcrop on the paleogeographic map (fig. 4) suggest that the dome was elevated and stripped of overlying Devonian shales by the end of Devonian time.

By earliest Mississippian time the Penasco dome was a peneplained surface cut on Precambrian metamorphic and igneous rocks. Baltz and Read (1960) suggested the lower part of the Arroyo Penasco formation in the Sangre de Cristo Mountains of northern New Mexico may be of upper Devonian age. They failed to cite any paleontologic or other age-determining data to support their belief that Devonian strata are still present. Furthermore, they did not take into account the published illustrations by Armstrong (1958b) of large *Plectogyra* from the lower part of their supposed Devonian. *Plectogyra* of this size are highly suggestive of Meramec age; and, as has been shown by St. Jean (1957), endothyrids are unknown from the Devonian.

The writer believes that there is a good possibility that a thin veneer of Devonian elastic rocks was present over much of the Penasco dome before Kinderhook time, but that if this thin sequence was present, it was undoubtedly stripped off before Osage time.

In southern New Mexico the hiatus between the Devonian and Mississippian systems represents, at a minimum, a span of time from upper Devonian Percha (Conewango) sedimentation to the base of lower Mississippian Caballero (Chouteau) sedimentation.

KINDERHOOK FORMATION

The exact extent and fauna of the earliest Mississippian (Chouteau) Caballero formation is not clearly known. Dr. G. A. Cooper (personal communication, 1959) is studying the Caballero fauna, which will appreciably help in our understanding of this poorly known rock unit.

The geographic extent and thickness of the Caballero sediments is shown in the correlation diagram (fig.) and the Kinderhook paleogeologic map (fig. 5). Strata equivalents of Caballero time are absent in member A of the Keating formation. Caballero sedimentation appears to have been essentially restricted to an area east of the Rio Grande and south of Truth or Consequences, New Mexico. The only known occurrences of Caballero-age strata west of the Rio Grande are at the mining camp of Lake Valley and in the Robledo Mountains northwest of Las Cruces. The Caballero formation disconformably overlies various Devonian formations. It varies from a feather edge to 60 feet thick and consists primarily of calcareous shales, thin zones of gray nodular limestone, and thin beds of crinoidal limestone. The advancing Caballero sea, reworking the underlying Devonian regolith and shale, deposited part of the shales within the formation. Streams which flowed southward across the Precambrian Penasco

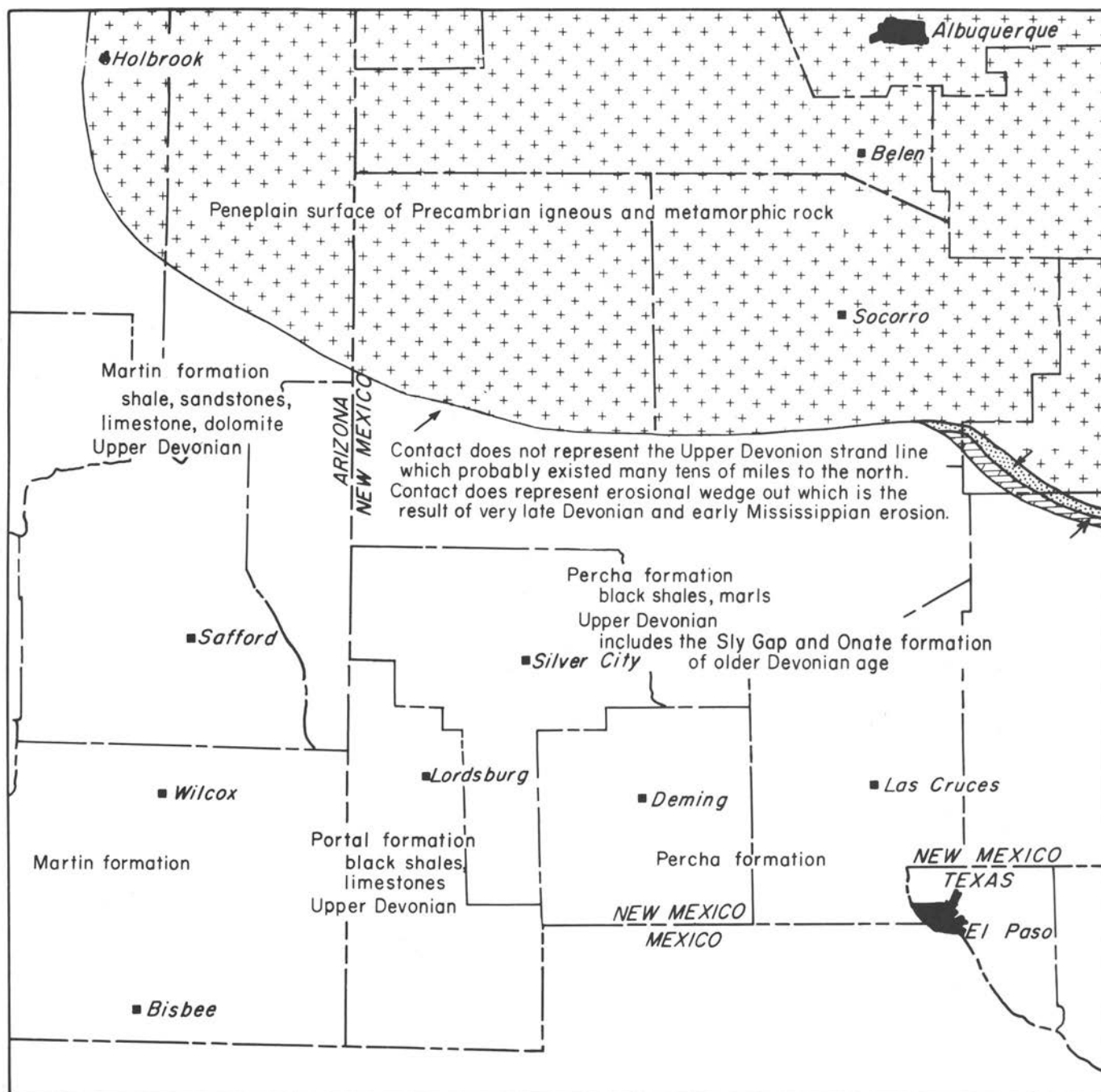


Figure 4

LATEST DEVONIAN PALEOGEOLOGIC MAP

dome and Devonian terrane carried clay and fine-grained sediments into the Caballero marine embayment.

This report is not a study of the Caballero fauna or sediments, but the following field observations were made. The Caballero formation is much more argillaceous than any of the succeeding Osage or Meramec strata of the region. The Caballero sea was shallow, of short duration, and of restricted geographic distribution.

Laudon and Bowsler (1949) postulated a disconformity between the Kinderhook and the Lake Valley formation (Osage). This hiatus was apparently of short duration, but existed over a wide area.

OSAGE

A sedimentary pattern was initiated in this region in earliest Osage time that persisted throughout the Mississippian. Three elements are apparent.

The southern part of the Penasco dome in northern and central New Mexico was a shelf area which extended into northeastern Arizona. It consisted of Precambrian rocks which were peneplained. This surface remained at, or near, sea level and was occasionally submerged for short intervals. At the beginning of Osage time, this dome had little or no relief, and the rocks on its surface must have been deeply

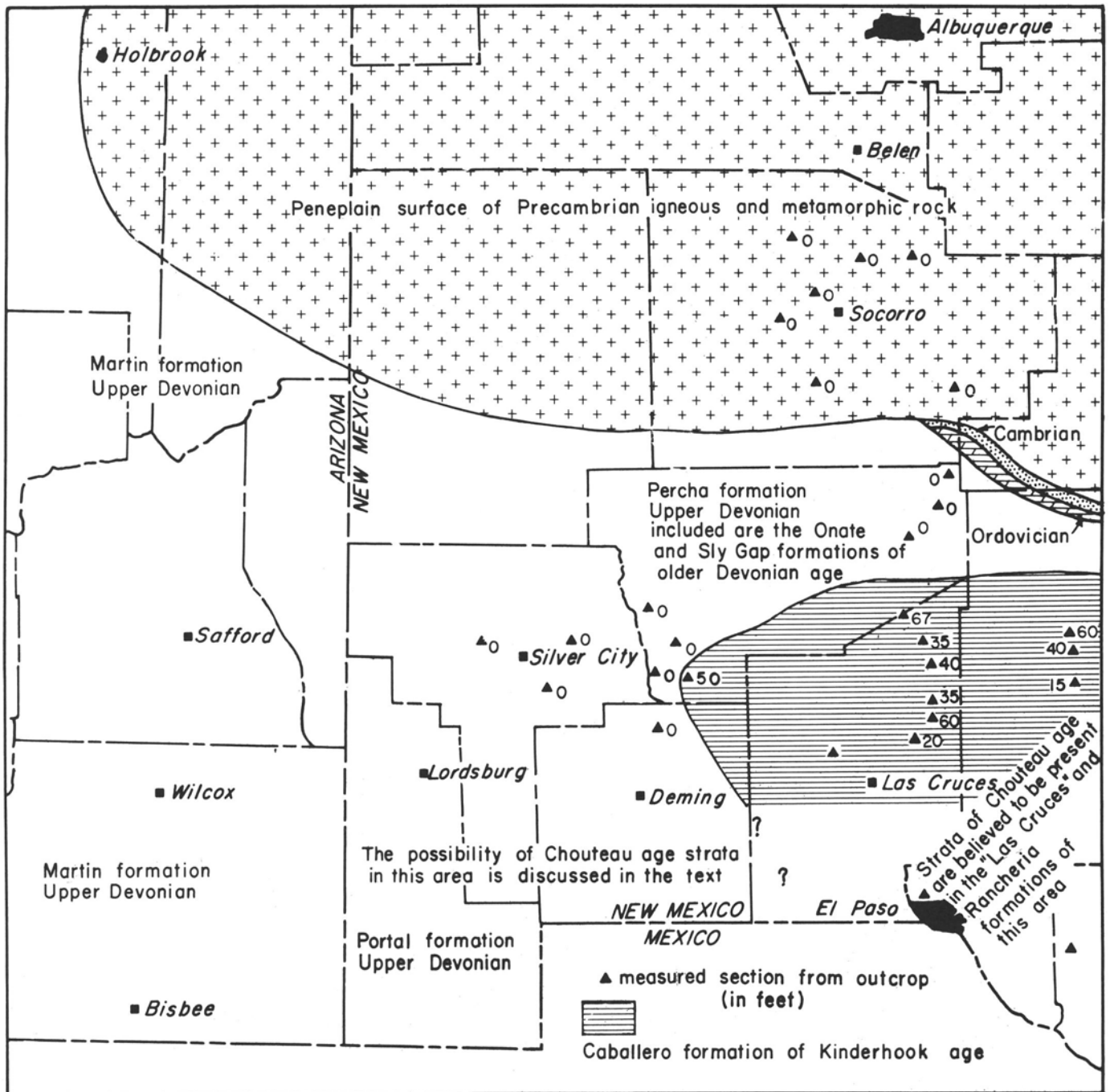


Figure 5
PALEOGEOLGIC MAP AT END OF CHOUTEAU-KINDERHOOK TIME (OSAGE)

weathered. Because it was a very low-lying area, through Osage and Meramec time it contributed essentially no clastic material into the surrounding sea.

The remaining two elements were in the southern part of the State. The shelf area of central New Mexico was gently bent southward beneath sea level, and continued to sink at a steady, slow rate until the end of Meramec time. On this gently sloping shelf area of shallow water developed the Lake Valley facies with its east-west band of crinoidal "reefs." In the southern part of the State, where submergence (fig. 6) was more rapid, two distinct facies developed. In southwestern New Mexico and southeastern Arizona, calcium carbonate

secreting organisms (primarily crinoids) kept pace with the rate of submergence and maintained the sea floor at or above wave base through Osage time. In south-central New Mexico and the adjacent area of Texas (Trans-Pecos region), the waters were not conducive to organic activity, and a starved basin developed which was fringed on the north by reefs of the Lake Valley formation and on the west by the crinoidal limestones of the Escabrosa group. In the Rancheria basin there was deposited the fine-grained, gray, siliceous, essentially unfossiliferous limestones of Osage to Meramec age. The Rancheria formation, as originally proposed by Laudon and Bowsler (1949, p. 19), was considered to be a northward

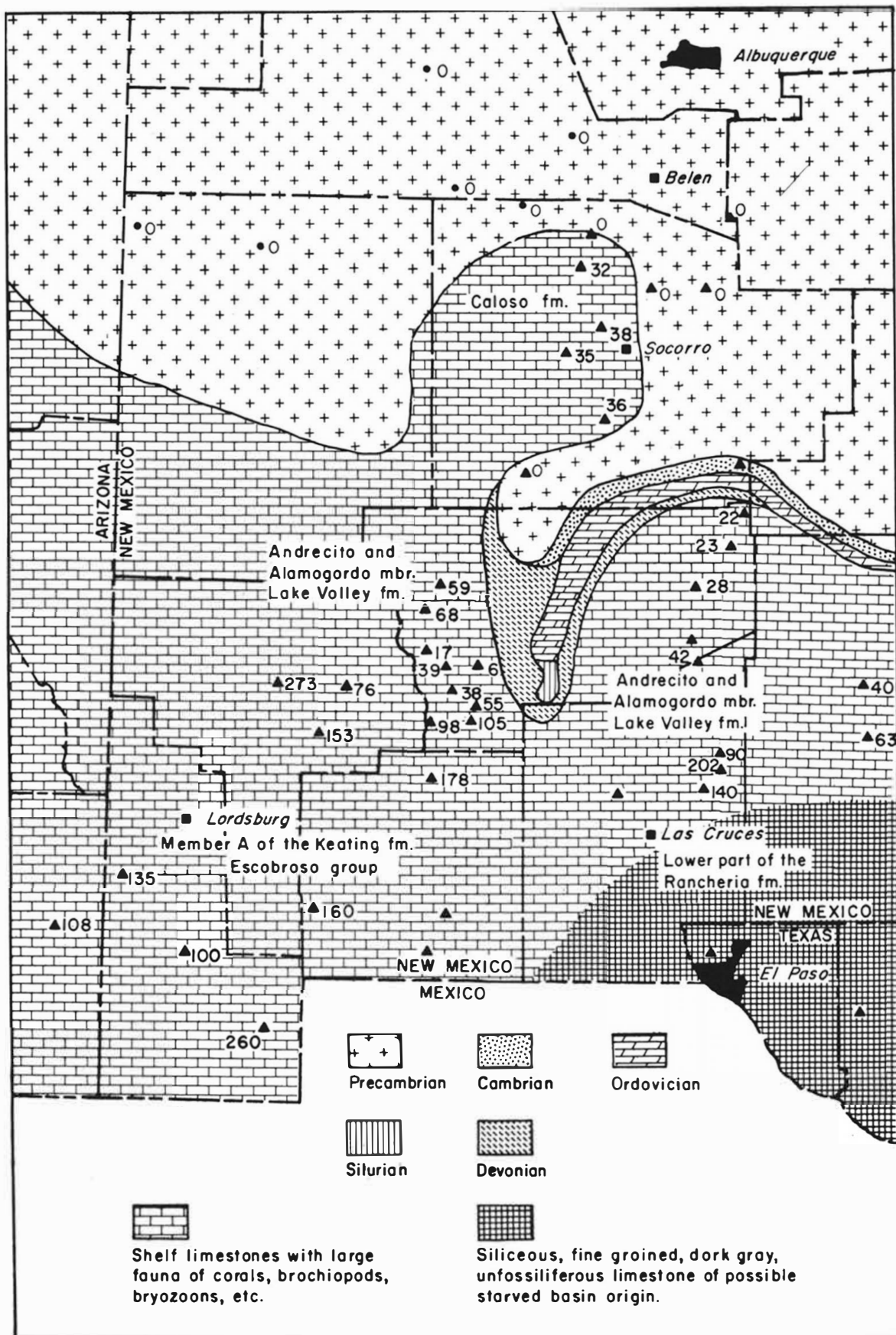


Figure 6

LITHOFACIES AND THICKNESS OF EARLY OSAGE, FERN GLEN, STRATA

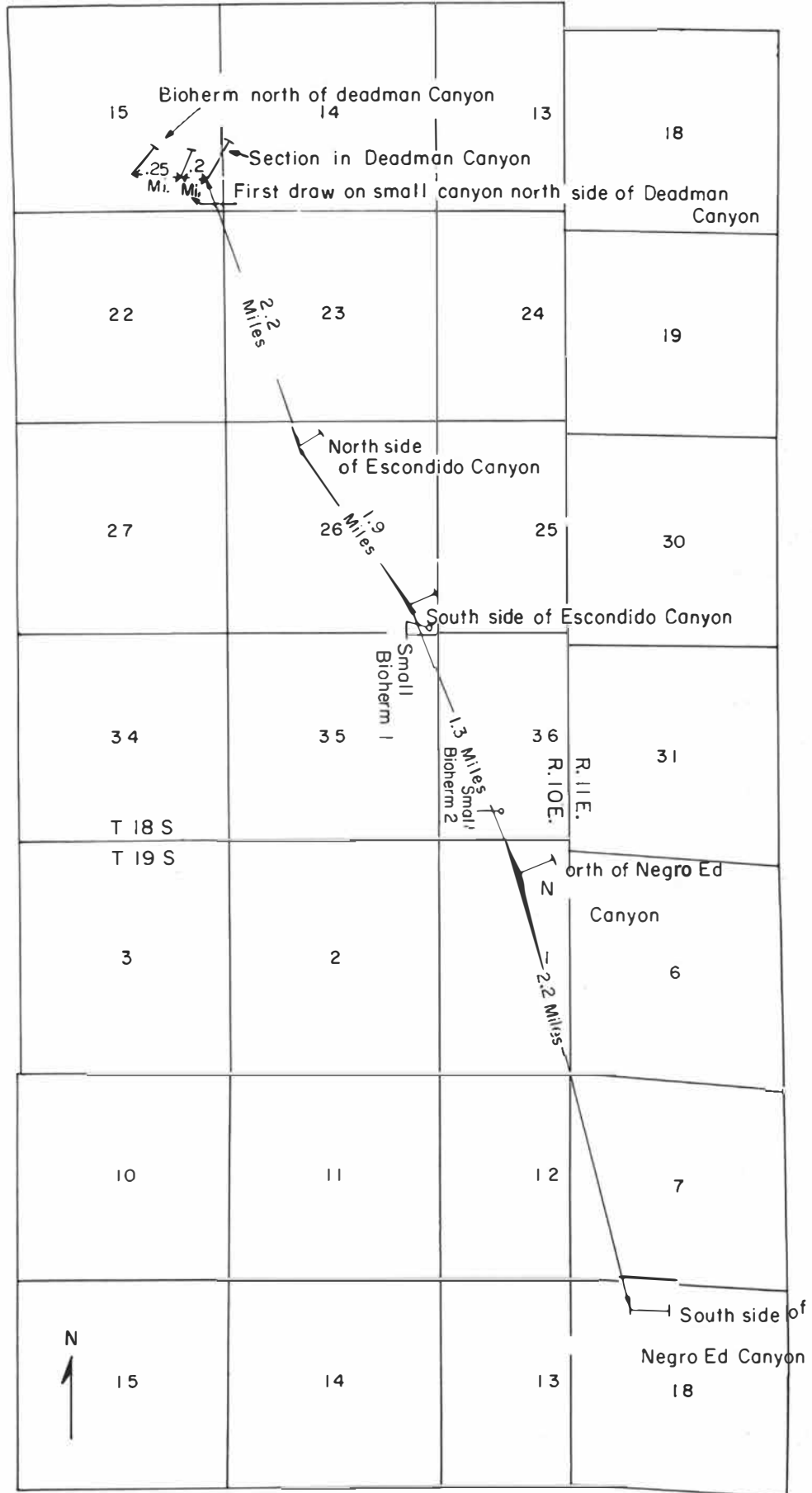


Figure 7

INDEX MAP OF SECTIONS MEASURED IN SOUTHERN SACRAMENTO MOUNTAINS

North side of Deadman Canyon
NW 1/4 SE 1/4 sec. 15, T. 18S., R. 10E.

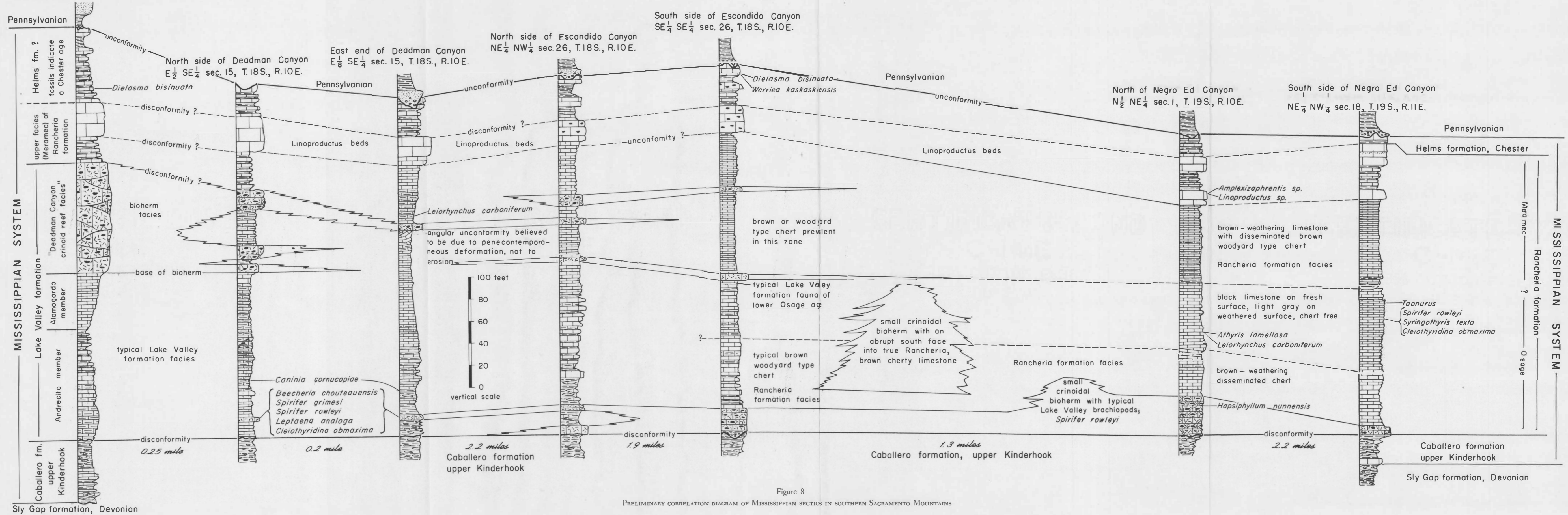


Figure 8

PRELIMINARY CORRELATION DIAGRAM OF MISSISSIPPIAN SECTIONS IN SOUTHERN SACRAMENTO MOUNTAINS

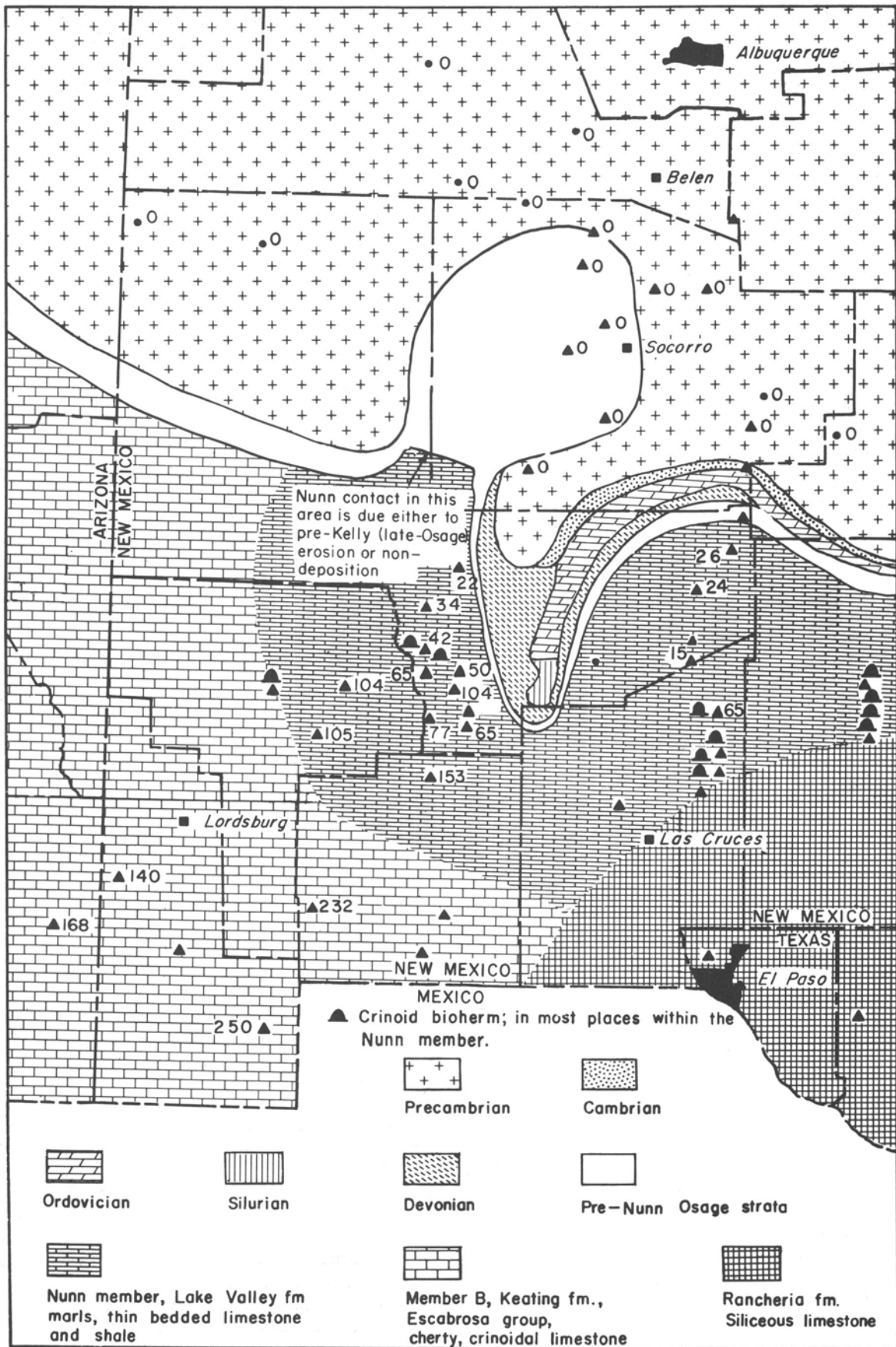


Figure 9

LITHOFACIES AND THICKNESS OF LOWER OSAGE (UPPER FERN GLEN AND BURLINGTON) STRATA.

overlap of lower Meramec age onto eroded Lake Valley (Osage) rocks.

In the Franklin Mountains of Texas and southern Sacramento Mountains of New Mexico, field studies indicate (fig. 7, 8) that the facies change between the Lake Valley and the Osage part of the Rancheria formation is abrupt. In time, the Rancheria facies advanced northward over older Lake Valley facies sediments. Within the Osage part of the Rancheria facies are long tongues of Lake Valley crinoidal limestone. These apparently represent crinoidal debris swept by currents from the higher area of Lake Valley sedimentation into the Rancheria basin of deposition. By walking out the outcrop tongues it is possible to trace these crinoidal limestones back into the Lake Valley formation.

In extreme southwestern New Mexico and extreme southeastern Arizona, the basal Mississippian is represented by member A of the Keating formation (fig. 6). Member A can be divided into two lithic units. The lower of these is 70 to 150 feet thick and is an encrinite which locally is secondarily altered to dolomite. In the Klondike Hills, the highest Devonian is a shale and thin-bedded limestone. Here basal Mississippian reflects the lithology of the Devonian containing as it does much reworked shale. In most places, where the upper Devonian is calcareous or is a limestone, the basal Mississippian is a limestone and generally an encrinite.

Wherever conditions were suitable in this early Osage sea, the crinoids established themselves rapidly and outnumbered most other types of preservable invertebrates. Crinoids thrive best in areas where the waters are clean and agitated, and the bottom stable. During earliest Osage time, in rather localized areas and through a short interval, the crinoids dominated the fauna. This was a short preview of events characteristic of later Osage time. The basal beds of member A were deposited in shallow water at or above wave base. This condition is reflected in the broken and abraded skeletons of the invertebrates. The sea floor during this time was characterized by large areas covered by clay and calcite ooze, and by other large areas dominated by crinoid gardens.

According to Cloud and Barnes (1957, p. 176), on the Bahama Banks, "bottom-living organisms appear to be abundant only where there is an outcrop of bare rock on the sea floor. It is probable that much of the dead shell material which is spread over the rest of the banks has been derived from these comparatively well-colonized areas." Similar conditions may well have existed for most of Osage and Meramec time.

The upper half of member A contains a highly diagnostic coral fauna and two distinctive lithologies. These lithologies can be traced over a wide region. Although some of the rock types indicate that the deposition was at times primarily of calcitic ooze in shallow, quiet water, by far the most characteristic limestones were deposited in high energy zones. Two types of limestone have been observed here, a bioclastic limestone with sparry calcite, and an oolitic limestone.

Investigators who have studied the problem recently believe that in order for oolites to form, marine waters must be swept across a narrow shelf area, where the water becomes warm and supersaturated with calcium carbonate. This supersaturated marine water must then be vigorously agitated. Studies by Illings (1954), Newell and Rigby (1957) and Folk (1959) have indicated two important factors in the formation of oolites: (1) They are characteristic of high energy currents (normally tidal), and (2) they do not occur in the extreme marginal area of a shelf adjacent to deep marine waters. Simi-

lar conditions must have existed over a wide area during the deposition of the coral zone fauna in New Mexico and Arizona. This wide area is thought of as slowly sinking, while the organisms with calcium carbonate shells maintained the sea floor at or above wave base. The sea was broad, shallow, and warm and constantly swept by waves and tidal currents. There were at different places and at different times shallow depressions below wave base in which lime ooze, shell fragments, and fecal pellets accumulated. The sea floor swarmed with invertebrate animals. The unconsolidated lime sands and muds contained countless burrowing organisms (worms and worm-like creatures). The brachiopods, particularly the spiriferoids, orthotetids, terebratulids, chonetids, and productids, thrived. The most conspicuous part of the fauna were the corals which, throughout the area of the Escabrosa group and at this time, were at their apogee. The rugose corals were abundantly represented by the hapsiphyllids, lithostrotionids, and caninids. Large robust colonies of *Syringopora* represented the tabulate corals. The foraminifera are abundant in some of the oolitic horizons. The crinoids and blastoids were a major feature of the fauna, as indicated by the large number of broken plates and stems.

This shallow and warm early Osage sea was not confined to the area of Escabrosa deposition but extended into the central part of the State where it is represented by the Andrecito and Alamogordo members of the Lake Valley formation. The most northerly known sediments representing this regional submergence is the Caloso formation in the Ladron Mountains of west-central New Mexico. This sea may have extended much further north and originally may have covered much, if not all, of New Mexico, but early Pennsylvanian erosion has obscured its original extent (Armstrong 1958a; 1958b; 1959).

The Andrecito and Alamogordo members of the Lake Valley formation were not studied in detail, but faunal evidence indicates that these are a northward facies of member A of the Keating formation. The Andrecito member varies in thickness and is a series of thin-bedded argillaceous limestone, which, depending on the location of the outcrop, rests either upon the Caballero formation (Chouteau) or on shales of late Devonian age. The argillaceous material in the Andrecito member in many places contains well-preserved fossils, such as articulated brachiopods; bedding planes are covered with fenestelloid bryozoans and locally crinoid calyxes with arms and stems. The Andrecito member was apparently deposited in rather quiet, muddy waters. The Andrecito member grades up imperceptibly into the Alamogordo member. The latter is from 30 to 60 feet thick and massive, consisting in part of bioclastic debris and calcirudites, but primarily of calcilutites. The Alamogordo member is stratigraphically a northeastward continuation of the coral zone of member A, Keating formation. The Alamogordo member is believed to have been deposited in much less turbulent waters than was member A.

The Caloso formation of west-central New Mexico is a northward continuation of this lower Osage marine sedimentation. Its relationship to member A of the Keating formation is graphically shown in the Escabrosa group-Lake Valley formation correlation chart (fig.). It rests upon Precambrian rocks and is primarily a massive, fine-grained, unfossiliferous limestone, some 40 to 50 feet thick. It appears to have been deposited in an atypical marine environment with algae the dominant rock-forming organism. The Caloso formation was previously described by the author (Armstrong, 1958b).

The lower part of member B of the Keating formation is correlated with the Nunn member of the Lake Valley formation, partially on lithologic and partially on paleontologic evidence. The key section is in the Klondike Hills southwest of Deming, New Mexico. Here the lower part of member B is undergoing a two-fold lithologic change. One change is toward the gray, siliceous limestones with brown chert which is characteristic of the Rancheria formation to the east in the Franklin Mountains. The other change is toward the shales and argillaceous limestones of the Nunn member to the north in the Cooks Range. In these shale zones are found *Spirifer rowleyi* Hall and *Caninia cornucopiae* Michelin. These fossils, particularly *Caninia cornucopiae*, are characteristic of the Nunn member. Lithologically the lower part of member B, from Blue Mountain to the Big Hatchet Mountains is a dense, fine-grained limestone, composed of fine-grained, bioclastic material, lime ooze, and fecal pellets, with horizons of coquinite and encrinite. At higher levels in this part of the section, the encrinites become proportionally more conspicuous. Fossils in this part of the section are rare but, when found, are generally well preserved, although they appear to have suffered crushing during compaction. The brachiopods are generally articulated, and the rugose coral skeletons are usually complete. The fossils indicate that they were not deposited in a zone of high wave energy and were thus below wave base.

To the northeast the Nunn member of the Lake Valley formation is primarily a soft blue-gray marl and nodular crinoidal limestone. The brachiopods are generally articulated and well preserved, and crinoid calyxes are common. These fossils, as was pointed out by Laudon (1957, p. 966), appear to represent periods when some life was overwhelmed by sudden influxes of muds. The Nunn member reflects waters with only mild agitation on the sea floor. It is believed that the time represented by the lower part of member B of the Keating formation, and by the Nunn member of the Lake Valley formation, was a period of general lowering of the sea bottom in the southern part of the State. This resulted in sedimentation occurring at, or just below, wave base in the region. Paradoxically, the Penasco dome to the north was slightly elevated, and the marine water receded southward a short distance (50-70 miles). The Penasco dome, with its fringing emergent plain of marine limestones, underwent for a short period of time slightly more active subaerial erosion. The streams, which flowed southward across the plain, carried muds which were deposited in the relatively quiet waters of Nunn time. This interpretation is supported by the Mississippian rocks in west-central New Mexico in the Ladron and Magdalena Mountains. Here the Caloso formation of lowest Osage age is separated from the crinoidal Kelly formation of Keokuk age by a paraconformity which represents all of Burlington time and that part of Fern Glen time represented by the Nunn member to the south (fig.9).

In the Escabrosa basin the crinoids were able in a short period of time to build up the sea floor and maintain it at or above wave base.

Although crinoid remains are the major elements in the upper part of member B, they do not dominate the fossils. Other organisms are abundantly represented by broken remains—brachiopods, bryozoans, corals, and lesser amounts of gastropods and trilobites.

One of the most striking aspects of member B is the massive, lenticular beds of chert. The wide areal distribution of this

chert from the Chiricahua Mountains of Arizona eastward to the Klondike Hills of New Mexico and its persistence through a thick stratigraphic section (150-200 feet) necessitates some paleoecological interpretation. The chert shows direct evidence of a replacement origin—persistence of bedding through the chert, relic structures and textures, and partial silicification of fossils and other carbonate fragments which extend across the chert-carbonate rock boundary. The silica is believed to have been originally disseminated throughout the unconsolidated calcite sand and ooze. During diagenesis the silica was concentrated into nodules by metasomatic replacement. The author believes the sea water in the area during the deposition of member B may have contained a higher concentration of dissolved silica than at other times.

The upper part of member B is composed primarily of crinoid fragments and an appreciable amount of broken and abraded remains of the following organisms: brachiopods, rugose corals, bryozoans, trilobites, and gastropods. The limestone is dark gray; petrographic studies indicate the dark color is due to the high percentage of fecal pellets. Insoluble residue studies reveal the almost complete absence of terrigenous material and the presence of an appreciable amount of organic (hydrocarbon) material. The organic matter is believed to be contained primarily in the brown fecal pellets. The dark color of the rocks, the abundant fecal pellets, abundant hydrocarbons, and small, disseminated pyrite suggest the muds beneath the water-substratum interface were in a strongly reducing environment.

At higher stratigraphic levels of member B, there is an increase in the size of the bioclastic materials. Near the top of this unit are found intraformational conglomerates and the problematic worm burrows, *Taonurus*. The highest bed of the Keating formation contains extensive zones of intraclasts, intraformational conglomerates. The abundance of crinoid, brachiopod, and bryozoan remains indicate the sea waters were well oxygenated. These factors suggest marine water which became progressively more shallow. The limestones of the middle and upper part of member B are believed to have been deposited in an epineritic environment, and the stratigraphically higher horizons had at times locally supratidal environments.

EMERGENCE OF CRINOIDS TO DOMINANCE IN OSAGE TIME

There was present, over all of southwestern and south-central New Mexico, an extensive blanket of crinoidal limestone. In the southeastern part of the State this was replaced by the non-crinoidal Rancheria facies. This crinoidal limestone extended westward into southeastern Arizona. The encrinite represents most, if not all, of Burlington and Keokuk time. It covered a large area, as can be seen on the Burlington and Keokuk lithofacies maps (fig. 9, 10). Its thickness ranges from 40 feet in the central part of the State to 300 feet along the Mexican border. This series of encrinites is composed almost entirely of broken and abraded crinoid remains and occasional crinoid-commensal gastropods of the genus *Platyceras*. The whole is cemented by sparry calcite and by microcrystalline calcite. Fecal pellets are almost completely absent.

Other groups of marine invertebrates, such as brachiopods, bryozoans, corals, endothyrids, and trilobites, are virtually absent. The environment, which permitted the crinoids to

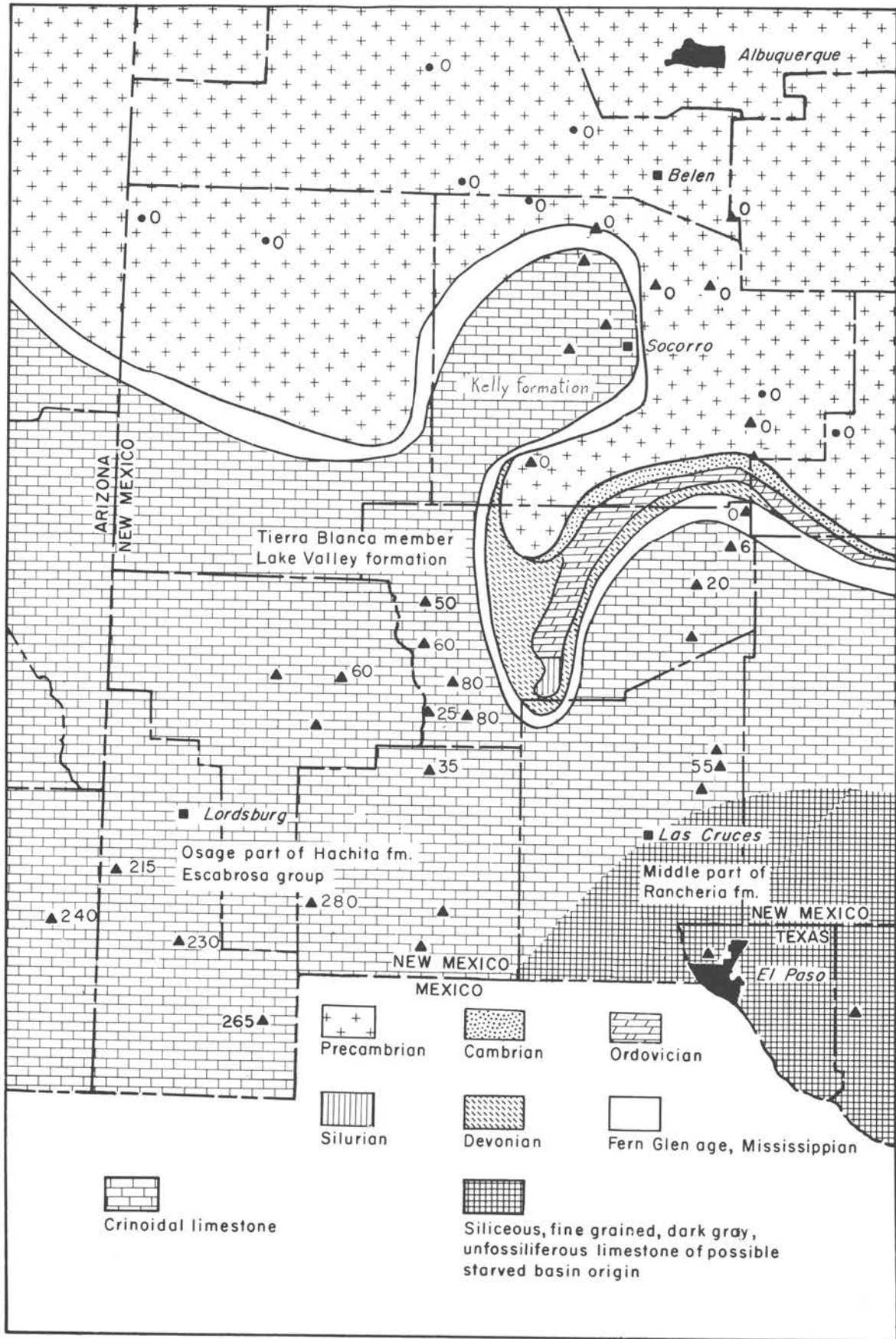


Figure 10

LITHOFACIES AND THICKNESS OF UPPER OSAGE (KEOKUK) STRATA

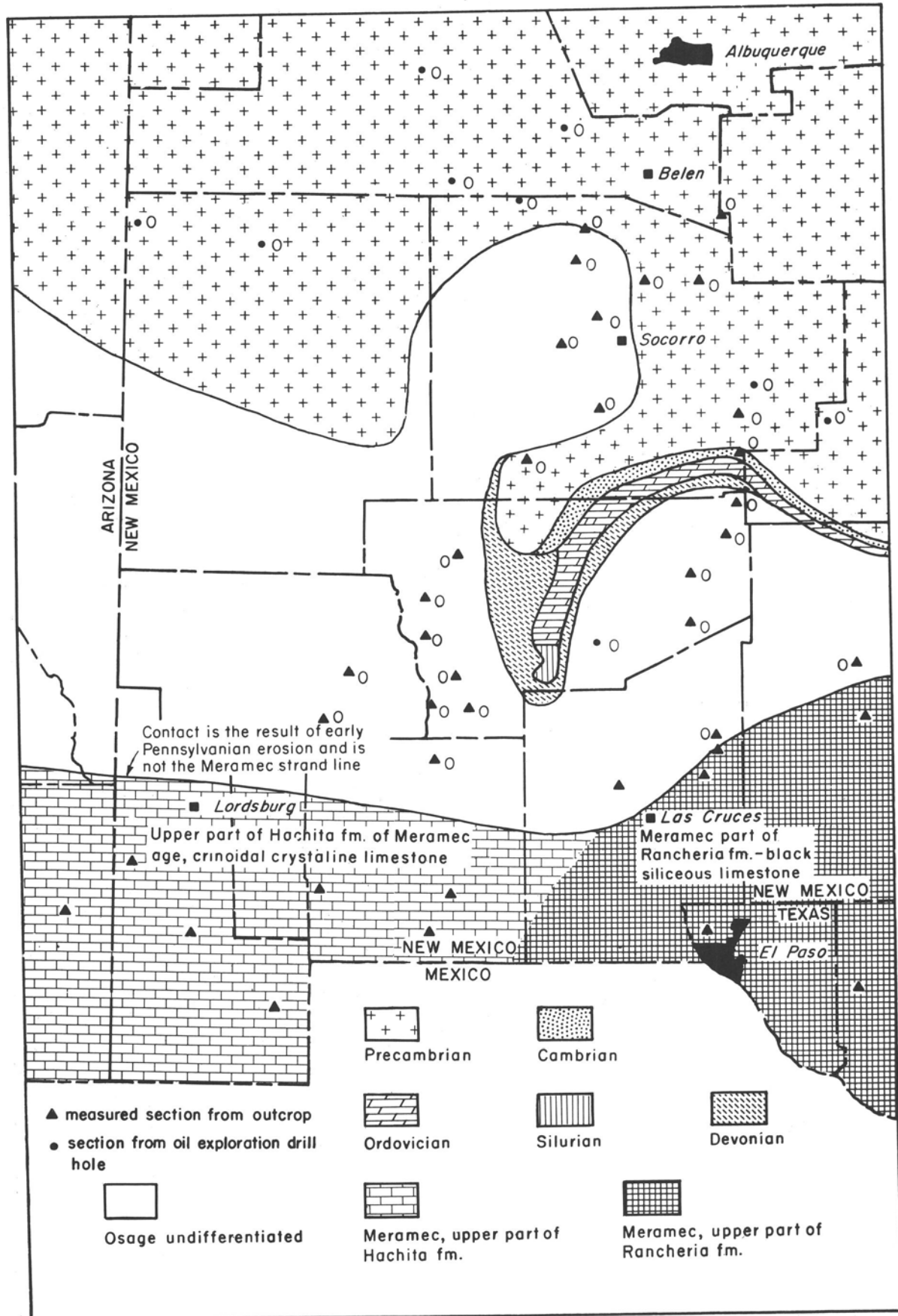


Figure 11

LITHOFACIES MAP OF MERAMEC STRATA CHESTER

flourish to the almost complete exclusion of other animals, appears to have begun somewhat earlier in south-central New Mexico. In the area of the Lake Valley formation, the transition zone from the marls of the Nunn member to the encrinites of the Tierra Blanca member is 5 to 15 feet thick. The transition occurred in highest Fern Glen or lowest Burlington time. To the south and southwest in the Escabrosa basin, the transition from the impure, highly cherty, dark-gray encrinites in the Keating formation to the pure encrinites in the Hachita formation is abrupt; and the meager paleontological data indicate it occurred in early Burlington time. The luxurious crinoid gardens of Burlington to Keokuk time are considered to have been on a very flat shallow sea floor which extended over an extensive region covering a minimum of 45,000 square miles. This broad submarine plane sank very slowly. Its hinge-line with the Penasco dome in northern New Mexico appears to have been in the central part of the State, and to have extended in a northwestern arc across northeastern Arizona. The region along the Mexican border in southwestern New Mexico and southeastern Arizona sank the most, receiving as much as 300 feet of encrinite during Burlington and Keokuk time.

The accumulation of crinoid remains on the sea bottom during this time maintained the sea floor at a rather constant, shallow depth despite the slow downwarping of the region. The rocks indicate that some sedimentation did occur in rather quiet waters. The marine waters were warm, semi-tropical to tropical, clear, and well-oxygenated, and must have contained abundant nutrients. The unconsolidated sediments below the water-substratum interface were in an oxidizing environment. The sea bottom during this time must have been primarily shifting bioclastic calcite sands intermixed with lime ooze, which were washed into deeper depressions below wave base. Terrigenous clastic material was essentially absent over the whole region. On this broad marine plane, where the substratum was stable, there must have existed vast meadows of crinoids.

As the basin of deposition downwarped, the sea extended northward onto the Penasco dome. The most northerly known advance of the Osage encrinite sea is in the Ladron Mountains of west-central New Mexico. Here the crinoidal Kelly formation of Keokuk age rests with a marked disconformity on the Caloso formation of Fern Glen age. The hiatus separating the two formations represents all of Nunn and Tierra Blanca (Burlington) time. At the north end of the Ladron Mountains, an early Pennsylvanian unconformity truncates the Kelly formation, so that its original northward extent is unknown. Armstrong (1958b) believed the strand line probably existed many tens of miles to the north.

MERAMEC

A recapitulation of events and paleoecology during Meramec time in New Mexico is extremely difficult because of the widespread removal of these sediments during early Pennsylvanian time. Scattered and isolated remains of Meramec limestone indicate that many separate stages of Meramec seas may have covered much of the State during the epoch. The thin, upper Meramec limestones of the Arroyo Penasco formation represent the only known Mississippian and pre-Pennsylvanian submergence of the peneplained Precambrian Penasco dome of northern New Mexico (Armstrong, 1955; 1958a; 1959). Meramec rocks are unknown in the central

part of the State, but this is believed to be the result of Pennsylvanian erosion. To the south they are now confined to the extreme southern parts of the State (fig. 1 D).

Meramec time is represented in the Trans-Pecos region by the upper Rancheria facies. In southwestern New Mexico all of Meramec time appears to be represented in the upper part of the Hachita formation, Escabrosa group. In this area sedimentation continued from Osage to Meramec time without a break. This condition also existed in extreme southeastern Arizona. Warsaw deposition clearly began in a late Osage setting (i.e., encrinites) in the Escabrosa group. But with the progression of Meramec time, other groups of invertebrates, brachiopods, bryozoans, and—sporadically—endothyrids, made increasingly major contributions to limestone-forming sediments. Lithology of the limestones indicates that the Meramec sea floor was shallow and in the zone of strong wave action. Some unknown factor or factors in the environment progressively prevented exclusive domination by crinoids and presented the brachiopods and bryozoans with many ecological niches. In the Meramec strata rugose corals are very rare, and the tabulates are represented only by an occasional *Michelinia leptosphragma* n. sp. Some ecological factor (temperature, water depth, turbidity) must have been very detrimental to coral development.

As can be seen on the Escabrosa group—Lake Valley correlation chart, the Meramec limestones were truncated by the early Pennsylvanian erosion surface in the northern part of the Escabrosa basin. The ancient northern limits of Meramec marine sedimentation may never be known, nor whether the younger parts may have been continuous with the Arroyo Penasco sea. It seems likely that various bays of the Meramec sea may have extended many tens or even hundreds of miles northward. Originally 100 to 200 feet of limestone may have been deposited above the Lake Valley formation.

CHESTER

The Paleozoic systems of New Mexico previous to Chester time had been characterized by shallow platforms repeatedly covered by broad, epicontinental seas. The thickest accumulations of sediments were in the southern part of the State, and the Penasco dome to the north was generally emergent, very flat, and stable. The Mississippian seas advanced into the northwestern part of the San Juan Basin and, in northeastern New Mexico, into Union County (Maher and Collins, 1949). The pre-Chester Mississippian marine sedimentation closely resembled that of the older periods. Chester sedimentation and tectonics were markedly dissimilar to those of earlier Mississippian time. The beginning of the epoch heralded the inception of structural and sedimentation patterns which were to dominate the Pennsylvanian period (Kottlowski, 1960). At the end of Meramec time, marine waters withdrew from the northern shelf areas, and by Chester time were confined to the extreme southern part of the State (fig. 12). The Zuni (fig. 13), Sierra Grande, and Pederal highlands, which were to become such conspicuous elements during Pennsylvanian time, developed concurrently with the retreat of the marine waters. The Osage and Meramec epochs were times of uniform environment and widespread stability. The Chester sediments indicate, in contrast, a time of fluctuating sedimentation and crustal instability. The sediments of the Paradise formation are cyclic, impure, microcrystalline to bioclastic

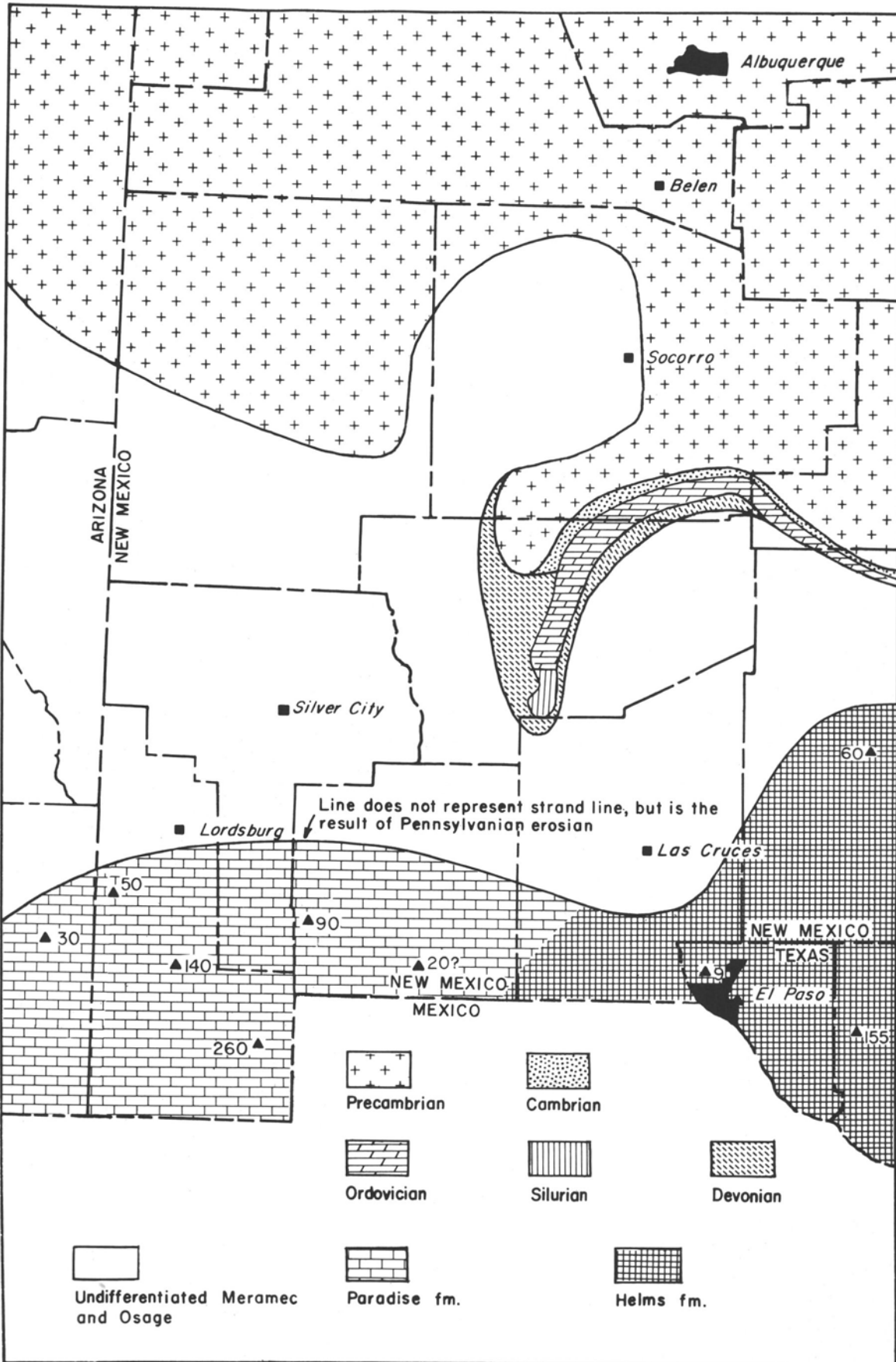


Figure 12

LITHOFACIES MAP AND THICKNESS OF CHESTER STRATA

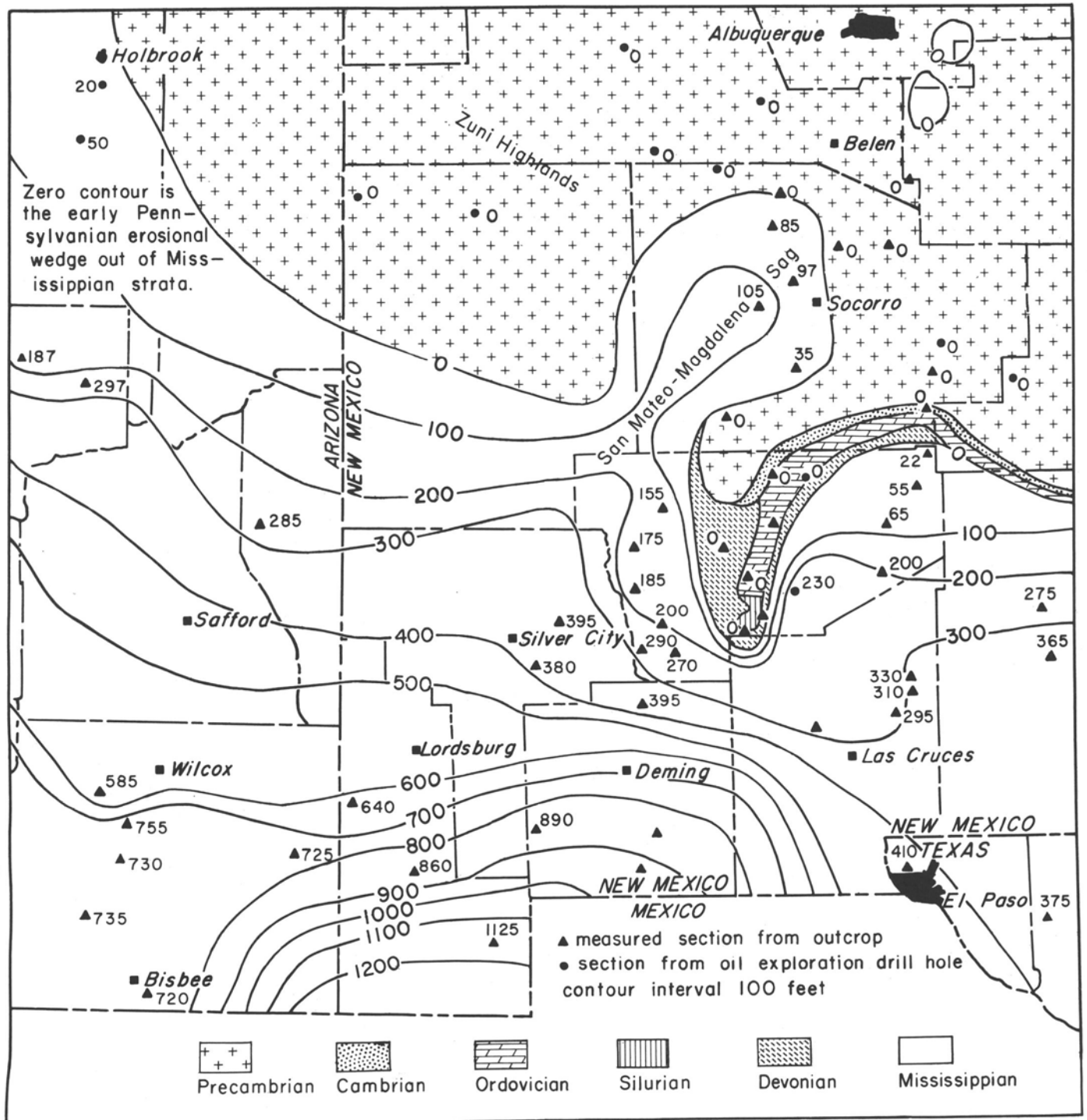


Figure 13

ISOPACH MAP OF MISSISSIPPIAN STRATA

limestones, fine-grained sandstones, and shales. Some of the shales, particularly those in the higher part of the section, contain plant remains that indicate interfingering of marine and terrestrial environment or material washed in from adjacent lands. The Paradise formation in the Big Hatchet Mountains, which is about 230 feet thick, shows a noticeable increase of elastic materials in the higher part of the section. The marine waters evidently fluctuated repeatedly over a wide area but generally retreated progressively southward during Chester time. This was caused by the increased influx of elastic material from the elevated highlands to the north and to the gradual emergence of the whole region above sea level.

A detailed study of the Paradise fauna was not made, but preliminary studies indicate that in the Big Hatchet Mountains, the hiatus between the Chester and the Morrow Pennsylvanian is very short. The writer believes it represents only latest Chester and very earliest Pennsylvanian time. Conceivably, to the south in Mexico, this basin contains continuous sedimentation from Chester to Morrow time. The base of the Pennsylvanian in the Klondike Hills and Big Hatchet Mountains is marked by 10 to 25 feet of orthoquartzite, which grades upward into shales and massive limestones. Westward in the Animas and Chiricahua Mountains, the basal Pennsylvanian is a brown to gray marine shale overlain by massive limestones. But in the Naco Hills, Arizona, southwest of these outcrops, the basal Pennsylvanian is a red shale and conglomerate.

MISSISSIPPIAN BIOHERMS

The Escabrosa exposures were examined in detail in a search for biohermal buildups. Abundant bioherms were expected within the massive encrinities of the Hachita formation; however, they are absent within this unit. The Hachita encrinities were deposited in a shallow sea in which there must

have existed, wherever the bottom was stable, scattered gardens of crinoids. With the death of a crinoid, its remains were swept away by currents and deposited in areas which were not colonized. Areas colonized by crinoids apparently only persisted for a short period of time in one location. These colonies furthermore did not build up in biohermal masses above the surrounding sea floor.

The only definite biohermal structures observed within the Escabrosa group are found in the massive basal encrinite of member A of the Keating formation, on the northeastern side of the Big Hatchet Mountains. Here there are small crinoidal bioherms 60 feet high and about 150 feet wide. They are very conspicuous because silicification has altered them to dark brown, which contrasts with the light gray of the enclosing encrinities.

The Osage Lake Valley formation contains a number of crinoidal bioherms which appear to have a generalized east-west lineation. These are graphically illustrated on the upper Fern Glen—Osage lithofacies map (fig. 9). The early studies on these bioherms were done by Laudon and Bowsher (1941, 1949) in the Sacramento and San Andres Mountains. Pray's (1958) detailed study in the Sacramento Mountains showed the biohermal cores to be of fenestrate bryozoans. It also demonstrated that some of the large bioherms may have risen 300 feet or more above the sea floor but probably did not grow into the vigorously agitated surface water.

The majority of the bioherms in the Sacramento Mountains rise out of the Alamogordo member, but a few small bioherms occur entirely within the Tierra Blanca member. The Lake Valley bioherms in the southern San Andres Mountains are similar to those of the Sacramento Mountains but have not been studied in detail. The other major concentration of Lake Valley crinoid bioherms is in the North Percha Creek area of the Black Range. Here the bioherms are small, about 100 feet high, and occur entirely within the Tierra Blanca member.

Systematic Paleontology

Phylum PROTOZOA

Class RHIZOPODA von Siebold, 1845

Order FORAMINIFERA Zborzewski, 1834

Superfamily ENDOTHYRACEA Brady, 1884

Family ENDOTHYRIDAE Brady, 1884

Subfamily ENDOTHYRINAE Brady, 1884

Stratigraphic zoning based on the endothyrids in the Mississippian Period is now very difficult for a time interval finer than a series. Endothyrids may prove to be valuable for tighter zonation, particularly within a basin of deposition, but they may never prove to be so useful for stratigraphic purposes as the fusulinids, due principally to the simplicity of their tests.

Zeller's (1957) study of the endothyrids of the Cordilleran region was a significant advance in our knowledge of this group; it is, however, deficient in two respects: First, the megafaunal contents and the stratigraphic time involved in the majority of the sections he used for setting up endothyrid zones (biozones) was essentially unknown. Second, apparently Zeller was unaware that some of these sections were structurally complex and errors were made in the measured sections.

The sensitivity of endothyrid species to ecologic environments that cross time lines is not fully known. James Lee Wilson (personal communication, 1960) believes they have a strong tendency to migrate across temporal zones and that this greatly limits their stratigraphic value.

Genus ENDOTHYRA Phillips, 1843

Endothyra Phillips, J., 1843, in Brown, T., The Elements of Fossil Conchology, London, p. 17.

Endothyra, Phillips, J., 1846, Geol. and Polytech. Soc., West Riding, Yorkshire, Proc. for 1844-1845, Leeds, V. 2, p. 277.

Endothyra, Brady, H. B., 1876, Paleont. Soc. Pub., London, V. 30, p. 90.

Endothyra, Plummer, H. J., 1945, Texas Univ. Bull. 4401, p. 237.

Endothyra, Scott, H. W., Zeller, E., and Zeller, D. N., 1947, Jour. Paleont., V. 21, p. 557.

Endothyra, Zeller, E., 1950, Kansas Univ. Paleont. Contr., n. 7, Protozoa, art. 4, p. 3-4.

Endothyra, St. Jean, J., 1957, Indiana Geol. Surv. Bull. 10, p. 23-27.

Endothyra, Woodland, R. B., 1958, Jour. Paleont., v. 32, p. 799-800.

Type Species. Endothyra bowmani, Phillips, J., 1846, Geol. and Polytech. Soc., West Riding, Yorkshire, Proc. for 1844-45, Leeds, v. 2, p. 277, Lower Carboniferous, Yorkshire, England.

Range. Mississippian.

Diagnosis. Shell is involute, discoidal, and planispiral. The chamber may be swollen between sutures. The aperture is low and slit-like. A tunnel or low passage extends back through the entire coil to the proloculus and is secondarily enlarged by resorption. The coiling is logarithmic but is in one plane. The wall is calcareous, two distinct layers being present and an indistinct third.

Remarks. The reader is referred to the remarks under *Paraendothyra* Chernysheva.

Endothyra symmetrica Zeller

Pl. 1, fig. 34

Endothyra symmetrica Zeller, E. J., 1957, Jour. Paleont., v. 31, p. 701-702; pl. 75, fig. 14, 18, 19; pl. 78, fig. 8, 9; pl. 80, fig. 6.

Endothyra symmetrica, Woodland, R. B., 1958, Jour. Paleont., V. 32, p. 800; pl. 101, fig. 7, 9, r0.

Description. The shell is discoidal and involute, and the chambers are slightly swollen between the sutures. The coiling is planispiral. Moderately long septa show a slight anterior direction. Proloculus is 30 to 40 microns in diameter. Secondary deposits are confined to the development of a prominent hamulus in the final chamber. The specimens studied by the writer ranged in size from 0.4 mm to 0.8 mm in diameter.

Horizon. Within the Escabrosa group *E. symmetrica* was found to range stratigraphically from 20 feet below the *Syringothyris subcuspidatus* zone (Warsaw age) to the top of the Hachita formation (St. Louis age).

Remarks. In the description of the type material from the Chiricahua Mountains, Zeller (1957, p. 701) stated the species averaged 0.4 mm in diameter. Woodland (1958, p. 800) described *E. symmetrica* from central Utah as having a maximum diameter of 0.6 mm. Topotype material from Blue Mountain, Arizona, show the species to range in diameter from 0.4 mm to 0.8 mm. *E. symmetrica* differs from *E. disca* Zeller by its much larger size and secondary deposits. *E. symmetrica* is separated from *E. spiroides* Zeller by its larger size, its more rapid rate of expansion, its less numerous septa and its smaller number of volutions. *Endothyra prodigiosa* Armstrong is larger, has a slightly higher septal count, and better-developed secondary deposits than *E. symmetrica*. *E. symmetrica* as interpreted in this report is closely related to *E. prodigiosa* from the Meramec Arroyo Penasco formation of northern and central New Mexico. Zeller (1957, p. 694) believed *E. symmetrica* in the Cordilleran region was characteristic of upper Meramec equivalent to the upper St. Louis and Ste. Genevieve formation of the Mississippi Valley. Detailed studies of the brachiopods associated with *E. symmetrica* indicate the species within the Escabrosa group ranges from basal Warsaw to St. Louis, Meramec time.

Endothyra sp. indet.

Pl. 1, r, fig. 35

Description. The oolitic horizons of the coral fauna (lower Osage), member A, Keating formation, contain sporadic examples of a very large endothyrid. Adequate horizontal axial sections could not be obtained for specific description. The shell is involute, the last whorls are strongly swollen, and the walls are thin. Secondary deposits are absent. The diameter of the shell is from 0.8 mm to 1.2 mm. (Text fig. 14.)

Remarks. *Endothyra* s. s. is apparently absent in pre-Meramec strata of the Midcontinent region (Zeller, 1950). In the



Figure 14
Endothyra SP. INDET.

Cordilleran region Zeller (1957) and Woodland had found in pre-Meramec Mississippian strata only small (0.4 mm in diameter) *Endothyra*. These forms have very weakly developed secondary deposits.

The Kinderhook—Osage transition beds of member A, Keating formation, Escabrosa group, have yielded a very few large (maximum diameter of 1.2 mm) *Endothyra*. Their size and contour are comparable to species of *Endothyra* described from Meramec-age strata. Internally they display a primitive character, the lack of secondary deposits within the shell. Furthermore, they are separated from their apparent Meramec homeomorphs by the possession of a final whorl which is expanded, and by their very thin walls.

Genus **PARAENDOTHYRA** Chernysheva, 1940

Paraendothyra Chernysheva, N. E., 1940, Societe des Naturalistes de Moscou Bull., v. 48, p. 129; pl. 134.

Plectogyra Zeller, E. J., 1950, Kansas Univ. Paleont. Contr. n. 7, Protozoa, art. 4, p. 3.

Plectogyra, Zeller, D. N., 1953, Jour. Paleont., v. 27, p. 195.

Plectogyra, Woodland, R. B., 1958, Jour. Paleont., v. 32, p. 797-780.

Type Species. (Original designation) *Paraendothyra nalivkini* Chernysheva, N. E. (1940, Societe des Naturalistes de Moscou Bull., v. 48, p. 129-130, 135); lower Carboniferous Tournaisian stage, western slope of the southern Ural Mountains.

Range. Mississippian—Pennsylvanian.

Diagnosis. The shell is discoidal and probably umbilicate on one side. It is involute and the chambers swollen between sutures. The aperture is low and slit-like. A tunnel or low passage extends back through the entire coil to the proloculus and is secondarily enlarged by resorption. The coiling is logarithmic; the spirals are twisted along an axis so that a three-dimensional spiral is produced. The wall is calcareous, two distinct layers being present and an indistinct third.

Remarks. Brown (1843) published a description and illustration of *Endothyra bowmani* Phillips. This was the first time that *Endothyra* had been described in a publication. Brown indicated that the genus was not his, and by placing Phillips' name after *Endothyra* he indicated that Phillips and not Brown was the author of the genus. Three years later Phillips (1846) published a description and figure of *Endothyra bowmani*. A comparison of the figures of the two workers shows marked differences. Both describe and show a planispiral foraminifera; but Brown's drawing is more typical of *Endothyra*, whereas Phillips' drawing looks suspiciously like the equatorial section of a Pennsylvanian fusulinid. The consensus among modern workers is that Phillips is the author

of *Endothyra*. A series of papers dealing in detail with this subject has been published (Scott, Zeller, and Zeller, 1947; Zeller, 1950; Henbest, 1953; and St. Jean, 1957).

Brown (1843) and Phillips (1846) both lucidly described and illustrated planispiral forms. Brady (1876) redescribed *Endothyra* Phillips from supposed topotype material and considered as a typical example the asymmetrically coiled American species, *E. baileyi* (Hall). Chernysheva (1940) in a relatively unknown Russian publication erected the genus *Paraendothyra* for the asymmetrically coiled endothyrids. Zeller (1950) apparently without knowledge of Chernysheva's *Paraendothyra*, proposed his genus *Plectogyra*, also for asymmetrical forms, restricting the planispiral forms to *Endothyra*. Henbest (1953) thought the possibility existed that the asymmetrical forms (*Plectogyra*), which had a relatively small proloculus, were the microsphere generation of *Endothyra*. He considered *Endothyra*, with its large proloculus, to be the megasphere generation. He also argued that the genus *Endothyra* should be amended to Brady's definition so as to include both symmetrical and asymmetrical endothyrids. The strongest criticism of Zeller's genus *Plectogyra* came from St. Jean (1957), who contended that American paleontologists had for the last three-quarters of a century agreed with Brady (1876) that *Endothyra* included both asymmetrical and symmetrical forms, with *Endothyra baileyi* as a typical representative. St. Jean was also disturbed by the fact that if Zeller's *Plectogyra* were considered valid, the generic assignment of the commonly accepted species of *Endothyra* would need to be changed, and the genus *Endothyra* s. s. would be in the minority.

The fact that American paleontologists and Brady (1876) considered the genus *Endothyra* to include asymmetrical forms is not the ultimate criterion for defining the genus. Phillip's original description (in Brown) of the genus, which relates only to planispiral forms, is in reality the final definition. The arguments of St. Jean that a number of well known species of *Endothyra* would become *Plectogyra* is not valid taxonomically. Prior to Zeller's (1950) study, most American paleontologists customarily referred to all Mississippian endothyrids, regardless of stratigraphic or geographic position, to *E. baileyi* (Hall). The genus was of little value stratigraphically or taxonomically, and nothing was known of the phylogeny within the group. Henbest's theory, that the asymmetrical forms may be the microsphere form of *Endothyra*, has merit. It is possible that detailed population studies may prove the asymmetrical form is in part a microsphere form, but the majority of asymmetrical forms are probably true species. The writer has observed, from a number of thinsections in an endothyrid-rich zone, that one horizon will yield a population consisting exclusively of either *Paraendothyra* or *Endothyra*. This phenomenon has been observed many times. It seems plausible to expect that, if the two forms are an alteration of generations, there should be a ratio of *Endothyra* to *Paraendothyra* in the populations studied. This condition has not been observed in the studies made. In the Escabrosa group and related formations the majority of *Paraendothyra* are in strata of Osage and Chester ages whereas *Endothyra* is dominant in the Meramec. Criticism has been raised against *Paraendothyra*, whose generic traits are primarily its asymmetrical coiling. There do exist transitional species, which are difficult to place as either planispiral or as asymmetrical forms. However, it has been found that the great majority of endothyrids are easily identified as either *Endothyra* or *Para-*

endothyra. The gradation in form observed in the endothyrids is not extraordinary and is found commonly in most taxonomic categories, particularly at the generic and specific level in paleontology.

St. Jean (1957, p. 26) stated correctly that Zeller's genus *Plectogyra* is known entirely from thinsections, that, as yet, no one has illustrated or described the external characters, and that *Endothyra* probably cannot be distinguished from *Plectogyra* (the *Paraendothyra* of this paper) on external characters. St. Jean further pointed out that if these foraminifera are used for stratigraphic work, as in the correlation of well samples, sectioning would probably not be feasible. St. Jean apparently believes the generic and specific traits of endothyrids should be based on the exterior of the shell. The vast majority of endothyrids in the Mississippian system occur almost exclusively in limestones, and they are virtually impossible to obtain free from the matrix, as Zeller (1950, 1957) mentioned. Because of the nature of the enclosing rock and preservation, Mississippian endothyrid studies must rely almost entirely on thinsection studies.

Paraendothyra sp. indet.

Pl. 1, fig. 33

Discussion. The genus *Paraendothyra* is sporadically represented within the Escabrosa group. They are first encountered in the section in the oolitic limestones associated with the coral zone of member A (lowest Osage), Keating formation. The genus has not been encountered in member B, Keating formation. Occasional *Paraendothyra* are found in the lower part of the Hachita formation (upper Burlington age). Above this zone the genus has not been found in Keokuk through Chester strata. Because of the rarity of *Paraendothyra* in the Escabrosa group, suitably oriented specimens for specific determinations were not encountered in the thinsections. The majority of *Paraendothyra* found were apparently of the *Paraendothyra torquida* (Zeller) species group.

Family FUSULININEA Moller, 1878

Genus **PARAMILLERELLA** Thompson, 1951

Paramillerella Thompson, M. L., 1951, Cushman Foundation Foram. Res., Contr., v. 2, pt. 4, p. 115.

Type Species. (Original designation) *Millerella? adventa* Thompson, 1944, Kansas Geol. Surv. Bull. 52, pt. 7, p. 427-429. Morrowan (Lower Pennsylvanian) of Kansas.

Range. Late Mississippian (Chester) and throughout most, if not all, of the Pennsylvanian. The writer has consistently observed *Millerella tortula* in the Mississippian Chainman formation of White Pine County, Nevada, and some 400 feet below the *Goniatites choctawensis* Shumard P2 zone. The zone of *Millerella* therefore extends into strata of middle Meramec age.

Paramillerella tortula (Zeller)

Pl. 1, fig. 30

Millerella tortula Zeller, D. E. N., 1953, Jour. Paleont., v. 27, p. 192-194.

Paramillerella tortula, Zeller, D. E. N., 1957, Jour. Paleont., v. 31, p. 703.

Description. The shell is small, umbilicate. The proloculus is very small, juvenarium plectogyroid. Coiling essentially

planispiral, causing elongation of the shell in some specimens. The walls are of moderate thickness and the septa show slight anterior direction. Secondary deposits are very sparse and irregularly deposited. Mature specimens are between 0.25 mm and 0.35 mm wide and 0.08 mm and 0.10 mm long.

Horizon. E. J. Zeller (1957, p. 694, and text fig.) stated that at Blue Mountain, Chiricahua Mountains, Arizona, "The fusulinid *Paramillerella tortula* is present in abundance throughout the Paradise formation." At this locality the writer made a number of thinsections throughout the Paradise section and found *P. tortula* to be restricted to the higher beds of the Paradise formation and to occur very sporadically. The Paradise section in the Big Hatchet Mountains is more than twice as thick as at the type section at Blue Mountain, and apparently contains strata of younger Chester age. Here also the genus *Paramillerella* is restricted to the stratigraphically higher limestone and occurs only sporadically. It has been observed that those horizons which contain *Archimedes* will probably contain *Paramillerella*. The coquinid and microcrystalline limestone horizons in the Paradise formation are generally devoid of fusulinids.

Remarks. According to D. E. N. Zeller (1953, p. 194) *P. tortula* differs from *Paramillerella designata* (Zeller) in its smaller size and smaller number of volutions. *Paramillerella cooperi* (Zeller) differs from the above species in having a greater number of chambers per volution, larger proloculus and a more nearly planispiral manner of coiling.

Paramillerella? sp.

Pl. 1, fig. 31, 32

Discussion. Limestone thinsections made approximately 10 feet above the *Syringothyris subcuspidatus* zone of Warsaw age at Blue Mountain, Arizona, revealed the presence of an axial section of a small (0.28 mm in width) calcareous foraminifera. It has a very short axis of coiling and is obviously planispiral. The specimen had been partly obliterated by incipient recrystallization, and the exact nature of the secondary deposits is obscured. This *Paramillerella?* sp. occurs within the zone of *Endothyra symmetrica* Zeller and it is conceivable that the specimen may represent the megalospheric generation of *E. symmetrica*, or an immature individual.

Phylum **COELENTERATA**

Order **RUGOSA** Milne-Edwards and Haime, 1850

Suborder **STREPTELASMATINE** Wedekind, 1927

Superfamily C Y A T H A X O N I C A E Milne-Edwards and Haime, 1850

Family **HAPSIPHYLLIDAE** Grabau, 1928

Genus **AMPLEXIZAPHRENTIS** Vaughan, 1906

Amplexi—Zaphrentis, Vaughan, A., 1906, Quart. Jour. Geol. Soc. London, v. 62, p. 315-316, pl. 29, fig. 7.

Triplophyllites, Easton, W. H., 1944, Illinois Geol. Surv. Rept. Invest., n. 97, p. 35.

Triplophyllites (Triplophyllites) Easton, W. H., 1951, Jour. Paleont., v. 25, p. 391-392.

Amplexizaphrentis, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F (Coelenterate), p. F267.

Amplexi—Zaphrentis, Sutherland, P. K., 1958, Canada Geol. Surv. Mem. 295, p. 44-51.

Type Species (By subsequent designation: Lang, Smith, and Thomas, 1940, p. 16) *Zaphrentis bowerbanki* Milne-Edwards and Haime, Thomson (1883, Proc. Phil. Soc. Glasgow, V. 14, p. 368).

Range. Mississippian to lower Pennsylvanian.

Diagnosis. Corals small to medium-sized, solitary ceratoid or trochoid with cardinal fossula on the concave side. Fossula commonly oblique. Septa wavy. Alar fossulae may be prominent. Minor septa very short. Major septa withdraw from axis, first in the counter quadrants, typically shortened in late ephebic stage. Cardinal septum long in neanic stage, short in ephebic. Tabulae horizontal or domed, complete or incomplete.

Remarks. *Amplexizaphrentis* was proposed by Vaughan (1906, p. 62) as a subgenus of *Zaphrentis* Simpson. Easton (1944b) argued that *Amplexizaphrentis* was inadequately known and erected in its place the genus *Triplophyllites*. Easton (1951, p. 391-393) elaborated his genus *Triplophyllites* into two subgenera based upon the position of the cardinal fossula on the corallum. His subgenus *Triplophyllites* (*Triplophyllites*) has the cardinal fossula on the concave side, whereas *Triplophyllites* (*Homalophyllites*) has the cardinal fossula on the convex side. Hill (1956, p. F278) restricted the family Zaphrentidae, which includes the genus *Zaphrentis* Simpson, to the Devonian and placed the genus *Amplexizaphrentis* in the Mississippian family Hapsiphyllidae.

Hill (1956, p. F267) divided the family Hapsiphyllidae into two parts based upon the position of the cardinal fossula. She raised *Amplexizaphrentis* and *Homalophyllites* to generic rank and reduced T. (*Triplophyllites*) Easton to a junior synonym of *Amplexizaphrentis*.

Sutherland (1958, p. 44-50) believed that the genus *Amplexizaphrentis* included forms with the cardinal fossula at any position on the corallite. He did not think that the position of the cardinal fossula was constant on any species, and therefore doubted its taxonomic value. On a large number of *Homalophyllites* and *Amplexizaphrentis* etched from the limestones of the Escabrosa group, it has been found that the position of the cardinal fossula is highly constant in a species.

Amplexizaphrentis hespere (Grove)

P1. 2, fig. 13-18

Triplophyllum cliff ordanum var *hespere* Grove, 13. H., 1935, Am. Midl. Nat., v. 16, p. 346-347; pl. 8, fig. 6; pl. 11, fig. 8-11.

Diagnosis. Simple, trochoid, curved corals; ephebic stage with 26 to 30 long radial septa which fuse above the closed cardinal fossula. Septa in counter quadrants noticeably thickened. No minor septa; incomplete tabulae.

Description. The majority of the specimens of this species collected from the Nunn member had their apical ends broken off or, if it was present, the silicification was of such a nature as to destroy or obscure the original neanic characters.

The corallite is ceratoid and curved, 25 mm to 30 mm tall and 12 mm to 15 mm in diameter. The exterior of the epitheca has pronounced annulations and constrictions. The calyx is deep. At a diameter of 9 mm, 20 septa are present which are amplexoid. The cardinal fossula is open; cardinal septum is short. The counter septum is slightly longer than adjacent septa, which fuse with it. Septa in the cardinal quadrants are strongly pinnate. In the mid-ephebic stage with a diameter of 14 mm, there are 26 to 30 radial septa, which are fused at the

axis. The fossula is closed, extending to the axis, and generally pear shaped. Cardinal septum is short. The septa in the counter quadrants are thicker than those of the cardinal quadrants. The epitheca is 1.5 mm to 2 mm thick. In the late ephebic stage, the septa in the counter quadrants withdraw from the axis. Minor septa are absent throughout the ontogeny.

Longitudinal section shows the tabulae to be incomplete arched upwards in the region of the cardinal fossula, and slightly bent down near the epitheca. Tabulae occur about every 2 or 3 mm.

Remarks. *A. hespere* from the Nunn member of the Lake Valley formation belongs to the *Amplexizaphrentis enniskilleni* (Milne-Edwards and Haime) species group of Hill (1938, p. 141). *A. hespere* approaches *A. enniskilleni* var *debiense* (Lewis, 1930, p. 289) except that the latter has 4 to 6 more septa, and that the septa are amplexoid in the ephebic stage. *A. sonoraensis* from the Keating formation of the Escabrosa group differs from *A. hespere* in having a more pronounced cardinal fossula extending beyond the axis. The septa in the counter quadrants are not thickened, but are more strongly and massively fused together, and consistently have 2 or 3 more major septa in the ephebic stage.

A. hespere and *A. sonoraensis* occupy the same relative stratigraphic position, but appear to have lived in different environments. *A. sonoraensis* is common in the lower Osage part of the Keating formation in extreme southwestern New Mexico. It is conceivable that these two morphological species were an interbreeding population in the area where the Keating and Lake Valley facies met. At present these two form species can be distinguished, and are believed to represent true biospecies.

Grove (1935, p. 346-347) described a specimen from the Lake Valley formation as a variety of *Amplexizaphrentis cliffordanum* (Milne-Edwards and Haime) from the Fern Glen (lowest Osage) of the Midcontinent region. This form is characterized by 36 septa and a smaller corallum than the typical *A. hespere*. Grove's photographs (pl. I 1, fig. 8) of his variety *A. cliffordanus hespere* from the Lake Valley formation is believed to be an immature individual of *A. hespere*.

Horizon. Abundant in the calcareous shales of the Nunn member of the Lake Valley formation, throughout its area of outcrop in south-central New Mexico. The type specimens are from Apache Hill, northwest of Lake Valley, New Mexico.

Amplexizaphrentis northropi n. sp.

P1. 1, fig. 1, 7-10

Diagnosis. Coralla of medium to large size, trochoid, curved, 40 to 42 long major septa, U-shaped cardinal fossula, neanic and early ephebic septa thickened and fused by steroplasmata. Short minor septa, tabulae domed and incomplete.

Description. Coralla are of medium to large size, trochoid, gently curved with longitudinal striations and faint annulae. During the early ephebic stage, at a diameter of 17 mm, there are present 34 septa which have a generalized radial symmetry, with the septa in the cardinal quadrants showing a slight pinnate arrangement. The septa extend to the axis, and in the counter quadrants they are thickened and fused throughout their length. The septa of the cardinal quadrants are thickened and fused at their ends, but near the epitheca have small open spaces between them. The closed cardinal fossula is prominent. The cardinal septum is thin and extends half the radius to the axis. Minor septa are short and thick

and have an almost buried peripheral zone. Alar fossulae are indistinct. There are 38 septa in the middle ephebic stage at a diameter of 23 mm. The right and left cardinal quadrants have 10 major septa each, and there are 18 in the counter quadrants. Major septa, which extend to the axis, are greatly thickened and fused at their ends. The cardinal fossula is U-shaped and expanded at the axial end. Minor septa are short, and a discontinuous ring of dissepiments may be present. Cardinal septum is short, and the alar fossulae are weakly developed. In the late ephebic stage, at a diameter of 36 mm to 40 mm, 40 to 42 major Sept, which tend to withdraw from the axis, are present. The cardinal septum is short; the counter septum remains slightly longer than adjacent septa. Minor septa are short. Tabulae are incomplete and dome shaped.

Remarks. The late ephebic stage of *A. northropi* is similar, in respect to size of corallite, number and size of major and minor septa, and cardinal fossula, to *Amplexizaphrentis centralis* (Milne-Edwards and Haime) of the Midcontinent region. It is in the ontogeny of the two species that a pronounced difference exists. In the early ephebic stage of *A. centralis*, according to Easton (1944a, p. 39), 30 thin major septa, well-developed alar fossulae, and a thin narrow epitheca are present. This is in marked contrast to *A. northropi*, which is at this stage of its ontogeny characterized by septa thickened and fused by stereoplasma. The writer observed that the strati-graphically higher representatives of *A. northropi* not only appeared to be more robust, but had in their older ephebic stages a progressive trait toward thickening and fusing of their major septa.

Horizon. *A. northropi* is characteristic of the upper half of member B of the Keating formation and the lower part of the Hachita formation, Escabrosa group, throughout its area of outcrop in southwestern New Mexico and southeastern Arizona. The species was found to be particularly abundant in the Keating formation 50 feet below its contact with the Hachita formation in the Big Hatchet Mountains and the Klondike Hills of New Mexico, and in Blue Mountain, Chiricahua Mountains, Arizona.

Amplexizaphrentis sonoraensis n. sp.

Pl. 2, fig. 19-28

Diagnosis. Medium-sized, trochoid coralla of the *A. enniskilleni* type with 30 to 32 long major septa joined around a conspicuous linear cardinal fossula; minor septa absent; tabulae incomplete, domed.

Description. The corallite is of medium-size, gently curved, trochoid. In the late neanic stage at a diameter of 6 mm there are 21 septa. The conspicuous, closed cardinal fossula extends beyond the axis. The axial ends of the septa unite around the fossula. The septa in the cardinal quadrants have pinnate arrangements. The cardinal septum is short. Alar fossulae are indistinct.

At a diameter of 10 mm, 24 septa are present. The closed cardinal fossula is prominent and extends to the axis of the coral. The cardinal septum is long and extends the length of the cardinal fossula. The septa have a radial arrangement, and their axial ends fuse above the cardinal septum.

In the mid-ephebic stage, at a diameter of 14 mm, 30 to 32 septa are present. A distinct cardinal fossula is present with parallel walls, which extend to the axis. The septa have a radial arrangement, with those in the cardinal quadrants

showing a slight pinnate tendency. The axial ends of the septa are thickened and fused above the cardinal fossula. Alar fossulae are indistinct. Minor septa are absent throughout the ontogeny. In the late ephebic stage the epitheca is thick (1 .5 mm-2.0 mm) owing to the presence of a peripheral stereozone. Tabulae are incomplete, conical, and slightly downbent near the epitheca.

Remarks. *A. sonoraensis* has the characteristic traits of the European *Amplexizaphrentis enniskilleni* group. It differs from the typical examples of this group by its much lower septal count. A form similar to *A. sonoraensis* is the European variety, *A. enniskilleni* var *derbiense* (Lewis, 1930, p. 279) with about 34 septa, but it differs markedly in that it has an ephebic stage with considerably shortened septa. *A. sonoraensis* is closely related to, and possibly conspecific with, *A. hespere* from the Lake Valley formation (see remarks under *A. hespere*). Girty's (1899, p. 511) *Menophyllum excavatum* from the Madison limestone and Easton and Gutschick's (1953, p. 14-15) *Triplophyllites persimilis* from the Redwall limestone of northern Arizona are very similar to *A. sonoraensis* in number of septa and size.

Horizon. *A. sonoraensis* occurs very rarely in member A and much more abundantly in the lower part of member B of the Keating formation, Escabrosa group, in all areas of exposure in extreme southeastern Arizona and southwestern New Mexico. The type specimen was collected from the lower part of the member B, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.

Amplexizaphrentis clinatus (Greene)

Pl. 5, fig. 3-4

Zaphrentis clinatus Greene, G. K., 1906, Indiana Paleont. Contr., pt. 19, p. 187, pl. 56, fig. 6-9.

Zaphrentis clinatus, Beede, J. W., 1906, Indiana Dept. Geol.

Nat. Resc., 30th Ann. Rept., p. 1204, 1373, pl. 2, fig. I2-IC.

Triplophyllites (Triplophyllites) clinatus, Easton, W. H., 1951, Jour. Paleont., v. 25, p. 395-396, pl. 60, fig. 1-6.

Diagnosis. Trochoid coralla, markedly compressed in early stages, less so in late ephebic stages where transverse sections are oval; keel centered on counter side of corallum; 34 long major septa, minor septa indicated by ridges on epitheca; cardinal fossula closed and conspicuous.

Description. The corallite is wedge-shaped in its earlier two-thirds of its development (Easton's 1951, cuneate shape). The apex of the wedge follows the counter septum. In the middle and late ephebic stage the calyx has an ovate shape that is characteristic of the majority of the amplexizaphrentids. Corallite is 22 mm long; the calyx has in the cardinal-counter septum plane a length of 17 mm and a width in the plane of the alar septum of 14 mm. Annulations of growth are present on the exterior of the corallite.

One individual was available for study, and it is a silicified specimen obtained by dissolving the enclosing limestone in acid. The silicification is of such a nature that grinding serial sections would probably not reveal finer internal details. The following description is taken from the late ephebic stage observed in the calyx.

A pronounced, long, elliptical closed cardinal fossula is present which extends past the axis of the corallite. Alar pseudofossulae indistinct. Major septa number 33. Minor septa reduced to low ridges on the epitheca. Right cardinal

quadrant with 7 septa, left cardinal quadrant with 6 septa, counter quadrants with 20 septa.

Horizon. *A. clinatus* is represented in the Escabrosa group by one almost complete specimen from the lower part of member B (lower Osage) Keating formation, Big Hatchet Mountains, New Mexico.

Remarks. *A. clinatus* from the Keating formation is very similar to the holotype as redescribed by Easton. The holotype has 34 major septa, and the Keating representative has 33 major septa. The weakly developed minor septa in the Keating formation specimen may be due in part to poor preservation. Greene (1906, p. 187) described the holotype from Warsaw limestone (lower Meramec) of Indiana. Easton (1951, p. 396) reported the species common in the Warsaw and Salem limestones and reported it to be doubtfully known from the lower Burlington limestone. The specimen from the lower part of member B, Keating formation occurred in horizons of at least lower Burlington or slightly older age.

Genus HOMALOPHYLLITES Easton, 1944

Hapsiphyllum (*Homalophyllites*) Easton, W. H., 1944, Illinois Geol. Surv. Rept. Inv. 97, p. 42.

Triplophyllites (*Homalophyllites*), Easton, W. H., 1951, Jour. Paleont., V. 25, p. 398.

Homalophyllites, Hill, D., 1956, Treatise of Invertebrate Paleontology, pt. F (Coelenterata), p. F267.

Type Species. (Original designation) *Lophophyllum calceola* White, C. A., and Whitfield, R. P. (1862, Boston Soc. Nat. Hist. Proc., v. 8, p. 305): Burlington limestone, Burlington, Iowa.

Horizon. Mississippian.

Diagnosis. The corallum is ceratoid to calceoloid. Fossula is on the convex side of the corallum. The fossula may expand axially but is mainly parallel sided; the bounding septa are reinforced and thickened. The cardinal septum is pronounced in neanic stage, and very reduced in ephebic stage. Very frequently the convex side of the corallum is flattened near the apex.

Remarks. Easton (1944a, p. 42) originally conceived of *Homophyllites* as a subgenus based upon the convex position of the cardinal fossula. He allied it with the genus *Hapsiphyllum* Simpson 1900. The latter is noted for its minor septa, which are contratingent with the major septa. The type species of his subgenus *Homalophyllites*, *H. calceolus* (White and Whitfield), does not possess this contratingent nature of the septa.—Easton (1951, p. 398) subsequently removed from the genus *Hapsiphyllum* his subgenus *Homalophyllites*, and placed the latter under his genus *Triplophyllites*. Hill (1956, p. F267) raised *Homalophyllites* to generic rank and placed *Triplophyllites* with the cardinal fossula on the concave side in synonymy with *Amplexizaphrentis* Vaughan (1906).

Homalophyllites circularis Easton

Pl. r, fig. 11-13

Triplophyllites (*Homalophyllites*) *circularis* Easton, W. H., 1960, Smithsonian Misc. Coll., V. 119, n. 3; p. 22-24; pl. I, fig. 4, 79.

Homalophyllites calceolus, Bowsher, A. L., 1961, Jour. Paleont., v. 35, pl. 109, fig. 5a-5c.

Diagnosis. Corallum small, slightly curved; ceratoid; not

flattened; cardinal fossula slightly expanded axially; cardinal septum short, 31 to 32 major septa, minor septa very short.

Description. The corallum is small, ceratoid, 10 mm to 16 mm long, and the theca has rugae and striae. In transverse section the mature theca is from 7 mm to 8 mm in diameter and has 31 to 32 septa, which fuse around an axially enlarged cardinal fossula. The cardinal septum is shorter than the adjacent septa. Minor septa are short. Alar fossulae are very indistinct. Dissepiments are absent.

Remarks. *H. circularis* was erected by Easton (Easton et al., 1958, p. 22-24) for a species of *Homalophyllites* from the Represo formation of northwest Sonora. It is similar to *Homalophyllites calceolus* except in two respects: It has a circular corallite and longer minor septa. Easton noted in the Represo formation *H. circularis* occurred to the exclusion of *H. calceolus*. *H. calceolus* is very abundant in member A, Keating formation, and *H. circularis* rare. Easton suggests that, if there is any phylogenetic significance to the progressive flattening of *H. calceolus*, then it would seem it evolved from an unflattened ancestor. Since member A of the Keating formation is believed to be an almost exact time equivalent of the Represo formation of Sonora, and since the Andrecito member of the Lake Valley formation, which contains both *H. calceolus* and *H. circularis*, is an eastward facies of the above two, it is probable that the geographic distribution of *H. calceolus* and *H. circularis* in earliest Osage time, was due to an ecological factor. It is conceivable that the two species are in reality one biospecies, which assumed in different environments two somewhat different forms.

Range. The species occurs infrequently in member A, Keating formation, throughout its area of outcrop.

Homalophyllites calceolus (White and Whitfield)

Pl. r, fig. 19-29

Lophophyllum calceola, White, C. A., and Whitfield, R. P., 1862, Boston Soc. Nat. Hist., Proc., v. 8, p. 305.

Zaphrentis calceola, White, C. A., 1883, U.S. Geol. and Geog. Surv. Terr., 12th Ann. Rept., pt. I, Invertebrate Paleont. Contr., n. 8, p. 156; pl. 39, fig. 6a-6d.

Zaphrentis calceola, Heyes, R. R., 1894, Missouri Geol. Surv., v. 4, p. 110.

Homalophyllum calceolum, Grove, B. H., 1935, Am. Midl. Nat., v. 16, p. 354; pl. 9, fig. 20-24; pl. 13, fig. 1-6.

Homalophyllum calceolum, Hill, D., 1937, Royal Soc. Queensl., Proc., V. 48, p. 25, text fig. 5, p. 24.

Hapsiphyllum (*Homalophyllites*) *calceolus*, Easton, W. H., 1944a, Illinois Geol. Surv., Rept. Inv. n. 97, P. 43/44, Pl. 4, fig. 4-7; pl. 16, fig. 23-25.

Triplophyllites (*Homalophyllites*) sp., Easton, W. H., 1951, Jour. Paleont., v. 25, p. 399; pl. 61, fig. 8a-8c.

Homalophyllites calceolus, Bowsher, A. L., 1961, Jour. Paleont., v. 35, pl. 109, fig. 6a-6b.

Diagnosis. Corallum small, slightly curved; ceratoid, flattened apically on cardinal side. Closed cardinal fossula slightly expanded toward axis. Cardinal septa short; average of 30 major septa in mature individuals; minor septa almost obsolete, dissepiments very sparse.

Description. Corallum is slightly convex with proximal third of convex side of corallite progressively flattened toward the apical end. Cross section of corallite at its apical end is slightly ovate. The dimensions of an average mature specimen

are: on concave side of corallite 20 mm long, on convex side 30 mm long, 11 mm wide and 4 mm to 5 mm deep. Cardinal fossula, which is on the convex side of fossula, is closed and slightly expanded toward the axis. Alar fossulae are indicated by interruptions in dominantly radial septal arrangement. Cardinal fossula relatively small and narrow. Average specimen has 30 major septa, but a normal population will have mature individuals with as few as 25 major septa or as many as 38. The minor septa are inconspicuous. Tabulae are rare.

Horizon. *Homalophyllites calceolus* is abundant in member A of the Keating formation throughout its area of outcrop in southeastern Arizona and southwestern New Mexico. It is also present in eastern Arizona in member B of the Keating formation.

Remarks. *H. calceolus* occurs in large numbers as generally well-silicified individuals in member A of the Keating formation. A number of limestone blocks containing silicified individuals were collected and etched with hydrochloric acid in the laboratory. Upon close examination the individuals from a given horizon showed the cardinal fossula remained constant in its position; but the individuals displayed a relatively wide range in the number of septa. The finding of an ontogenetic series (fig. 15) of specimens of *Homalophyllites*, which display a septal count between 25 and 38, in a block of limestone with a volume of about one cubic foot, raises some doubt about the validity of numerous species of this genus. The writer believes septal count to be a better measure of ontogenetic stage than the calyx diameter. Many species of this genus have been erected in the literature on the study of a few individuals, with the separation of species primarily on the basis of an addition or subtraction of 2 to 4 septa. *H. calceolus*, which has been described by many workers from the Midcontinent region, is similar in all respects to the Keating representatives except the latter are some 30 to 40 percent larger. The size difference is believed to be an ecological factor and not a specific trait. Easton (1951, p. 399, pl. 61, fig. 8a-8c) described and illustrated an unnamed species of *Homalophyllites* lent to him by Dr. A. Stoyanow. This specimen was from the Escabrosa group of Arizona, and from the illustration and description it belongs to *H. calceolus* as defined in this study. In their study of the corals from the Redwall limestone (Lower Mississippian) of northern Arizona, Easton and Gutschick (1953) did not report *H. calceolus*, but did describe two new,

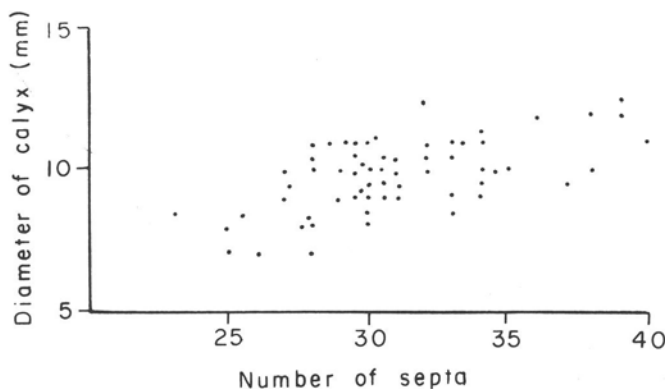


Figure 15

SCATTER DIAGRAM OF *Homalophyllites calceolus*

large species of *Homalophyllites*, *H. subcrassus* with 40 to 44 major septa and *H. paucicinctus* with 46 major septa. Neither of these species has been encountered in the Escabrosa group.

Easton (Easton et al., 1958) described a new species, *Homalophyllites circularis*, from the Represo limestone of northwestern Sonora, Mexico. According to Easton (Easton et al., 1958, p. 24) the species is similar to *H. calceolus* except that it has an evenly circular cross-section throughout its calyx. Easton suggested *H. circularis* was the ancestor of *H. calceolus*. Faunal evidence indicates that the Represo limestone is a stratigraphic equivalent to member A, Keating formation. Easton stated that *H. calceolus* is completely absent in the Represo limestone and that *H. circularis* is abundant. In member A, *H. calceolus* is by far the most abundant coral, whereas *H. circularis* is rare. It is believed that these two may represent two species which are contemporaneous but are influenced in their distribution primarily by ecology.

Genus **HAPSIPHYLLUM** Simpson, 1900

Hapsiphyllum Simpson, G. B., 1900, New York State Mus. Bull., v. 8, p. 203.

Enalophyllum Greene, G. K., 1901, Indiana Paleont. Contr., v. I, pt. 7, p. 54.

Hapsiphyllum, Grove, B. H., 1935 Am. Midl. Nat., v. 16, p. 361-362.

Hapsiphyllum, Easton, W. H., 1951, Jour. Paleont., v. 25, p. 289.

Hapsiphyllum, Hill, D., 1956, Treatise Invertebrate Paleontology, pt. F, (Coelenterata), p. F267.

Non Hapsiphyllum, Easton, W. H., 1944a, Illinois Geol. Surv., Rept. Inv., n. 97, p. 42.

Non Hapsiphyllum, Moore, R. C., and Jeffords, R. M., 1944 Texas Univ. Pub. 4401, p. 123, 124.

Type Species. (Original designation) *Zaphrentis calcariiformis* Hall, 1822, State Geologist of Indiana, 12th Ann. Rept., p. 33, St. Louis group, Indiana.*

Range. Mississippian.

Diagnosis. (After Hill, 1956, p. F267) Small ceratoid corals, with cardinal fossula on concave side; fossula expanded axially; septa arranged pinnately in cardinal quadrant, radially in counter quadrant; minor septa are long and contratingent; cardinal septum short in adult stages. Tabulae incomplete, conical with highest point at inner edge of fossula; dissepiments absent.

Remarks. Only three species of *Hapsiphyllum* are described from the Mississippian of North America. They are the type species *H. cassedayi* (Milne-Edwards) from the St. Louis group, *H. ulrichi* (Worthen) from the Warsaw limestone of Kentucky, and *H. grabau* (Greene) from the Salem limestone of Indiana. All of these species are described from their late epebic stages, and nothing is known of their earlier ontogeny. Sutherland (1958, p. 48) stated the genus *Hapsiphyllum* is based on an inadequately known type species. He considers the genus to include only forms having contratingent minor septa and no dissepiments, and with an inner wall developed around the cardinal fossula.

The genus *Amplexizaphrentis* Vaughan would embrace Moore and Jeffords (1944) description of *Hapsiphyllum* from the lower Pennsylvanian of Texas.

Hapsiphyllum calcariiformis (Hall) is believed by Grove 1935, p. 362, and myself to be a junior synonym of *Hapsiphyllum cassedayi* (Milne-Edwards).

Hapsiphyllum nunnensis n. sp.

Pl. 1, fig. 2-6

Diagnosis. Medium-sized, solitary, ceratoid coral; 36 to 38 long major septa of which the majority have contratingent minor septa, large closed cardinal fossula, cardinal septum long in earlier stages, short in late neanic. Tabulae incomplete.

Description. The corallum is ceratoid and slightly curved, has the fossula on the concave side and is 30 mm to 35 mm tall and 20 mm to 22 mm in diameter. The epitheca shows slight longitudinal ribbing and strong annulation. In a late neanic stage at 8 mm in diameter are 21 septa which have met and fused at the axis. Alar fossula are conspicuous. The cardinal fossula is long and closed. The cardinal septum is long. At a diameter of 16 mm, 34 major septa are present; minor septa are very short but bend toward and are contratingent with adjacent, major septa. Cardinal fossula is large, closed, bulb-shaped and extending beyond the axis. The cardinal septum is long. The septa of the counter quadrants are withdrawn from the axis. In the middle ephebic stage, at a diameter of 20 mm, 38 somewhat sinuous, major septa fuse above the cardinal septum. The cardinal fossula is closed and long, and extends to the axis. The cardinal septum is still long, but withdraws from the axis. In the late ephebic stage, or at a diameter of 25 mm, are 38 major septa, which are sinuous at their ends and are fused and thickened above and around the closed cardinal fossula. The minor septa are long, and the majority of those in the cardinal quadrants are not all contratingent but lean towards adjacent major septa. The cardinal fossula is large, extends beyond the axis, and is slightly expanded axially. The cardinal septum is short. Longitudinal sections show incomplete tabulae, which are bent upwards in the region of the fossula.

Horizon. *H. nunnensis* is present in the Nunn member of the Lake Valley formation, and is found in this horizon throughout its area of outcrop in central New Mexico. Type species came from Apache Hill, northwest of Lake Valley, New Mexico.

Remarks. Three species of *Hapsiphyllum* have been described from the Mississippian of North America. These are the genotype *H. cassedayi* (Milne-Edwards) from the St. Louis group of Indiana, *H. ulrichi* (Worthen) from the Warsaw limestone of Kentucky and *H. grabau* (Greene) from the Salem limestone of Indiana. These three species are described from their late ephebic stages, and nothing is known of their earlier ontogeny.

H. cassedayi and *H. ulrichi* show in their late ephebic stage that all of their minor septa are contratingent with the major septa (Simpson, 1900, p. 23; Easton, 1951, pl. 61, fig. II). *H. nunnensis*, in the opinion of the writer, would fit illogically into the genus *Amplexizaphrentis*, where there does not exist any known species with persistent contratingent minor septa.

Family C Y A TH OPSIDAE Dybowski, 1873

Genus CANINIA Michelin, 1840

Caninia Michelin, H., 1840, in Gervais, P., Article "Astree, Astrea" in Dictionnaire des Sciences naturelles, Supplement, v. I, p. 485 (*fide* Hill, 1948, p. 105).

Cyathopsis d'Orbigny, A., 1850, Prodrôme de Paleontologie, Paris, v. I, p. 105.

Pseudozaphrentoides Stuckenbergh, A., 1904, Corn. Geol., St.

Petersburg, *Mem.*, v. 5, n. 4, p. 91 (*fide* Hill, D., 1956, p. F 292).

Caninia, Carruthers, R. G., 1908, *Geol. Mag.*, v. 5, p. 108.

Caninia, Bather, F. A., 1908, *Geol. Mag.*, v. 5, p. 287.

Caninia, Salee, A., 1910, *Nouv. Mem. Soc. Belgique Geol.*, fasc. 3, p. 13; (*fide* Hill, 1939, p. 105).

Caninia, Lewis, H. P., 1924, *Quart. Jour. Geol. Soc. London*, v. 80, p. 390.

Peetzia Tolmatchoff, I. P., 1924, *Mater. Geol. gen. appl. Leningrad*, livr. 25, p. 309 (*fide* Hill, D., 1939, p. 105; 1956, p. F292).

Caninia, Smith, S., 1935 *Jour. Paleont.*, v. 9, p. 38.

Caninia, Hill, D., 1939, *Paleont. Soc.*, p. 105, 106.

Caninia, Busch, D. A., 1941, *Jour. Paleont.*, v. 15, p. 399.

Caninia, Easton, W. H., 1944b, *Jour. Paleont.*, v. 18, p. 123-124.

Caninia, Easton, W. H., 1944a, *Illinois Geol. Surv. Rept. Invest.*, n. 97, p. 49.

Pseudozaphrentis Moore, R. C., and Jefford, R. M., 1944 *Texas Univ. Pub.* 4401, p. 145.

Caninia, Moore, R. C., and Jefford, R. M., 1944, *Texas Univ. Pub.* 4401, p. 145.

Caninia, Hill, D., 1956, *Treatise on Invertebrate Paleontology*, pt. F, (Coelenterata), p. F292.

Caninia, Sutherland, P. K., 1958, *Canada Geol. Surv. Mem.* 295, p. 62-64.

Pseudozaphrentis, Sutherland, P. K., 1958, *Canada Geol. Surv. Mem.* 295, p. 66.

Type Species. (Original designation) *Caninia cornucopiae* Michelin, H., in Gervais, P., 1840, Article "Astree, Astrea" in Dictionnaire des Sciences naturelles, Supplement, v. 1, p. 485. Lower Carboniferous of Tournai.

Diagnosis. After Hill (1956, p. F292). Solitary; in youth the long major septa are slightly sinuous, with lanceolate dilations in tabularium, particularly in cardinal quadrants. Septa become amplexoid and less dilated in adult stage, when a marginarium of concentric, inosculating or lonsdaleoid dissepiments may develop; fossula open, neighboring septa curving about it; tabulae flat with down-turned margins.

Range. Mississippian to Permian.

Remarks. *Siphonophylla* Scouler is similar to *Caninia* except it has a wide lonsdaleoid dissepimentarium. *Caninophyllum* Lewis is also distinguished by its dissepimentarium, which has wide, angular dissepiments. *Bothrophyllum* Trautschold and *Kakwiphyllum* Sutherland both have axial structures which separate them from *Canina*. *Paracaninia* is like *Caninia* but has epithecal spines and no dissepiments.

Caninia cornucopiae Michelin, 1840

Pl. 1, fig. 14-18

Caninia cornucopiae Michelin, H., 1840, in Gervais, P., Article "Astree, Astrea" in Dictionnaire des Sciences naturelles, Supplement, v. I, p. 485.

Cyathophyllum subcaespitosum Miller, S. A., 1884, *Cincinnati Soc. Nat. Hist.*, Jour., v. 4, p. 308.

Caninia cornucopiae, Carruthers, R. G., 1908, *Geol. Mag.*, v. 5, p. 159; pl. 6, fig. 1-4.

Caninia cornucopiae, Salee, A., 1910, *Nouv. Mem. Soc. Belgique Geol.*, fasc. 3, p. 10, pl. I, fig. 1-4.

Caninia cornucopiae, Hill, D., 1938, *Palaeont. Soc.*, v. 92, p. 106-107.

Caninia arcuata Jeffords, R. L., 1943, Jour. Paleont., v. 17, p. 548, 549; text fig. 1-7.

Caninia cornucopiae, Sloss, L. L., 1945, Jour. Paleont., v. 19, p. 310-311; pl. 48, fig. 5-9.

Description. The corallum is at first a very deep, conical cone and then a long cylinder which is usually curved or bent. The epitheca has numerous, fine annulations and constrictions. In the earlier, or conical, phase the septa are long and reach toward the axis but are not joined together. The cardinal fossula is pronounced, and the cardinal septum is greatly reduced. The minor septa are very short, and dissepiments are absent. In the cylindrical stage at a diameter of 20 mm, 28 major septa are present but withdrawn from the axis. The cardinal fossula is open, cardinal septum short. Minor septa are short, and a single discontinuous ring of dissepiments is present. Dissepiments are absent in the earlier stages and develop in the later ephebic stages. The tabulae are complete, downbent at the margins, and those near the fossula are deeply invaginated.

Remarks. In his description of the new species, *Caninia arcuata*, from the Nunn member of the Lake Valley formation, Jeffords stated that it differs from *C. cornucopiae* in its large size, shorter septa in the earlier part of the corallum, and downbending of the tabulae around the fossula. Sloss (1945, p. 311) pointed out that the maximum diameter of 28.2 mm given for *C. arcuata* is well within the range of diameters of *C. cornucopiae*. Sloss further noted that Carruthers (1908, p. 164) had shown that the British and Belgian *C. cornucopiae* commonly pass through an amplexoid neanic stage (Carruthers' "nystiana phase") and is characterized by depressions of the tabulae at the cardinal fossula.

From the Nunn member, Lake Valley formation, the writer has found, in addition to the nystiana type, several *C. cornucopiae* which in the late neanic stage have long, major septa and a pronounced open cardinal fossula (Carruthers' dumonti growth stage). This latter condition is, according to Hill (1940, p. 106), more characteristic of the species.

The Lake Valley form is closely related to *C. cornucopiae* s. s. as described by Hill (1938, p. 106-108) in that they both possess a single row of nonpersistent dissepiments. Sloss' (1945, p. 310-311) example *C. cornucopiae* from the Yakini-kak limestone of Montana has up to three rings of dissepiments. This is more characteristic of *Caninia cornucopiae* var. *brockleyensis* (Thomas) of Scotland. *C. cornucopiae* is present, according to Hill (1938, p. 106), throughout the Tournaisian and the lower Visean of the British-Belgian Province. In the Lake Valley formation it occurs in a horizon which carries a prolific fauna characteristic of lower Osage age (Fern Glen). Sloss (1945, p. 309) reported *C. cornucopiae* from the Yakini-kak limestone of Montana to be of possible St. Louis age.

Genus **VESICULOPHYLLUM** Easton, 1944

Vesiculophyllum Easton, W. H., 1944a, Illinois Geol. Surv., Rept. Invest. n. 97, p. 52.

Kakwiphyllum Sutherland, P. K., 1954, Geol. Mag., v. 91, p. 366.

Kakwiphyllum, Hill, D., 1956, in Treatise on Invertebrate Paleontology, pt. F (Coelenterata), p. F294.

Kakwiphyllum, Sutherland, P. K., 1958, Canada Geol. Sum. Mem. 295, p. 69.

Vesiculophyllum, Sando, W. J., 1960, U.S. Geol. Surv. Bull. r071-F, p. 179-180.

Type Species. (Original designation) *Chonophyllum sedaliensis* White (U.S. Geol. Surv. 12th Ann. Rept., p. 157, pl. 39, fig. 3a). Chouteau limestone, lower Mississippian, Missouri.

Diagnosis. Detailed description is given by Sando (1960, p. 179-180).

Vesiculophyllum sutherlandi n. sp.

Pl. 3, fig. o

Diagnosis. Solitary cylindrical corals with long, major septa, 38-44, which extend to but do not join at the axis. Radial symmetry, an obscure cardinal fossula, a pronounced but thin zone of lonsdaleoid dissepiments and wider zone of concentric dissepiments. Minor septa present, tabulae incomplete, axially depressed.

Description. The corallum is a cone in the early stages, and a straight or sinuous cylinder in the ephebic stage. All the specimens studied were abraded before burial, and the details of the surface of the epitheca were destroyed. The early or neanic portion of the corallum was absent on all of the specimens.

A transverse section at a diameter of 16 mm reveals 32 major septa present; those in the counter quadrants extend past the axis but are not joined, whereas those in the cardinal quadrants show a pinnate arrangement. A ring of discontinuous, lonsdaleoid dissepiments is present next to the epitheca. Minor septa are very short and are not continuous through the zone of dissepiments to the epitheca.

At a diameter of 26 mm, 40 major septa are present which extend to the axis but do not join. A strong radial symmetry obscures the cardinal fossula. The septa in the cardinal quadrants are thickened in the tabularium, whereas those of the counterquadrant are not. There are two zones of dissepiments. An outer zone of lonsdaleoid dissepiments is present next to the epitheca. The peripheral ends of the major and minor septa rest against the lonsdaleoid dissepiments. The dissepiments of the inner zone are of the concentric type.

A longitudinal section near the calyx shows the lonsdaleoid dissepiments to be steeply or almost vertically inclined and the inner zone of dissepiments to be inclined downwards. The tabularium is very narrow and has small, incomplete, concave tabulae. The corallum in the late ephebic stage has a slight elongation in the cardinal counter plane.

Remarks. Sutherland (1954, p. 365-368; 1958, p. 70-71) in addition to *Vesiculophyllum dux*, also described and figured *Vesiculophyllum* cf. *V. dux* and *Vesiculophyllum* sp. A. The three taxa differ in number of septa with 66 in *V. dux*, 72 to 78 in *V. cf. V. dux*, and 84 in *V. sp. A*.

Stensaas and Langenheim (1960, p. 182-184) describe *V. dux* with a maximum of 65 septa from the middle and upper Joana limestone of Nevada.

V. sutherlandi is similar to the type species *V. dux* except that the zone of lonsdaleoid septa in the cardinal quadrants is enlarged and the minor septa are proportionately longer.

Vesiculophyllum cf. *incrassatum* (Easton and Gutschick)

Pl. 3, fig. 46

Caninophyllum incrassatum Easton, W. H., and Gutschick, R. C., 1953 Southern Calif. Acad. Sci. Bull. 52, p. 17-18, pl. 3, fig. 14.

Caninophyllum sonorensis, Easton, W. H., 1958, Smithsonian Misc. Coll., V. 119, n. 3, p. 29-30, pl. 2, fig. 1-4.

Caninophyllum incrassatum, Langenheim, R. L., Jr., and Tischler, H., 1960, Univ. Calif. Pub. Geol. Sci., v. 38, n. 2, p. 125-127, fig. 14.

Description. The specimens available for study were broken and highly abraded corallites. Most of the specimens consisted only of the tabularium and parts of the dissepimentarium. The epitheca and the peripheral parts of the dissepimentarium were not preserved. In transverse section, an epehelic individual will have 42 to 44 long major septa, which in the cardinal quadrants are dilated, and strongly dilated in the tabularium. The cardinal fossula is open, and the cardinal septum and adjacent major septa are short. The counter septum is long, dilated and extends into the axis. In the epehelic stage major septa are withdrawn slightly from the center of the corallite. Major septa penetrate the dissepimentarium and fuse with the epitheca. Minor septa are short and ill-defined. Dissepimentarium is well developed with concentric to lonsdaleoid dissepiments.

In the early epehelic stage, 15 mm by 12 mm in diameter, 38 major, somewhat dilated septa are present. The cardinal septum is short; minor septa appear to be absent. Dissepiments are absent.

Horizon. This species has been found only in the coral zone, member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. Easton (1958, p. 30) stated *V. sonorensis* differs from *V. incrassatum* (Easton and Gutschick) from the Redwall limestone of Arizona, in having only rudimentary minor septa and concentric dissepiments instead of herringbone dissepiments. The writer, after comparing Easton's illustrations of *V. sonorensis* (1958, pl. 2, fig. 1-3) and *V. incrassatum* (Easton and Gutschick, 1953, pl. 3, fig. 1-4) and the type specimen of *V. incrassatum*, believes there are no specific differences between Easton's two species. The two have coralla of the same general size, similar septal counts and very similar dissepiments.

V. cf. incrassatum from member A, Keating formation, Escabrosa group, differs from Easton's described specimens in having a longer counter septum, which extends into the axial space of a mature corallite. Exact comparison could not be made because of the lack of sufficient numbers of individuals to be sectioned and because of the poor preservation.

Vesiculophyllum sp. A

Pl. 3, fig. 11

Discussion. Fragmentary remains of a large caninid coral are found occasionally in the middle of the Hachita formation (upper Osage). The specimens were abraded before burial and are devoid of an epitheca. The coralla in transverse section are from 20 mm to 30 mm in diameter. There are 39 to 46 long, somewhat sinuous, major septa, the majority of which penetrate into the axial region but are not fused into an axial structure. The minor septa do not penetrate into the tabularium and are approximately half as long as the major septa. Both classes of septa penetrate the dissepimentarium and appear to fuse with the wall. The dissepimentarium is well developed and wide.

Horizon. This species is rare and found only in the middle part of the Hachita formation (upper Osage) from the Tombstone Hills of Arizona eastward to the Klondike Hills of New Mexico.

Remarks. *Vesiculorohyllum* SD. A from the Hachita forma-

tion is clearly distinct from *Vesiculophyllum incrassatum* (Easton and Gutschick) from the Osage Redwall limestone of Arizona and lower Osage Represo limestone of Sonora, Mexico. The latter has strongly dilated major septa in the tabularium and rudimentary minor septa. *Vesiculophyllum sedaliense* (White) is separated from *Vesiculophyllum* sp. A by its sinuous, dilated major septa, and weakly developed minor septa.

Vesiculophyllum sp. B

Pl. 3, fig. 12

Description. Large, solitary, caninid type corallum which is in an epehelic individual 25 mm to 30 mm in diameter. In transverse section the corallum is generally ovoid, with the greatest length in the cardinal-counter plane. The cardinal-counter septa form a blade-like columella to which are fused the major septa. Major septa are long, slightly sinuous and dilated in the tabularium. Dissepimentarium are wide with concentric dissepiments. Minor septa are apparently absent.

Horizon. This form of *Vesiculophyllum* sp. is rare and found only in the middle portion of the Hachita formation (upper Osage) in the Tombstone Hills and south of Warren, Arizona, eastward to the Klondike Hills, New Mexico.

Remarks. The form of *Vesiculophyllum* is found as broken, abraded, and frequently crushed corallites. The crushing was apparently the result of compaction within the encrinites during diagenesis.

Genus RYLSTONIA Hudson and Platt, 1927

Type Species. (Original designation) *Rylstonia benecom-pacta*, Lower Carboniferous, England.

Rylstonia (Girty)

Pl. 2, fig. 1-3

Rylstonia teres, Girty, G. H., 1899, U.S. Geol. Surv. Mon. 32, pt. 2, p. 514-515; pl. 67.

Rylstonia cf. teres, Sando, W. J., 1960, U.S. Geol. Surv. Bull. 1071 F, p. 172-173, pl. 17, fig. 1-5.

Rylstonia columnirota, Langenheim, R. L., Jr., and Tischler, H., 1960, Univ. Calif. Pub. Geol. Sci., v. 38, n. 2, p. 128-130, fig. 17.

Diagnosis. Small- to medium-sized coralla with 36 to 40 major septa, the majority of which reach the columella; minor septa are short, tend to be contralingent; dissepiments are present only in epehelic stage; tabulae incomplete, inclined upwards toward columella.

Description. The coralla are curved, trochoid. The dimensions of four individuals are:

Length (concave side)	Diameter
43 mm	25 mm
34	18
34	16
32	14

All of the specimens available for study had their surface ornamentation obliterated. Epehelic individuals have 36 to 40 major septa. The major septa are long and arranged essentially radially except near the cardinal fossula. The septa are

strongly dilated in the early ephebic stage, and become progressively more attenuated in the middle and late ephebic stages. In the dissepimentarium, the septa at all growth stages are generally dilated.

The minor septa are short, generally best developed in the ephebic stage, and commonly contratingent with the major septa. The dissepimentarium is very weakly developed and in some individuals nonexistent. A prominent, open cardinal fossula is present, extending to the columella. The cardinal fossula is on the convex side of the corallite, but its position may vary (fig. 16) among individuals from the same horizon. The cardinal septum at the neanic and early ephebic stages is long, reaching to, and joining, the columella; in the late ephebic stage it is withdrawn and almost obsolete.

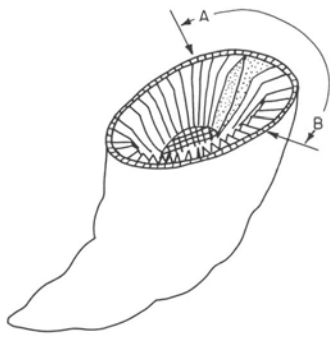


Figure 16

VARIABLE POSITION OF CARDINAL FOSSULA OF *Rylstonia teres*

The columella is formed primarily of counter and major septa which are fused together. In the neanic and early ephebic stages the columella is well developed and has an elliptical cross-section in the plane of the cardinal counter septum. In the late ephebic stages the columella generally degenerates, and the septal lamellae on the tabulae intersect in a manner reminiscent of a spider web. The tabulae are incomplete and inclined upward. Their inclination is the strongest where they join the columella. In all the material available for study, the finer details of the structure of the septa, dissepiments and tabulae have been destroyed by silicification.

Horizon. *Rylstonia teres* is abundant in the coral zone, member A, Keating formation, Escabrosa group, in southeastern Arizona and southwestern New Mexico. The species is very common on the Big Hatchet Mountains and the Klondike Hills.

Remarks. A large number of individuals of *Rylstonia teres* were studied from the Keating formation, Klondike Hills, and they clearly indicate that the species is highly variable within one population as to number and arrangement of major and minor septa and the development of axial structures.

The descriptions of Sando (1960, p. 172-173) for *Rylstonia* cf. *teres* from the Madison group, Williston Basin, and Langenheim and Tischler (1950, p. 128-130) for *Rylstonia columnirotata* from the lower Mississippian, upper Tin Mountain limestone, Death Valley, Inyo County, California, fall within the limits of *Rylstonia teres* population observed from member A of the Keating formation.

Family LONSDALEIIDAE Chapman, 1893
Subfamily LONSDALEIINAE Chapman, 1893 Genus
LITHOSTROTIONELLA Yabe and Hayasaka, 1915

Lithostrotionella Yabe, H., and Hayasaka, I., 1915, Geol. Soc. Tokyo Jour., v. 22, p. 94.

Lithostrotionella, Hayasaka, I., 1936, Taihoku Imp. Univ., Mem. Geol. Sci. and Agriculture, v. 13, n. 5, p. 48-50.

Lithostrotionella, Kelly, W. A., 1942, Jour. Paleont., v. 16, p. 351-352.

Lithostrotionella, Merriam, C. W., 1942, Jour. Paleont., v. 16, p. 378-379.

Lithostrotionella, Shimer, H. W., and Shrock, R. R., 1949, Index fossils of North America, p. 89.

Lithostrotionella, McLaren, D. J., and Sutherland, P. K., 1949, Jour. Paleont., v. 23, p. 629.

Lithostrotionella, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F (Coelenterata), p. F306-F307.

Lithostrotionella, Sutherland, P. K., 1958, Canada Geol. Surv. Mem. 295, p. 94-95.

Type Species. *Lithostrotionella unicum* Yabe, H., and Hayasaka, I. (Original designation, 1915, Jour. Geol. Soc. Tokyo, v. 22, p. 94), Permian of South China.

Range. Mississippian to Permian.

Diagnosis. A detailed description is given by Hill (1956, p. F306-F307).

Lithostrotionella lochmanae n. sp.

Pl. 4, fig. 6-8

Diagnosis. Ceratoid corallum corallites with 4 to 6 slightly curved sides, a conical axial structure; corallites from 5 mm to 8 mm in diameter, 13 to 15 septa of each order, and one primary series of dissepiments.

Description. Corallum is a flattened cone, up to one-half meter in diameter. In a transverse section (fig. 17) there are 13 to 15 septa of each order. The columella is generally elongated in the plane of the cardinal-counter septa. The major septa are continuous through the tabularium. Occasionally in the tabularium a minor septum may fuse with an adjoining major septum. Major and minor septa are dilated in the tabularium.

In a longitudinal section the dissepimentarium consists of a single and occasionally double row of dissepiments. The tabulae are up-arched to meet the columella.

Remarks. *Lithostrotionella lochmanae* shows closest affinities to *Lithostrotionella macouni* Lambe from the southern Canadian Rockies. The exact stratigraphic position of this species is unknown (Nelson, 1960, p. 122). *L. macouni* differs

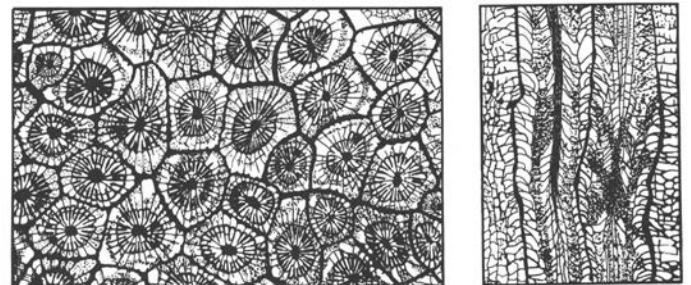


Figure 17

SECTIONS OF *Lithostrotionella lochmanae*; 1, transverse section, 2, longitudinal section

in several important respects. The minor septa are very weakly developed, rarely penetrate into the tabularium, and are infrequently continuous through the dissepimentarium. The septa are not noticeably thickened in the tabularium, and the columella is weakly developed. There are fewer major septa, only 10 or 12 being present.

The nature and number of septa, columella and the tabularium of both *L. lochmanae* and *Lithostrotionella micra* Kelly are very similar, except that in the latter the dissepiments are much better developed and are lonsdaleoid.

L. lochmanae and *Lithostrotionella confluens*, which occur in the same stratigraphic level and over much of southwestern New Mexico and southern Arizona, can readily be distinguished in the field. Individual colonies of *L. confluens* are smaller and more conical in shape; the individual corallites are more erect and 2 to 3 times larger than those in coralla of *L. lochmanae*. The number of septa in an ephelic corallite of *L. confluens* will have between 17 to 24 major septa as compared with 13 to 15 in *L. lochmanae*, although this latter species occasionally displays individual corallites with as many as 22 septa.

Horizon. The species is abundant in member A, Keating formation (lower Osage), throughout its area of outcrop in southwestern New Mexico and southeastern Arizona. It is also found in the Andrecito and Alamogordo members of the Lake Valley formation in the Santa Rita Mining district, Cooks Range, and northwest of Silver City on Lone Mountain. It is particularly abundant in the Klondike Hills and westward to Blue Mountain, Chiricahua Mountains, Arizona.

Lithostrotionella confluens Easton

Pl. 4, fig. 1-5

Lithostrotionella confluens Easton, W. H., 1958, Smithsonian Misc. Coll., V. 119, n. 3, p. 31-33; pl. I, fig. 12; pl. 2, fig. 8, 9.

Lithostrotionella microstyla Bowsher, A. L., 1961, Jour. Paleont., v. 35, pl. 110, fig. 5a-5c.

Diagnosis. Cerioid corallum with 5 to 8 slightly curved sides, 20 to 24 septa of each order, a pronounced zone of dissepiments, tabulae up-arched toward central columella.

Description. Colonies are as much as one-fourth of a meter in diameter, and are shaped like compressed cones. The corallites vary in size, ranging in maximum diameter from 10 mm to 16 mm. In each corallite 20 to 26 septa of each order are present. The columella is elongated in the plane of the cardinal and counter septa. Major septa are rarely continuous through the dissepimentarium. The inner portion of the dissepimentarium consists of somewhat concentric dissepiments placed more closely than in the outer region. The major and minor septa are slightly thickened in the tabularium. The minor septa are very short in the tabularium, whereas most of the major septa fuse with the columella. In transverse section the tabulae are seen as concentric rings (fig. 18). The tabulae are at first down-bent sharply and then up-arched to join with the columella. In longitudinal section the dissepimentarium is a broad zone.

Remarks. The New Mexico examples of *L. confluens* agree very closely with Easton's (1958) type specimen from the Represo limestone of northwest Sonora, Mexico. A review of the literature reveals that *L. confluens* is very closely related, if not specifically identical, to *L. jasperensis* Kelly. Nelson (1960) showed that this latter species also occurs in Canada at about the same stratigraphic position as *L. confluens*.

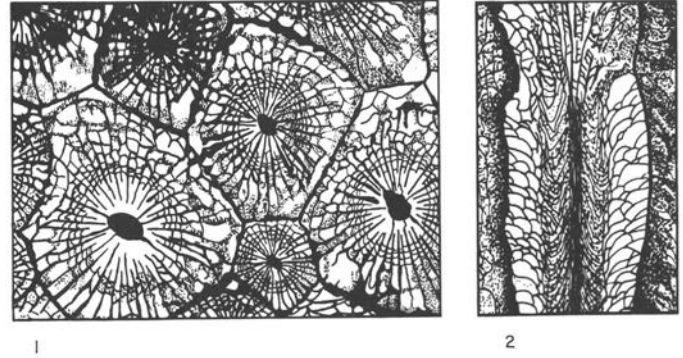


Figure 18

SECTIONS OF *Lithostrotionella confluens*; 1, transverse section, 2, longitudinal section

writer noted the following differences between the two, which at the present time tentatively justify their separation into two species. *L. jasperensis* differs from *L. confluens* in possessing only 16 major septa. The minor septa are slightly longer in the tabularium, and there is present a more pronounced zone of lonsdaleoid dissepiments with fewer intercepts. Stensaas and Langenheim (1960) described and illustrated with ink drawings a *L. jasperensis* from the Joana limestone. They believed their specimen came from horizons of Meramec age. During July 1961, the writer visited and collected from Stensaas and Langenheim's Joana limestone locality on Ward Mountain, south of Ely, Nevada. *L. jasperensis* occurs there with a large fauna of corals and brachiopods which are of upper Kinderhook and lower Osage age. This fauna of the Joana limestone is very similar to the fauna of member A of the Keating formation, Escabrosa group. They stated the average corallite is 10 mm in diameter, and some are as large as 15 mm. There are present 20 to 24 (rarely 24) major septa. Their drawings (text figures 9a and ob) do show corallites, which this author considers typical of both species. There does appear to exist between colonies and individual corallites within a colony from widely scattered localities in western North America a complete gradation of forms from *L. jasperensis* to *L. confluens*.

Nelson (1960, p. 112-113) placed *Lithostrotionella circinatus* Easton and Gutschick (1953, p. 19) as a junior synonym of *L. jasperensis*. Although the type of *L. circinatus* is illustrated by a simple line drawing of only three corallites, it is markedly separated specifically from the typical *L. jasperensis* by having in the dissepimentarium very weakly-developed septa, and very pronounced, wide-spaced lonsdaleoid dissepiments. In the tabularium the major septa infrequently join with the columella. The writer studied the holotype and found all of the corallites in the corallum displayed these particular characteristics.

Horizon. This species is very abundant in member A of the Keating formation throughout its area of exposure in southwestern New Mexico and at Blue Mountain, Chiricahua Mountains, Arizona. It is also present in the Andrecito member of the Lake Valley formation in the southern part of the Black Range, New Mexico.

Lithostrotionella shimeri (Crickmay)

Pl. 3, fig. 13-15

Lithostrotion pennsylvanicum Shimer, H. W., 1926 (*partim.*), Canada Geol. Surv. Bull. 42, p. 27.

Lithostrotionella pennsylvanica, Kelly, W. A., 1942, Jour. Paleont., v. 16, p. 352; pl. 5o, fig. 1, 2, 5, 6, 8.

Lonsdaleia pennsylvanica, Crickmay, C. H., 1955, The Minnewanka section, published by the author, p. 13, pl. 1; fig. , 12 (*vide* Nelson, 1960).

Lonsdaleia shimeri Crickmay, C. H., 1955, The Minnewanka section, published by the author, p. 13, pl. 1, fig. 9, 10 (*vide* Nelson, 1960).

Lithostrotionella shimeri, Nelson, S. J., 1960, Jour. Paleont., V. 34; pl. 21, fig. 9-15, pl. 22, fig. 1-3.

Diagnosis. Cerioid corallum, large corallites, 20 to 23 major septa, minor septa absent or present, weakly-developed columella, dissepimentarium with large dissepiments mainly in single series, tabulae sagging, flattened.

Description. The corallum is cerioid, and is as large as one-half meter in diameter. The corallites are erect, and the colony has the shape of an expanded cone.

In transverse section (fig. 19) the larger corallites are 13 mm in width. There are 20 to 23 major septa, which almost extend to, or actually reach, the weakly-developed axial structure. Minor septa may or may not be present. If present they are very short. The columella is generally formed by extension of the counter septum. The major septa may or may not penetrate the dissepimentarium, and they rarely join the epitheca. The dissepiments are widely spaced and have few intercepts. In longitudinal section, the dissepiments are arranged in single series. They leave the wall at an angle of about 45 to 90 degrees, sloping downward and becoming nearly vertical at the tabularium. The tabulae appear to slope gently downward from the dissepimentarium and become horizontal near the columella.

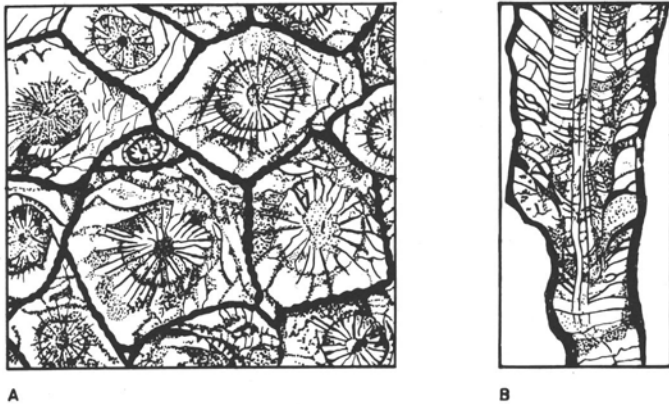


Figure 19

SECTIONS OF *Lithostrotionella shimeri*; A, transverse section, B, longitudinal section

Remarks. The *L. shimeri* from the Black Prince limestone agrees very closely with Nelson's (1960, p. 5) redescription of the holotype from the southern Canadian Rockies. He discussed the extreme variability of the species in respect to the presence or absence of minor septa, the pattern and spacing of the tabulae and dissepiments. The species in Canada has been found only in strata of Meramec age. It is interesting to note that lithostrotionoids have not been found in any Meramec equivalents in southwestern New Mexico and are absent in southeastern Arizona except sporadically at the base of the Black Prince limestone in the Gunnison Hills, Arizona.

The only other known Meramec lithostrotionoid coral

found in New Mexico is a fasciculate *Lithostrotion* aff. *L. whitneyi* from the Arroyo Penasco formation, near Taos, New Mexico. It has been the observation of the writer that in New Mexico and Arizona, lithostrotionoid corals are "fairly abundant" in lowest Osage rocks but very rare in Meramec strata.

Horizon. Shale at base of Black Prince limestone, Gunnison Hills, Arizona, NE1/4, SW1/4, sec. 4, T. 16 S., R. 23 E., U.S. Geol. Surv. Coll. No. 13844.

Family A U L O P HYLLIDAE Dybowski, 1837 Subfamily

A U L O P HYLLINAE Dybowski, 1837 Genus

DIBUNOPHYLLUM Thomson and Nicholson, 1876

Dibunophyllum Thomson, J., and Nicholson, H. A., 1876, Ann. Mag. Nat. Hist., V. 17, p. 457.

Albertia Thomson, J., 1878, Royal Phil. Soc. Glasgow Proc., v. 10, p. 164; (*vide* Hill, D., 1938, p. 65).

Histiophyllum Thomson, J., 1879, Royal Phil. Soc. Glasgow Proc., V. 11, p. 323; (*vide* Hill, D., 1938, p. 65).

Centrephyllum Thomson, J., 1880, Royal Phil. Soc. Glasgow Proc., V. 12, p. 227; (*vide* Hill, D., 1938, p. 65).

Dibunophyllum, Hill, D., 1938, Palaeont. Soc., p. 65-67.

Dibunophyllum, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F. (Coelenterata), p. F286.

Type Species. (By subsequent designation; Gregory, 1917, p. 232) *Dibunophyllum muirheadi* Nicholson and Thomson, 1876; Proc. Royal Phil. Soc. Glasgow, v. 10, p. 129; pl. 2, fig. 2, 3). Lower Carboniferous limestone, Scotland (*vide* Hill, 1938, p. 65).

Range. Upper Viséan and lower Namurian, British Isles, Belgium, France, Russia, and western Sahara. Bell (1929, p. 95) found the genus to be present in Nova Scotia, Merriam (1942, p. 373) reported the genus from the upper Mississippian Coffee Creek formation of central Oregon. This formation carries a distinct Eurasian fauna. Newell (1935) erected a new species of *Dibunophyllum*, *D. valeriae*, from the Missourian of Kansas. Newell's *Dibunophyllum* is undoubtedly referable to another genus. The only other occurrence of the genus in North America is the form from West Texas described in this paper, *D. bipartitum konincki* from rocks considered to be of Chester age.

Diagnosis. (After Hill, 1938, p. 65-67.) Large, simple rugose corals, whose variable axial structure is typically one-third as wide as the corallum, and consists of a long median plate, a few (usually four to eight) septal lamellae on either side, and numerous tabulae, sloping steeply down at its periphery; less typically the lamellae may become curved, the median plate disappears, and the bilaterally radiate arrangement may be lost. Minor septa are degenerate; the width of the dissepimentarium is about two-thirds the length of the major septa, which is two-thirds the radius of the corallum; the dissepiments are frequently inosculating. Tabulae are incomplete and bracket-shaped; the tabulae are of two series, the plates of the outer being fewer and less steeply inclined than those at the inner series. The septa are not curved about the small cardinal fossulae.

Remarks. *Dibunophyllum* is characterized by degenerate minor septa, and it is readily distinguished from *Koninckophyllum* Thomas and Nicholson. The latter form has long minor septa and also major septa which are withdrawn from the axis. *Koninckophyllum* may also have a corallum which is dendroid.

Dibunophyllum bipartitum konincki (Milne-Edwards and Hahne)
Pl. 5, fig. 5-13

Clisiophyllum Konincki Milne-Edwards, H., and Haime, J., 1851, Mon. Polyiers Fossiles des Terrains Paleozoiques, P. 410-411.

Dibunophyllum bipartitum konincki, Hill, D., 1938, Palaeont. Soc., p. 75-78; pl. 1, fig. 20, pl. 2, fig. 7-13.

Diagnosis. Large simple rugose coral having variable axial structure usually one-third to one-fourth the diameter of the corallite. This consists typically of a long median plate, and a few septa lamellae on each side of the plate directed towards the axis. Minor septa are withdrawn towards the periphery or are absent. The dissepimentarium is wide; the tabulae are conical and incomplete, tabulae arranged into series, those of the outer series being fewer and less steeply inclined than those at the inner series.

Description. The corallum is robust, curved in the early stage, cylindrical in the epebic stages. The epitheca is wrinkled transversely. Mature coralla frequently show rejuvenescence.

The major septa are numerous, 65 to 80 being present in a mature calyx. The septa are usually straight and are dilated in the tabularium. The cardinal fossula is the result of the shortening of one or more minor septa. The alar fossulae are very weakly developed. The minor septa are degenerate and if present are restricted to a very narrow zone extending from the periphery. Dissepiments are very abundant, towards the inner ring (i.e., near the tabularium) are smaller and more steeply inclined. The innermost ring is dilated.

The axial column is oval, about one-fourth to one-fifth the diameter of the corallite. It consists of a long median plate which is an extension of the counter septum. A number of rather sinuous septal lamellae are directed towards the median plate. The tabulae are flat near the dissepimentarium, becoming progressively more up-arched towards and particularly near the column. An outer series of tabulae may develop between those at the axial structure and the dissepiments. These are convex upward and outward.

Horizon. In the western hemisphere this European species is known to occur only at the top of the Helms formation (Chester), Franklin Mountain, SW1/4, sec. 67, Blk. 82, El Paso County, Texas.

Remarks. Hill (1938, p. 65-67) made an exhaustive study of approximately a thousand specimens of the British dibunophyllids, from one location over a stratigraphic interval of 350 feet. She found the genus to be continuously variable in time and space and consequently difficult to subdivide into species. She also found the genus to be in some horizons "riotously variable." In the past the English representatives of *D. bipartitum*, as defined by Hill, have been given an immense number of names, numbering 7 generic and 71 specific synonyms.

Dibunophyllum has been recorded only three times in the stratigraphic column of North America. Bell (1929, p. 95) reported *D. lambii* (Bell) from the Windsor series (Chester) of Nova Scotia. *D. lambii* differs from *D. bipartitum konincki* in having only about 40 septa in an epebic individual, two much more weakly developed dissepimentaria and a smaller mature corallite. Newell (1935, p. 33-346, pl. 33, fig. 1-3) reported *D. valeriae* Newell from the upper part of the Missourian series (Pennsylvanian). It differs markedly from *D.*

bipartitum konincki in having only 33 septa in mature specimens and a weakly developed dissepimentarium. The illustrations of *D. valeriae* show certain characteristics which indicate the species probably does not belong to *Dibunophyllum* (s. s.). *D. valeriae* has relatively long minor septa and major septa which are withdrawn from the axis.

Merriam (1942, p. 373) described *Dibunophyllum oregonensis* from strata of Chester age in central Oregon. This species differs from *D. bipartitum konincki* in having a much smaller number of major septa (38 to 40), better developed minor septa, longer dilated inner portions of the major septa, and a somewhat narrower dissepimentarium.

D. bipartitum konincki from the Franklin Mountains of west Texas differs from the majority of British material described by Hill (1938) in generally having septa which extend further into the axial region and a correspondingly smaller axial column.

The west Texas specimens, however, can be matched almost exactly to some of Hill's (1938, pl. 2, fig. 9, 13) illustrations of *D. bipartitum konincki*.

Genus **KONINCKOPHYLLUM** Thomson and Nicholson, 1876

Koninckophyllum Thomson, J., and Nicholson, H. A., 1876, Ann. Mag. Nat. Hist., V. 17, n. 4, p. 297.

Axophyllum Thomson, J., 1877, Royal Phil. Soc. Glasgow Proc., V. 10, p. 433 (*fide* Hill, D., 1938, p. 85).

Acrophyllum Thomson, J., 1883, Royal Phil. Soc. Glasgow Proc., v. 14, p. 455 (*fide* Hill D., 1938, p. 85).

Lophophyllum Carruthers, R. G., 1913, Geol. Mag. (ns), v. 10, p. 49.

Eostroton Vaughan, A., 1945, Quart. Jour. Geol. Soc., London, v. 71, p. 39.

Koninckophyllum, Hill, D., 1938, Palaeont. Soc., p. 85-89. *Koninckophyllum*, Hill, D., 1956, Treatise Invertebrate Paleontology, Pt. F (Coelenterate), p. F286.

Type Species. (Subsequent designation; Thomas, J., Royal Phil. Soc. Glasgow Proc., v. 14, p. 419), *Koninckophyllum magnificum* Thomson and Nicholson (1876, Ann. Mag. Nat. Hist. London, pl. 12, fig. z, 2a), Loser Limestone Series (Visean) Scotland.

Range. Hill (1938, p. 87, 88; 1956, p. F287; 1957, p. 54-55). The genus is common in the Tournaisian and Visean of the British Isles and Belgium, lower Visean of Asia Minor, and upper Visean of the Sahara. It is also present in the lower Carboniferous of Russia and is represented in North America by *K. avonensis* (Bell) and *K. cf. K. interruptum* Nicholson and Thomson. *K. elpasoensis* n. sp. from the Franklin Mountains of west Texas and *K. talonatum* Easton from the late Chester Pitkin formation of Arkansas are the only known occurrences of this genus in the New World outside of Nova Scotia. Langenheim and Tischler (1960, p. 120-121) reported poorly preserved material from the lower Mississippian, of Death Valley, California, that may represent an undetermined species of *Koninckophyllum*.

Diagnosis. Modified from Hill, 1938, 1956. Solitary or fasciculate rugose corals; major septa withdrawn from the axis except along the surface of the tabulae; minor septa long; axial structure a columella, which may be supported by a few septal lamellae, dissepiments fine and concentrically arranged; tabulae tented and incomplete; if columella is absent, the tabulae are flattened and may become complete.

Remarks. *Koninckophyllum*, with its weakly developed axial structure, long minor septa and major septa which are withdrawn from the axis, is readily distinguished from *Dibunophyllum* Thomson and Nicholson in which the axial structure is well-developed and the minor septa degenerate.

Koninckophyllum elpasoensis n. sp.

Pl. 2, fig. 29-37

Diagnosis. Trochoid *Koninckophyllum* with a dibunophylloid axial structure in neanic stage; in ephebic stages septal lamellae withdraw from the axis, leaving a columella in the axial space; in the gerontic stage columella may disappear. Minor septa long; major septa number 30 to 34 in ephebic specimens. Dissepimentarium wide.

Description. The corallum is curved in the neanic stages and cylindrical in the ephebic stages; gradually increasing in diameter, with growth constructions probably due to rejuvenescence. Diameters of mature coralla range from 15 mm to 22 mm.

In the ephebic stage there are 30 to 34 major septa which extend two-thirds the distance to the axis. Septa are slightly dilated in the tabularium. In the ephebic stage the minor septa are thin, somewhat sinuous, but long, being about three-fourths the length of the major septa. In the earlier growth stages, the minor septa are proportionately shorter in relation to the major septa.

In the late ephebic stage the minor septa are frequently discontinuous in the dissepimentarium. The dissepimentarium is well developed and extends half the distance to the center of the corallite. Dissepiments are abundant, smaller, and more steeply inclined in the inner ring. They inosculate so that in section they seem to be concentrated in this area. The tabularium consists of an axial and periaxial zone. The axial ends at the septa are withdrawn to the periaxial zone. The tabulae in the axial zone are slightly dome-shaped. The tabulae in the periaxial zone are short, tightly packed, and more strongly domed. The fossula is very weakly developed; the cardinal septum is perceptibly shortened in comparison to adjacent major septa. The major septa are neither curved about the cardinal septum nor away from it. In the neanic stages the columella is a lath-like plate in line with the cardinal and counter septa and occasionally joined to it are the axial end of a few major septa. In the ephebic stages, the septa withdraw from the axis, leaving the columella. In the late ephebic stage the columella may become obsolete.

Range. Bell (1929, p. 94) reports *K. avonensis* (Bell), and Lewis (1935, p. 133) reports *K. cf. K. interruptum* Nicholson and Thomson from Chester equivalents in Nova Scotia. These and *Koninckophyllum talonatum* Easton from the upper Chester Pitkin formation of Arkansas, are the only known previous recorded occurrences of this genus in North America. *K. elpasoensis* is known so far only from the Helms formation (Chester) of the Franklin Mountains, SW1/4, sec. 67, Blk. 82, El Paso County, Texas.

Remarks. *K. elpasoensis* shows closest kinship to *K. interruptum* Thomson and Nicholson from the upper Viséan of Scotland and England. The relationship between the two species is not close. *K. interruptum* has a much larger corallum (20 mm in diameter in an ephebic specimen) and at all growth stages has more septa. Lewis' (1931, p. 240) chart graphically illustrates both *K. interruptum* at various onto-genetic stages and the relationship between the size of the

corallite and the number of septa. *K. interruptum* at a diameter of 20 mm has 55 major septa, and an ephebic specimen of *K. elpasoensis* at the same diameter has only 32 major septa. Furthermore, *K. interruptum*, in comparison to *K. elpasoensis*, has minor septa which are weakly developed, particularly in the dissepimentarium. *Koninckophyllum talonatum* Easton from the upper Chester Pitkin formation of Arkansas is distinguished from *K. elpasoensis* by a much wider dissepimentarium, a thicker and more persistent median plate, and longer major septa in the ephebic stage.

Order **TABULATA** Milne-Edwards and Haime, 1850

Family **AULOPORIDA** Milne-Edwards and Haime, 1851

Subfamily **SYRINGOPORINAE** Nicholson, 1879 Genus

SYRINGOPORA Goldfuss, 1826

Syringopora Goldfuss, G. A., 1826, Petref. act. Germaniae, v. 1, p. 75 (*vide* Lang, Smith, and Thomas, 1940, p. 132).

Syringopora, Milne-Edwards, H., and Haime, J., 1851, Palaeont. Soc., p. 161-162.

Syringopora, Nicholson, H. A., 1879, On the Structure and Affinities of the Tabulate Corals of the Palaeozoic Period, p. 207-214.

Syringopora, Hill, D., 1934, Royal Soc. Queensl. Proc., v. 45, n. 2, p. 99.

Syringopora, Easton, W. H., 1944a, Illinois Geol. Surv., Rept. Invest. n. 97, p. 61.

Syringopora, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F (Coelenterata), p. F472.

Syringopora, Easton, W. H., 1958, Smithsonian Misc. Coll., V. 119, n. 3, p. 37, 38.

Type Species. (By subsequent designation; Milne-Edwards and Haime, 1850, British Fossil Corals, Palaeont. Soc., p. LXII) *Syringopora ramulosa* Goldfuss, G. A. (1826, Petrefacta Germaniae, v. I, p. 76; pl. 25, fig. 7). Carboniferous; aus dem Uebergangskalk von Olne im Limburgischen, Germany.

Range.—Silurian—Permian.

Diagnosis. (After Hill, 1956b, p. F272.) Closely or loosely set cylindrical corallites connected in most species by hollow, transverse stolons. Septa lacking or represented by 12 vertical rows of small spinules; tabulae closely set, deeply depressed axially, coalesced in some species to form a continuous axial tube.

Remarks. The characteristics generally used by most workers to determine the various species of *Syringopora* have been the shape, size, and distribution of septal spines and tabulae within the corallum. Taxonomic importance has been assigned to size and distance between corallites in a colony. A recent study by Nelson (1959) demonstrated that the frequency and diameter of corallites within a colony has stratigraphic significance.

At present little is known of the phylogenetic trends within the genus. Studies within the Escabrosa group show that the various species have long stratigraphic range and are not of particular value in correlation. Recent communication from Helen Duncan (personal communication, 1960) indicates she finds *Syringopora* in the Cordilleran region to be very useful for differentiating the various upper Paleozoic systems. Also she indicated that the common species appear to have long ranges and are of little value now in detailed correlation.

Syringopora aculeata Girty, 1899

Text fig. 20

Syringopora aculeata Girty, G. H., 1899, U.S. Geol. Surv. Mon. 32, pt. 2, p. 484, 509; pl. 67, fig. 5a, 5b.

Syringopora aculeata, Easton, W. H., and Gutschick, R. C., 1953, Southern Calif. Acad. Sci. Bull., V. 52, p. 22; pl. 2, fig. 13-16.

Syringopora aculeata, Sando, W. J., 1960, U.S. Geol. Surv. Bull. 1071 F, p. 184, pl. 20, fig. 1-4.

Diagnosis. *Syringopora* with corallites 1.5 mm in diameter, separated from adjacent corallites by 2 mm to 3 mm. Septal spines and infundibular tabulae present.

Description. Corallites are about 1.5 mm in diameter, generally separated from adjacent corallites by about 2 mm to 5 mm. In cross-section the septal spines are short and sharp with about 20 to 25 rows present in each corallite. Tabular intersections are arranged in 4 to 6 irregularly concentric ellipses. In some longitudinal sections (fig. 20) rows of vertical spines are visible. Tabulae dip steeply toward axial tube which is crossed by occasional tabulae or diaphragms which are spaced more widely than the outer tabulae.

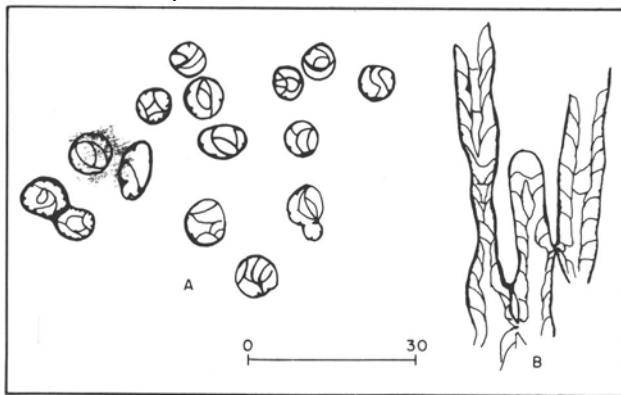


Figure 20

SECTIONS OF *Syringopora aculeata*, A, transverse section, B, longitudinal section

Horizon. *S. aculeata* is present in member A of the Keating formation throughout its area of outcrop in southwestern New Mexico. It is found also in the Arcente and Alamogordo members of the Lake Valley formation in south-central New Mexico. The specimen studied came from member A of the Keating formation, Klondike Hills, New Mexico.

Remarks. Partial silicification had obliterated much of the finer structure within the corallites of the specimens studied. *S. aculeata* is distinguished from *Syringopora harveyi* White of the Kinderhook and Osage rocks of the Midcontinent region by having slightly larger corallites and a more compact corallum.

Easton's (1957, p. 38) species *Syringopora tubifera* from the Represo limestone of northwest Sonora has within the corallites 30 to 34 rows of septal spines. Easton's (p. 39, fig. 3) inked drawing of a transverse section of *S. tubifera* is highly reminiscent of *S. aculeata*. Detailed studies of the holotype or of the type material may prove *S. tubifera* to be a junior synonym of *S. aculeata* Girty.

Syringopora surcularia Girty

Text fig. 21

Syringopora surcularia Girty, G. H., 1899, U.S. Geol. Surv. Mon. 32, pt. 2, p. 510; pl. 67, fig. 42-46.

Syringopora surcularis, Easton, W. H., and Gutschick, R. C., 1953, Southern Calif. Acad. Sci. Bull., V. 52, p. 22-23.

Syringopora surcularis, Sando, W. J., 1960, U.S. Geol. Surv. Bull. 1071 F, p. 184, pl. 20, fig. 5-8.

Diagnosis. *Syringopora* with corallites 2.5 mm in diameter, separated from adjacent corallites by about 4 mm. Septal spine short, 20 rows to a corallite.

Description. Corallites 2.5 mm in diameter are separated from adjacent corallites by about 4 mm. In transverse section (fig. 21) septal spines numbering about 20 are very short. Tabular intersections are arranged in about 6 to 8 concentric ellipses which are closely packed and are eccentrically located in the corallite. In the longitudinal section the tabulae overlap one upon the other and occupy about two-thirds of the corallite. The center is a long tube with occasional transverse tabulae. In some oblique and longitudinal sections the spines are readily visible in vertical rows.

Horizon. *S. surcularia* is one of the most common fossils in member A, but rare in member B in the Keating formation. The species is common in lower Osage strata throughout southwestern New Mexico and southeastern Arizona. This species is also abundant in the Andrecito and Alamogordo

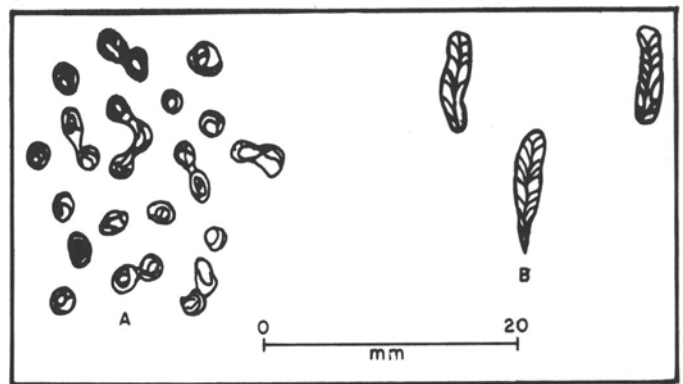


Figure 21

SECTIONS OF *Syringopora surcularia*; A, transverse section, B, longitudinal section

members of the Lake Valley formation in south-central New Mexico. The specimen studied by thinsection came from member A of the Keating formation, Klondike Hills and Big Hatchet Mountains, New Mexico.

Remarks. *S. surcularia* is distinguished from *S. aculeata* and *S. harveyi* by its larger corallites, which are more widely spaced in the corallum. The corallites of *S. aff. S. gigantea* Thompson are 4 mm in diameter and conspicuously larger than those of *S. surcularia*.

Syringopora aff. *S. gigantea* Thompson

Text fig. 22

Syringopora gigantea, Thompson, J., 1883, Glasgow, Philos. Soc. Proc., V. 14, p. 329, pl. 3, fig. 24.

Syringopora aff. *S. gigantea*, Sando, W. J., 1960, U.S. Geol. Surv. Bull. 1071F, p. 185, pl. 19, fig. 13-16.

Diagnosis. *Syringopora* with corallites 4 mm in diameter and widely spaced; septal spines absent.

Description. Corallites are 4 mm in diameter and separated from adjacent corallites by about 6 mm to 7 mm. In transverse section (fig. 22) the tabulae intersections are arranged in about 4 to 6 concentric ellipses, which are closely packed and are eccentrically located in the corallites. In longitudinal section

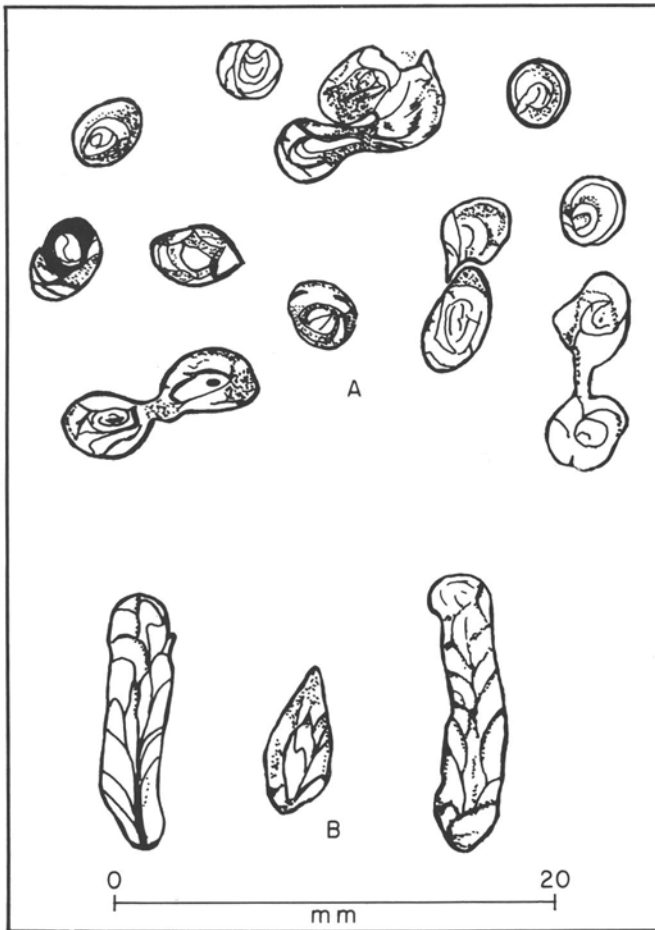


Figure 22

SECTIONS OF *Syringopora* AFF. *S. gigantea*; A, transverse section, B, longitudinal section

the tabulae overlap one upon the other and occupy about two thirds of the corallite. The center is a long tube with occasional transverse tabulae. Spines were not visible in either oblique or longitudinal sections.

Horizon. *S. aff. S. gigantea* is one of the few fossils which occurs in the middle of the massive crinoidal Hachita formation. It is present as an occasional, isolated, massive colony. The thin sections were made from a specimen that came from the northeast side of the Big Hatchet Mountains, New Mexico.

Remarks. *S. aff. S. gigantea* occurs in the middle of the massive crinoidal limestones of the Hachita formation. These limestones are characterized by extensive diagenetic recrystallization, which has tended to destroy the finer details of the corallites. Very short, narrow spines once may have been present on this species but may have been subsequently destroyed by recrystallization. *S. aff. S. gigantea* is readily distinguished in the field from *S. aculeata* and *S. surcularia* by its much larger corallites and wider spacing between corallites.

Family FAVOSITIDAEDANA, 1846

Subfamily MICHELINIINAE WAGGEN AND WENTZEL, 1886

Genus MICHELINIA de Koninck, 1841 *Michelinia* Koninck, L. G. de, 1841, Description des Animaux Fossiles qui se trouvent dans les Terrain carbonifere

de Belgique, p. 2I; (fide Milne Edwards and Haime, 1850, p. LX).

Michelinia, Nicholson, H. A., 1879, Tabulate Corals of Palaeozoic Period, p. 139-14z.

Michelinia, Hill, D., 1934, Royal Soc. Queensl. Proc., p. 97. *Pleurodictyum* Goldfuss, Easton, W. H., 1943, Jour. Paleont., v. 17, n. 2, p. 138.

Pleurodictyum Goldfuss, Easton, W. H., 1944a, Illinois Geol. Surv. Rept. Invest. n. 97, p. 55.

Pleurodictyum Goldfuss, Easton, W. H., and Gutschick, R. C., 1953, Southern Calif. Acad. Sci. Bull., v. 52, P. 23-24.

Michelinia, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F (Coelenterata), p. F466.

Pleurodictyum Goldfuss, Easton, W. H., 1958, Smithsonian Misc. Coll., v. 119, n. 3, p. 36.

Type Species. (subsequent designation, Milne Edwards and Haime, 1850, p. LX). *Michelinia tenuisepta* de Koninck, L. G. (Descriptions des Animaux fossiles qui se trouvent dans le Terrain carbonifere de Belgique; p. 31, pl. C, fig. 3a-3b).

Range. Upper Devonian through the Permian.

Diagnosis. Discoid, hemispherical and dendroid corallum; corallites large, thick to thin-walled, with irregularly distributed tunnel-like mural pores, septal spines; numerous, incomplete, convex tabulae.

Remarks. The type species of the genus *Pleurodictyum* Goldfuss (1829) is *P. problematicum* Goldfuss from the lower Devonian of Germany. Over the years there has existed considerable difference of opinion among workers on the possibility of *Michelinia* being a junior synonym of *Pleurodictyum*. Fenton and Fenton (1936, p. 23) and Lang, Smith, and Thomas (1940, p. 84, 102) considered exact determination of *Michelinia* must wait until an examination of the topotypes of *M. tenuisepta* de Koninck, the genotype of *Michelinia*, and a detailed study of *P. problematicum* Goldfuss were made. In the United States, Easton (1943, 1944; Easton and Gutschick, 1953; and Easton, et al., 1958) followed Lang, Smith, and Thomas and placed *Michelinia* as a junior synonym of *Pleurodictyum*. The issue was not totally settled, for Moore and Jeffords (1944, p. 167), working together on lower Pennsylvanian tabulate corals, reached divergent views regarding the two genera. Moore considered *Michelinia* to be generically distinct and Jeffords did not. Hill (1956, F452, F466), after studying type material, considers *Pleurodictyum* to be characterized by a few very thin complete tabulae and to be restricted to the lower Devonian, and *Michelinia* to have numerous incomplete tabulae and to range from the Devonian through the Permian.

Michelinia leptosphragma n. sp.

Text fig. 22

Diagnosis. *Michelinia* with a depressed hemispherical corallum; corallites are hexagonal to circular in section, 8 mm to 15 mm in diameter; septal spines obsolete; tabulae numerous, somewhat anastomosing, a few complete; corallite walls very thin.

Description. The corallum is a depressed hemisphere of irregular shape. The holotype (fig. 23) measured some 40 mm by 50 mm in diameter. The corallites are hexagonal to circular in outline, from 6 mm to 10 mm in diameter. Septal spines are obsolete. Mural pores very scarce. Tabulae abundant, generally convex, 8 to 15 occurring in the space of x o mm; some tabulae may be complete. The walls are thin and have a very thin investment of stereome.

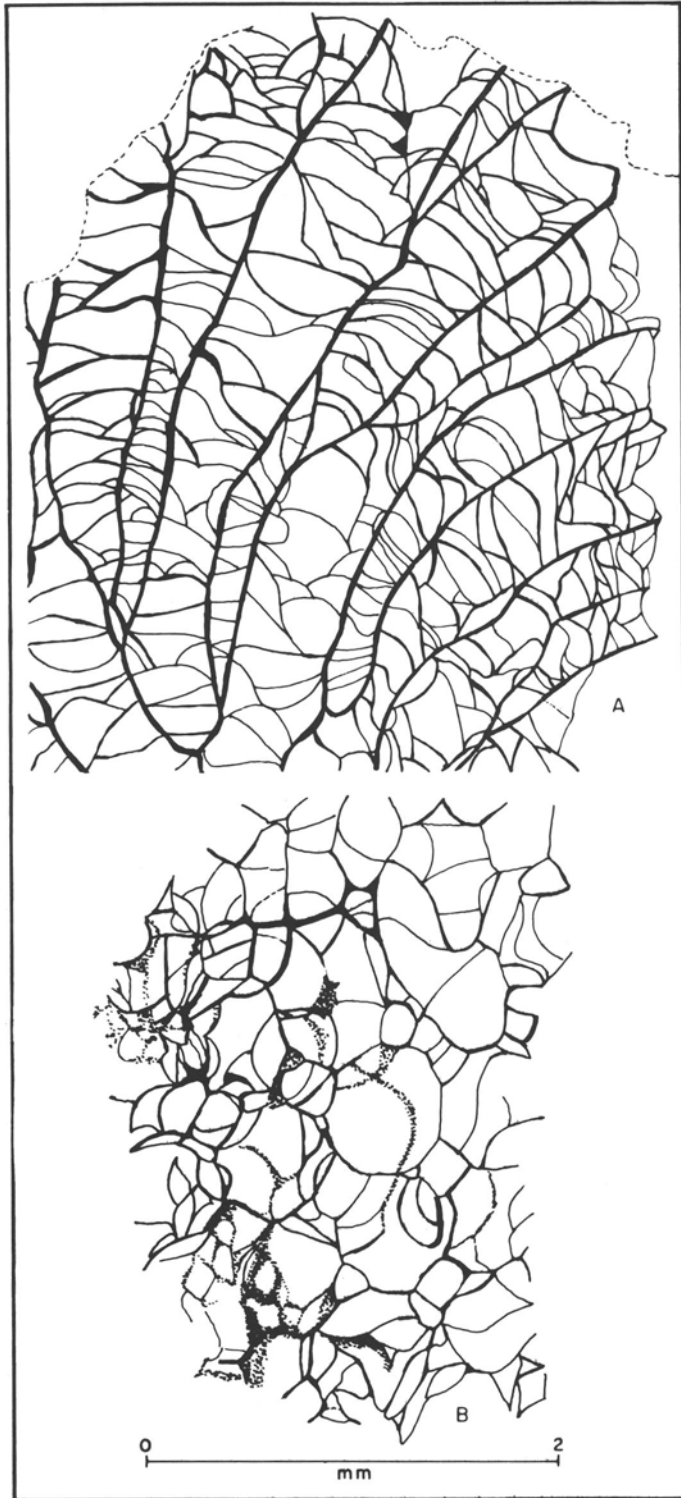


Figure 23

SECTIONS OF *Michelinia leptosphragma*; A, longitudinal section, B, transverse section

Horizon. *M. leptosphragma* has been found at the top of the Hachita formation, Meramec, Blue Mountain, Chiricahua Mountains, Arizona, and the lower part of the Paradise formation, lower Chester, Big Hatchet Mountains, New Mexico.

Remarks. The most distinguishing feature of *M. leptosphragma* is the large size of the corallites and the very thin

walls. *M. leptosphragma* is similar to the Kinderhook and Osage *Michelinia expansa* White except that the latter has thickened walls between the corallites and concave tabulae. *Michelinia meekana* Girty of Chester age is distinguished from *M. leptosphragma* by its smaller (4 mm in diameter) corallites and much thicker walls. *Michelinia williamsi* Greene and *Michelinia indianensis* Beede from the lower Meramec of Indiana have smaller corallites 2 mm to 3 mm in diameter. *Michelinia eugenei* White, primarily a Morrow (lower Pennsylvanian) species not known in strata of Chester age (Easton, 1943, p. 136), is distinguished from *M. leptosphragma* by much smaller corallites.

Phylum BRACHIOPODA Dumeril, 1806

Class ARTICULATA Huxley, 1869

Suborder STROPHOMENOIDEA Maillieux, 1932,

emend.; Opick, 1934, emend.; Williams, 1953

Superfamily ORTHOTETACEA Williams, 1953

Genus WERRIEA Campbell, 1957

Orthotetes Fischer de Waldheim, Weller S., 1914, Illinois Geol. Surv. Mon. i, p. 74-78.

Werriea Campbell, K. S. W., 1957, Jour. Paleont., v. 31, p. 44.

Diagnosis. The genus is described by Campbell (1957, p. 44).

Range. Mississippian.

Type Species. (Original designation) *Werriea australis* Campbell, K. S. W., 1957, Jour. Paleont., v. 31, p. 45, Upper Tournaisian of Watts, Babbinsboon, Australia.

Werriea keokuk (Hall)

P1.6, fig. 18-24

Orthis keokuk, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 640, pl. 19, fig. 5a-5b.

Streptorhynchus keokuk, Hall, J., 1883, New York State Geol. Rept., pl. 41, fig. 1-3.

Orthis keokuk, Gordon, G. H., 1890, Am. Geol., v. 5, n. 5, p. 261, pl. 1, fig. 7.

Derbya keokuk, Hall, J., and Clarke, J. M., 1892, New York Nat. Hist. Paleont., v. 8, pt. 1, pl. 11, fig. 1-3.

Orthis keokuk, Keyes, R. R., 1894, Missouri Geol. Surv., v. 5, p. 63.

Derbya keokuk, Girty, G. H., 1899, U.S. Geol. Surv. Mon. 32, p. 524.

Orthotetes keokuk, Weller, S., 1914, Illinois Geol. Surv. Mon. i, p. 75-77, pl. 7, fig. 1-4.

Description. Shell is large, subelliptical in outline, with greatest width slightly anterior to or at the hinge line, and its cardinal extremities obtusely angular. The dimension of three large pedicle valves in mm are: width, 70, 72, 81; and length, 43, 46, 47.

Pedicle valve nearly flat, occasionally slightly resupinate. Umbonal region slightly elevated towards the beak. Sinus is obsolete. The cardinal area is flat. Although the specimens were crushed, the cardinal area appears to be sloping at about 110 degrees from the hinge line.

The brachial valve is convex, with the greatest convexity posterior to the middle. Fold is absent. Growth was not regular and various stages are marked by broad irregularly developed concentric folds. Costae arise by bifurcation, 2 or 3 occupying the space of 1 mm.

In the adult pedicle valve the dental lamellae are thickened, unite with the median septum, and isolate a small triangular shaped spondylium. The median septum is well developed and extends anteriorly from the beak along one-fourth the length of the shell. The muscle scars are broad and flabellate and continuous into the umbo. The muscle scars are one-third to one-fourth the width and length respectively of the valve. Details of the interior of the brachial valve were not preserved on the material studied.

Range. This species is abundant in the *Syringothyris subcuspidatus* zone and higher horizon (Warsaw and Salem age) of the Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona, and the Big Hatchet Mountains of New Mexico. It is frequently found in these horizons as fragments, but even in this state it is an excellent biostratigraphic zone marker.

Remarks. *Werriea kaskaskiensis* (McChesney), which is found in the stratigraphically higher Paradise formation, is distinguished from *W. keokuk* by its smaller size, less protuberant umbonal region in the brachial valve, and more abruptly elevated and more acute beak on the pedicle valve. As was shown by Campbell (1957, p. 45), there is a strong resemblance between *W. keokuk* and the Australian species *W. australis* Campbell. The latter form has a wider hinge line, and in the pedicle valve the muscle field is in a more posterior position than it is in *W. keokuk*.

Suborder **DALMANELLOIDEA** Moore, 1952
 Superfamily DAL MANELLACEA Schuchert and
 Cooper, 1931

Genus **RHIPIDOMELLA** Oehlert, 1890
Rhipidomella jerseyensis (Weller)
 Pl. 6, fig. 8-1

Rhipidomella michelinia, Weller, S., 1909, Am. Geol. Soc. Bull., v. 20, p. 295, pl. 2, fig. 8-10.

Rhipidomella jerseyensis, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 157-158, pl. 20, fig. 36-43.

Description. Shell generally slightly wider than long; the greatest width posterior to the mid-length of the valve. Shell outline suborbicular to subovate. The anterolateral margins are rounded; the anterior margin may continue as a semicircle with the anterolateral margin, but is more often truncated. The posterolateral margins are straight, meeting at the beak at an angle of about 90 to 95 degrees. The dimensions of two individuals in mm are:

Specimen	Pedicle valve only	
	Length	Width
1.	13.5	14.0
2.	12.0	12.0

Pedicle valve moderately convex, greatest convexity posterior to the middle and on the umbo. Surface curves abruptly from the umbo to the cardinal area, much more gently to the lateral and anterior margins. A faint and ill-defined sinus begins on the umbo, widens and deepens slightly toward the anterior margin, where its lateral extent is ill-defined and is rounded on the bottom.

Brachial valve more convex than pedicle, greatest convexity posterior to the middle. Surface curves abruptly to the car-

dinal area, much less to the lateral and anterior margins. Surface of shell has lamellose extensions divided into flattened spines, 3 to 4 of which are present in 1 mm.

Interior. When a few silicified pedicle valves were etched by hydrochloric acid, they showed poorly preserved internal features. Short, stout, posteriorly recurved teeth are supported by dental lamellae, which are fused to the umbonal wall. Between the dental lamellae is a deep pedicle cavity. In front of this cavity is an ovate muscular area extending over half the length of the valve. The diductor scar is flabellate, well defined. A well-defined median septum is present for over half the length of the valve. Interior of a brachial valve was not available for study.

Horizon. *Rhipidomella jerseyensis* occurs and is particularly abundant in the upper half of member B, Keating formation.

Remarks. *Rhipidomella jerseyensis* from member B, Keating formation is slightly larger than the average specimen described by Weller (1914, p. 153-154) from the lower Osage of Missouri and Illinois. Fragments of a small species of *Rhipidomella* occur in the lower part of the Keating formation, but specific identification is impossible.

Genus **PERDITOCARDINIA** Schuchert and Cooper, 1931
Perditocardinia dubia (Hall)

Orthis dubia, Hall, J., 1856, Albany Inst. Trans., v. 4, p. 2.
Orthis dubia, Whitfield, R. P., 1882, Am. Mus. Nat. Hist., v. 1, p. 45, pl. 6, fig. 1-5.

Orthis dubia, Hall, J., 1883, Indiana Geol. Surv. 2th Ann. Rept., p. 324, pl. 29, fig. 1-5.

Orthis dubia, Hall, J., and Clarke, J. M., 1892, New York Nat. Hist. Paleont., v. 8, pt. 1, pl. 6A, fig. 18-22.

Orthis dubia, Keyes, R. M., 1894, Missouri Geol. Surv., v. 5, p. 64.

Rhipidomella dubia, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 160-161, pl. 20, fig. 22-26; pl. 83, fig. 9-10.

Perditocardinia dubia, Cooper, G. A., 1944, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 355, Pl. 139, fig. 30^o-34.

Description. Shell slightly wider than long; the greatest width posterior to the mid-length of the valve. Shell outline subovate. The anterolateral margins are round; anterior margins continue as a semicircle with the anterolateral margins. Posterolateral margins are straight, meeting at the beak at an angle of about 90 degrees.

The dimensions of seven individuals from the lower Meramec of the Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona, are:

Specimen	Both valves present		
	Length	Width	Thickness
1.	13.0	12.5	6.5
2.	12.0	12.0	6.5
3.	13.0	13.0	7.0
4.	9.0	8.0	4.0

Specimen	Pedicle valve only		
	Length	Width	Thickness
5.	19.0	20.5	
6.	14.0	14.0	
7.	10.5	11.0	

Pedicle valve convex; greatest convexity posterior to the middle. A faint sinus begins on umbo and continues to the anterior margin.

Brachial valve more convex than pedicle, greatest convexity posterior to the middle. Surface curves abruptly to the cardinal area, much less to the lateral and anterior margins. The beak is incurved beneath that of the opposite valve.

Fold generally obsolete, but on some specimens observable at the anterior margin. Surface of shell has lamellose extensions divided into flattened spines, 3 occupying the space of mm.

Horizons. *Syringothyris subcuspidatus* zone of the Hachita formation (lower Meramec) in the Chiricahua Mountains of Arizona and the Big Hatchet Mountains of New Mexico. J. Thomas Duto (personal communication, 1961) reported that a form which might be *P. dubia* occurs in the upper part of the Mississippian in some localities in Arizona in McKee's member D of the Redwall limestone and in the Meramec, Black Prince limestone in the Little Dragoon Mountains.

Suborder **CHONETOIDEA** Muir-Wood, 1955
Superfamily **CHONETACEA** Shrock and Twenhofel, 1953

Family **CHONETIDAE** Hall and Clarke, 1895
Genus **CHONETES** de Koninck, 1842

Type *Species.* (Subsequent designation, de Verneuil, 1845, p. 238): *T erebratulites sarcinulatus* Schlotheim, 1820 (Die Petrefactenkunde, pl. 29, fig. 3a, 3b). Lower and middle Devonian, Harz Mountains, Germany (*vide* Campbell, 1957).

Range. *Chonetes* auct. Silurian—Permian.

Chonetes klondikia n. sp.

Pl. 6, fig. 1-7

Diagnosis. Greatest width along hinge line, in outline anterolateral and anterior margins form a semicircle. Pedicle valve with faint median sinus. Shell surface marked

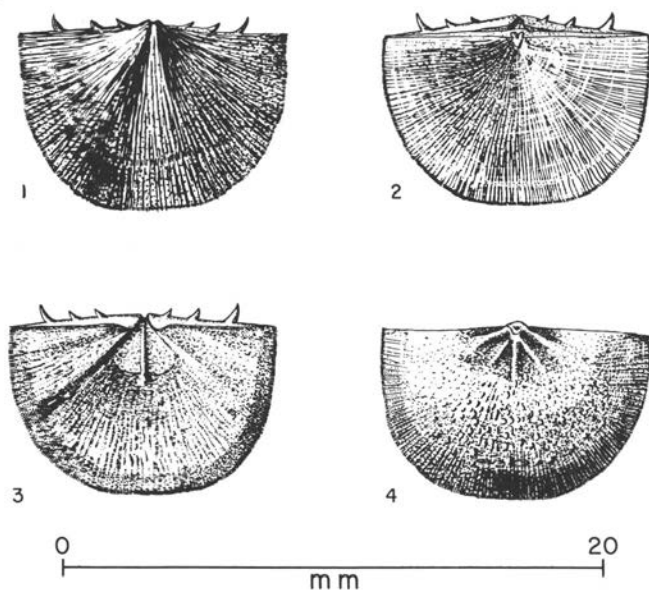


Figure 24

INKED DRAWINGS OF *Chonetes klondikia*; 1, pedicle valve exterior, 2, brachial valve exterior, 3, pedicle valve interior, 4, brachial valve interior

by 110-130 fine radiating costae (fig. 24). Pedicle valve has large teeth, median septum one-third length of valve. Brachial valve has low cardinal process with short socket plates and a faint median septum.

Description. The greatest width (fig. 24) is along the hinge

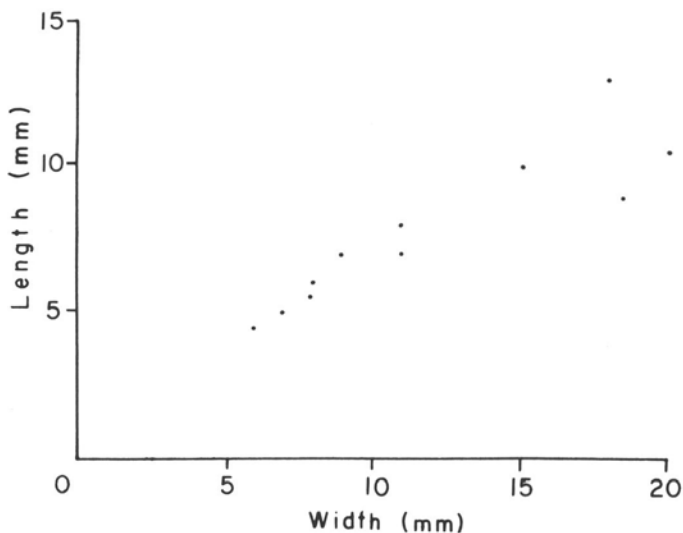


Figure 25

SCATTER PLOT OF *Chonetes klondikia* LENGTH:WIDTH RATIO

line. The outline of the anterior and anterolateral margins is a half circle. The anterior margin of the shell meets the hinge line at an angle of 90 degrees. The beak is very small and slightly incurved. A faint and ill-defined median sinus is present from the umbo to the anterior margin, where it is broad and shallow. Three to four spines are present along the cardinal margin on both sides of the umbo. The surface of the shell is marked by 110-130 fine costae, which become very indistinct on the cardinal extremities. Most of the costae arise by bifurcation upon or near the umbo. The cardinal area is moderately high and shaped like an elongate triangle. Deltidium and pseudodeltidium were not preserved on the material studied.

The brachial valve has an outline and costae similar to the opposite valve and is slightly concave; the cardinal extremities are flattened. The cardinal area is very narrow.

The pedicle valve has large teeth and a low, narrow median septum, which extends about one-third the length of the valve. The most anterior portions of the pedicle valve blend imperceptibly into the contour of the shell. The adductor scars are lobate, smooth areas on either side of the posterior half of the median septum. The shape is rather poorly defined. The adductor scars were almost imperceptible on the material preserved. The anterior and lateral surfaces appear to be papillose, or are the reflections of pseudopunctae.

The brachial valve has a low cardinal process with two low, short, socket plates. A very low and faint median septum is present behind the cardinal process, which extends 3 mm to 5 mm anteriorly. The whole surface except for the cardinal extremities is papillose.

Remarks. *Chonetes klondikia* is similar externally to smaller examples of *Chonetes hardrensis* Phillips from the lower Carboniferous of England in the number of costae and the shell outline. *C. hardrensis* as described by Davidson (1858, p. 186) lacks the sinus on the pedicle valve which is characteristic of

C. klondikia. *Chonetes illinoisensis* Worthen from the Burlington limestone shows a close relationship except for its much more rounded cardinal extremities and the greater number of costae (175-225). *Chonetes klondikia* is distinguished from Hall and Whitfield (1877, p. 253-254) *Chonetes loganensis*, from the Mississippian of the Wasatch Range, Utah, which appears by their description and illustration to have finer and more numerous costae. Snider's (1915, p. 76, pl. 3, fig. 2-15) *Chonetes oklabomensis* from the Fayetteville and Pitkins formations of Oklahoma differs from *C. klondikia* in that its pedicle valves are more convex and that it has no sinus. The species which shows the greatest similarity to *C. klondikia* is Campbell's (1957, p. 63, pl. 2, fig. 21-26) *Chonetes careyi* from the upper Tournaisian of New South Wales. *C. careyi* has a slightly wider shell and a better developed and longer median septum in the brachial valve than does *C. klondikia*.

Horizon. The species is present in the Klondike Hills and Big Hatchet Mountains of New Mexico, and in Blue Mountain, Chiricahua Mountains, of Arizona in the upper half of member B of the Keating formation.

Chonetes aff. *C. glenparkensis* Weller

Pl. 6, fig. 17

Chonetes glenparkensis, Weller, S., 1906, St. Louis Acad. Sci. Trans., v. 16, p. 441-442.

Chonetes glenparkensis, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 87-89, pl. 8, fig. 30, 47-49.

Chonetes glenparkensis, 1938, Branson, E. B., Missouri Univ. Studies, v. 8, p. 29-30, pl. I, fig. 22-24.

Description. The material available for study consisted of one incomplete, exfoliated exterior of a pedicle valve. The outline of the shell is semielliptical, the length shorter than the width, cardinal extremities slightly mucronated. Shell convex, greatest convexity posterior to the middle. The strongest curvature is in the middle, the ears are flat. Beak is very small, sinus very weak, indicated by flattening from umbo to anterior margin.

Surface of shell is marked by 34 costae, which become weaker and then almost imperceptible on the cardinal extremities. Internal structures were not observed.

Remarks. The poor preservation of a single valve makes specific and even generic identification somewhat hazardous. The size and shape, strong curvature of the umbo and related region, mucronated nature of the cardinal extremities, and coarse plication are all diagnostic characteristics of *C. glenparkensis*.

Horizon. Coral zone, member A, Keating formation (lower Osage), at the south end of Blue Mountain, Chiricahua Mountains, Arizona.

Suborder **SPIRIFEROIDEA** Allen, 1940, emend;
Muir-Wood, 1955

Superfamily **SPIRIFERACEA** Waagen, 1883

Family **SPIRIFERIDAE** King, 1846

Subfamily **SPIRIFERINAE** Schuchert, 1913

Genus **SPIRIFER** Sowerby, 1816, emend

Spirifer, Sowerby, J., 1816, The mineral conchology of Great Britain, London, v. 2, p. 41 (*vide* Holland, 1958).

Spirifer, King, W., 1850 (pars) Palaeont. Soc., Permian fossils of England, p. 25.

Spirifer, Davidson, T., 1851 (pars) Palaeont. Soc., British fossil brachiopods, v. I, p. 79-80.

Spirifer, Hall, J., and Clarke, J. M., 1899 (pars) New York Nat. Hist. Paleont., v. 8, pt. 2, p. 1-90.

Spirifer, Weller, S., 1919 (pars) Illinois Geol. Surv. Mon. 1, p. 307-308.

Spirifer, Chao, Y. T., 1929 (pars) Palaeontologica Sinica, ser. B., v. II, fasc. 1, p. 5.

Spirifer, Ozaki, K., 1931 (pars) Upper Carboniferous Brachiopods from North China, p. 24.

Spirifer, Dunbar, C. O., and Condra, G. E., 1932 (pars) Nebraska Geol. Surv. Bull. 5, p. 317.

Spirifer, Maxwell, W. G. H., 1954 (pars) Queensl. Univ., Dept. Geol., v. 4, n. 5, p. 48.

Spirifer, Dunbar, C. O., 1955, Meddel. om Grønland, bd. 110, nr. 3, p. 131.

Spirifer, Dresser, H., 1954 (pars) Am. Paleont. Bull., v. 35, n. 149, p. 52-53.

Spirifer, Cvancara, A. M., 1958 (pars) Jour. Paleont., v. 32, p. 873•

Diagnosis. Spiriferoid shell, subequally biconvex, hinge line shorter than greatest width of the shell. Shell usually wider than long. Plications numerous on fold and sinus, and the lateral slopes. Plications generally simple, may occasionally bifurcate, but never fasciculate. Internally the pedicle valve is characterized by a median septum and by short, thick dental lamellae which are confined to the rostral area at the shell. In the brachial valve the socket plates are not supported by plates reaching to the floor of the valve. The descending lamellae are developed from the socket plates.

Type *Species*. (By suspension of the rules by The International Commission on Zoological Nomenclature, Opinion 100

) *Conchyliolithus Anomites striates* Martin, W., 1793, "Figures and Descriptions of Petrifactors Collected in Derbyshire," pl. 23, fig. 1, 2; and Martin W., 1809, "Petrificata Derbiensia," pl. 23, fig. 1, 2 (*vide* Cvancara, 1958, p. 873). Lower Mississippian.

Range. Mississippian-Lower Pennsylvanian.

Remarks. Most of the confusion about the generic characteristics of *Spirifer* s. s. has arisen out of the fact that Martin's type specimen is lost. Campbell (1957, p. 67) has shown that the Copenhagen Congress of the Commission on Zoological Nomenclature has ruled that when a neotype of a species is chosen, it must be a specimen similar to the one which Martin figured, having a hinge line shorter than the maximum width of the valve, a multicostate fold and sinus, and a triangular area.

The genus *Spirifer* was considered by the authors listed in the synonymy to include forms with a hinge line both shorter than and as wide as the greatest width of the shell. As has been cited, Campbell (1957) has conclusively shown that the genus must include only those forms with a hinge line shorter than the greatest width of the shell.

The genus *Spirifer* s. s. as interpreted in this study would include such standard American species as *S. ronleyi* Weller, *S. grimes* Hall, *S. logani* Hall, *S. gregeri* Weller, *S. keokuk* Hall, and *S. bifurcatus* Hall.

Holland (1958, p. 214) observed that it is difficult if not impossible to distinguish, on external characters, because of the close similarity and gradation of forms, the genera *Cyrtospirifer* Nalivkin and *Spirifer* s. s. Holland further believed "neither can distinction be easily made on the basis of internal structures for it is a matter of degree or of gradation from

upper Devonian and lower Mississippian cyrtospiriferoids to lower Mississippian spiriferoids."

Holland (1958, p. 216) stated in general "that *Spirifer* s. s. differs from *Cyrtospirifer* in possessing fewer and generally stronger plications, lesser extent of the transverse subdelthyrial plate, dental plates confined to the rostral area, and common presence of a median septum in the pedicle valve." Nalivkin (1930, p. 196) emphasized the presence of a transverse delthyrial plate in the apex of the pedicle valve as a prominent feature of *Cyrtospirifer*. It is interesting to note that Sanders (in Easton et al., 1958, p. 55) found on a Mississippian spiriferoid, *Spirifer latior* Swallow, from the Represo limestone of northwestern Sonora, Mexico, transverse delthyrial plates. On the evidence of these plates, Sanders assigned *S. latior*, a Chouteau-age spiriferoid, to the genus *Cyrtospirifer*.

Neospirifer Fredericks is characterized by fasciculate plications and is distinguished by this trait from *Spirifer* s. s. *Spirifer* s. s. is, as in the case of *Neospirifer*, distinguished from *Unispirifer* Campbell on external characteristics. *Unispirifer* has a hinge line which is as long as the maximum width of the shell and is frequently mucronate. The sinus has relatively few plications. *Brachythyris* McCoy is very distinctive, with its very short hinge line, and with plications which are broad and flat on the lateral slopes and weakly developed or absent on the fold and sinus.

Spirifer cf. *S. gregeri* Weller

Pl. 7, fig. 22-23

Spirifer gregeri, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 359, pl. 55, fig. 1-8.

Spirifer gregeri, Branson, E. B., 1938, Missouri Univ. Studies, v. 8, p. 59, pl. 7, fig. 1-3, 15, 16.

Spirifer esplanadensis, Brown, R. A. C., 1952, Canada Geol. Surv. Mem. 264, p. 97, pl. 5, fig. 1a-1e.

Diagnosis. Shell wider than long, pedicle valve subhemispherical in shape, sinus ill-defined; 32. rounded, bifurcating plications on each lateral slope.

Description. Shell slightly wider than long, greatest width anterior to the hinge line. The dimensions of the pedicle valve are: length 44 mm, width 45 mm, height 21 mm. Pedicle valve is subhemispherical, with greatest thickness near the middle. Surface of shell curves abruptly to the anterior and anterolateral margins, strongly curved toward the cardinal area. Beak is of medium size and strongly incurved. Cardinal area is 5 mm high, concave, with curvature strongest toward beak, delthyrium an equilateral triangle. Sinus begins on umbo as an ill-defined, shallow depression, becoming wider, rounded on the bottom, but still ill-defined anteriorly. Sinus contains from 10 to 12 plications. Each lateral slope marked by about 32 rounded plications, which become more indistinct on the lateral extremities. The plications tend to bifurcate most frequently on, or anterior to, the umbonal region.

Horizon. Specimen was collected about 70 feet above the Devonian Portal formation, in the coral zone, member A, Keating formation (lower Osage), Escabrosa group; south end of Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. This species is represented by an exfoliated and broken pedicle valve. Although this is a very incomplete individual, its rotund form and the nature and size of the plications are characteristic of *S. gregeri*. Brown (1952, p. 97-98, pl. 5, fig. 1a-1e) described a new species, *Spirifer esplanadensis*, from the Banff formation of Alberta. According to Brown, the major differences between his species and *S. gregeri* are

that the former has valves which are more subequally convex and a narrower fold. It is believed that differences in *S. esplanadensis* are not of specific rank and that it should be considered at best a geographic subspecies of *S. gregeri*.

Spirifer bifurcatus Hall

Pl. 7, fig. 24-27

Spirifer bifurcatus, Hall, J., 1856, Albany Inst. Trans., v. 4, p. 8.

Spirifer leidy var. *Merimacensis*, Swallow, G. C., 1866, St. Louis Acad. Trans., p. 47, pl. 6, fig. 13-15.

Spirifer bifurcatus, Whitfield, R. P., 1882, Am. Mus. Nat. Hist. Bull. I, p. 47, pl. 6, fig. 13-14.

Spirifer bifurcatus, Hall, J., 1883, Indiana Geol. Surv. 2th Rept., p. 326, pl. 29, fig. 13-16.

Spirifer bifurcatus, Beede, J. W., 1906, Indiana Geol. Surv. 3oth Rept., p. 1314, pl. 22, fig. 13-15.

Spirifer bifurcatus, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 346-347, pl. 47, fig. 6-16.

Diagnosis. Spiriferoid; slightly wider than long, each lateral slope marked by 6 to 7 strong, angular, simple plications, sinus strongly developed with a median plication, fold pronounced, with strong bounding furrows and a weak median furrow.

Description. Shell is slightly wider than long, with the greatest width just anterior to the cardinal area. Cardinal extremities slightly rounded. The dimensions of one incomplete individual are width 21 mm, length 18 mm, thickness 11 mm.

The pedicle valve has its greatest convexity posterior to the middle, surface sloping abruptly from the umbonal region to the cardinal margins and more gently to the anterolateral margins. Beak pointed and incurved. Sinus pronounced on beak, widening and deepening anteriorly, median plication present but weakly developed, and possibly showing a slight tendency to bifurcate near anterior margin. Each lateral slope marked by 6 to 7 strong, angular, simple plications which become progressively weaker towards the cardinal extremities.

Brachial valve with its greatest convexity posterior to the middle, cardinal extremities slightly compressed. Fold defined on the beak, slightly raised above the surface of the shells. Bounding furrows of the fold are deeper and more pronounced than furrows on lateral slopes. Median furrow on fold is weakly developed. Lateral slopes have plications similar to those at the opposite valve. Internal structures were not preserved in any of the material studied.

Horizon. Abundant as fragments in the *Syringothyris subcuspidatus* zone, Hachita formation at Blue Mountain, Chiricahua Mountains, Arizona, and the Animas and Big Hatchet Mountains of New Mexico.

Remarks. Because of the nature of preservation, the Hachita formation examples of *S. bifurcatus* are difficult to compare in an exact or detailed manner with described specimens from the Midcontinent region. The limestone horizons from which the Hachita examples have come are generally recrystallized (see petrographic photomicrograph, pl. I I, fig. 3). Furthermore, all of the specimens are exfoliated and are represented by broken valves.

The Hachita *S. bifurcatus* does agree very well with described Midcontinent material in size, contour, or number and nature of the plications on the lateral slopes. The Hachita specimens differ in having a weakly-developed median plication in the sinus, weakly-developed furrows bounding the

fold, and a brachial valve which appears to be less convex than in the Midcontinent specimens. The exact extent of these differences cannot be accurately ascertained because of the poor state of preservation of the specimens.

In general, the material studied from the Hachita formation is, in the opinion of the writer, clearly conspecific with *S. bifurcatus* from the Salem and Warsaw limestones of the Midcontinent region.

Genus UNISPIRIFER Campbell, 1957

Unispirifer, Campbell, K. S. W., 1957, Jour. Paleont., v. 31, p. 67-68.

Diagnosis. (After Campbell, 1957.) This genus is erected to include Spiriferidae in which the hinge line is elongate and the cardinal extremities frequently mucronate during part or whole of the ontogeny. The lateral slopes bear costae, the greatest number of which are simple but some of which divide. In the sinus the costae are relatively few, consisting of a median, which may be simple or bifurcating, flanked by the primaries which arise at the umbo. Only the median and primary costae originate on the umbo, and none is intercalated between the primary and median costae. The surface is finely striate.

Internally the pedicle valve is thickened in the umbo, and the free portion of the dental lamellae is short and wedge shaped; but in some cases the dental lamellae may be completely embedded in the umbonal thickening. The inner margins of the socket plates are carinate, and they are not supported by plates reaching to the floor of the valve. The descending lamellae are developed from the socket plates.

Type Species. (Original designation) *Spirifer striatoconvoluta*, Benson, W. N., and Dun, W. S., 1920, New South Wales Linn. Soc. Proc., v. 45, n. 179, p. 350, pl. 20, fig. 7, 8. Middle and upper parts of the Burindi group (middle and upper Tournaisian), New South Wales, Australia.

Range. Campbell (1957) stated the genus was Tournaisian of Eurasia and Australia and also Kinderhook and Osage of North America. The writer considers *Spirifer lateralis* Hall, from the Warsaw and Salem (lower Meramec), to be also a member of the genus *Unispirifer*.

Remarks. Campbell (1957, p. 67-68) distinguished *Unispirifer* from *Cyrtospirifer* Nalivkin and *Sinospirifer* Tien on the nature of the sinal plications. In the *Cyrtospirifer-Sinospirifer* species group and sinal costae are always numerous, 7 or more in the adult; and in most species 2 or more pairs of costae originate on the umbo, and a median plication may or may not be present. The costae on the lateral slopes are almost always simple, whereas in *Unispirifer* they may occasionally bifurcate. The cardinal area of *Unispirifer* is crossed by deep, irregular grooves which are never present on specimens of *Cyrtospirifer*. The cardinal area on the latter is ornamented by fine regular striae.

Nalivkin's (1930, p. 157) genus *Imbrexia*, with *Spirifer imbrex* Hall as genotype, is similar to *Unispirifer* in general form and costation. *Imbrexia* is differentiated by its lamellose and non-striate surface.

Austrospirifer Glenister (1955) is distinguished from *Unispirifer* by its simple lateral plications, by the absence of dentide grooves on the cardinal area of the pedicle valve, and by its peculiar globose dental sockets.

Spirifer s. s. is distinguished from *Unispirifer* by a hinge line which is shorter than the greatest width of the valve, a multiplicate sinus and fold and a triangular area. *Brachy*

thyris McCoy, in marked contrast to *Unispirifer*, has a very short hinge line, tends to be as wide as long or frequently longer than wide, and has broad flat plications on the lateral slopes. Plications on the fold and sinus may be weakly developed or absent.

Within the Osage part of the Escabrosa group the following species of *Unispirifer* are recognized: *U. balki* n. sp. and *U. vernonensis* (Swallow). The lower Meramec strata contain *U. lateralis* (Hall).

Unispirifer balki n. sp.

Pl. 7, fig. 5-2

Diagnosis. Mucronate spiriferoid, greatest width along the hinge line, median plication in sinus, with 1 or 2 bounding plications, fold with 2 or 4 plications, 18 to 23 simple plications on each lateral slope.

Description. Shell (fig. 26) below medium size, broadly

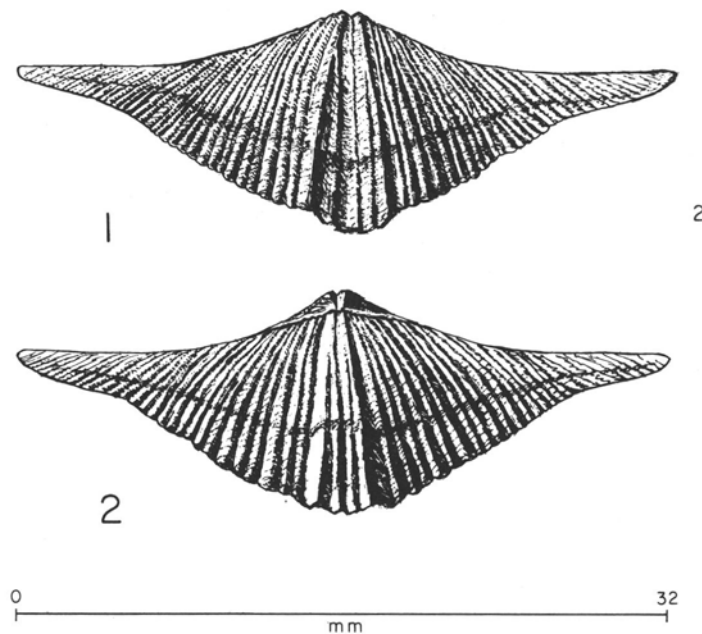


Figure 26

INKED DRAWING OF *Unispirifer balki*; 1, pedicle valve, 2, brachial valve

subtriangular in outline; greatest width along the hinge line; well-preserved specimens mucronated. The dimensions in mm of three disassociated valves are:

		Length	Width	Thickness
Pedicle	1.	11.5	32.0	6.0
	2.	14.0	32.0	6.5
Brachial	3.	13.0	30.0	6.0

Pedicle valve convex with greatest convexity posterior to the middle. The surface of the umbo curves abruptly to the cardinal margin. Surface of the shell is progressively flattened toward the cardinal extremities. Beak is large and incurved. Cardinal area is concave and of moderate height, delthyrium opening an equilateral triangle. Sinus present at beak, shallow, becomes wider but ill defined anteriorly. Median plication present at apex of beak and not bifurcate in its course to the anterior margin. Each lateral slope of the sinus has 1 to 2 plications which arise at or near the umbo by bifurcation from

the bounding plications. Lateral slopes of the valve marked by 18 to 23 simple, rounded plications which become fainter toward the cardinal extremities. Occasionally the first plication on the lateral slope originates on the umbo from one of the bounding plications of the sinus.

Brachial valve is less convex than pedicle. Umbo region and beak small. Fold defined at apex of beak by two furrows, which are deeper than those of lateral slopes. Fold begins as a slightly raised plication, which bifurcates on the umbo, giving rise to 2 or 4 plications at the anterior margin. Fold is only slightly higher than the shell surface. Plication similar to those of the opposite valve.

Horizon. *U. balki* is the most common brachiopod in the coral zone of member A, Keating formation (lower Osage), Escabrosa group, in its area of outcrop from the Chiricahua Mountains, Arizona, eastward to the Klondike Hills, New Mexico. It is also present in the Andrecito member of the Lake Valley formation in the Cooks Range area.

Remarks. *U. balki* is closely related to *Unispirifer platynotus* (Weller). It differs (fig. 27) from the latter in possessing

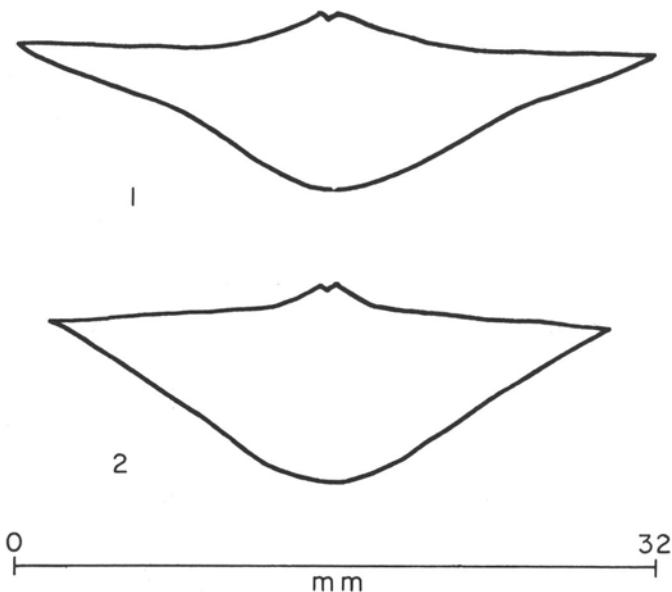


Figure 27
OUTLINE DRAWINGS OF 1, *Unispirifer balki*, AND
2, *U. platynotus*

an umbo and a beak which is much larger and more pronounced. *U. balki* at all stages of growth has pronounced, mucronate cardinal extremities, which tend to be longer and much more narrow than those in typical examples of *U. platynotus*. In *U. balki* the anterior lateral margins have a concave outline, whereas in *U. platynotus* they tend to be rectilinear or slightly convex.

Unispirifer vernonensis (Swallow)

Pl. 7, fig. 1-4

Spirifer vernonensis, Swallow, G. C., 1860, St. Louis Acad. Sci. Trans., v. 1, p. 644.

Spirifer vernonensis, Winchell, A., 1865, Phila. Acad. Nat. Sci. Proc., V. 17, p. 119.

Spirifer vernonensis, Weller, S., 1909, Am. Geol. Soc. Bull., V. 20, p. 310, pl. 37, fig. 3-8.

Spirifer vernonensis, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 310, pl. 37, fig. 8-17.

Spirifer vernonensis, Branson, E. B., 1938, Missouri Univ. Studies, v. 13, pt. 1, p. 64-65, pl. 7, fig. 8-10.

Diagnosis. Spiriferoid semicircular to subtriangular, shell wider than long, greatest width at hinge line, mucronate; in the sinus 6 to 8 plications present and a continuous median plication, 8 plications on the folds, 16 to 18 simple plications on each lateral slope.

Description. Shell is of medium size, subsemicircular to subtriangular in outline. Width is 41 mm, length 28 mm, thickness 19 mm. The greatest width is at the hinge line. The cardinal extremities in well-preserved specimens show a mucronate condition.

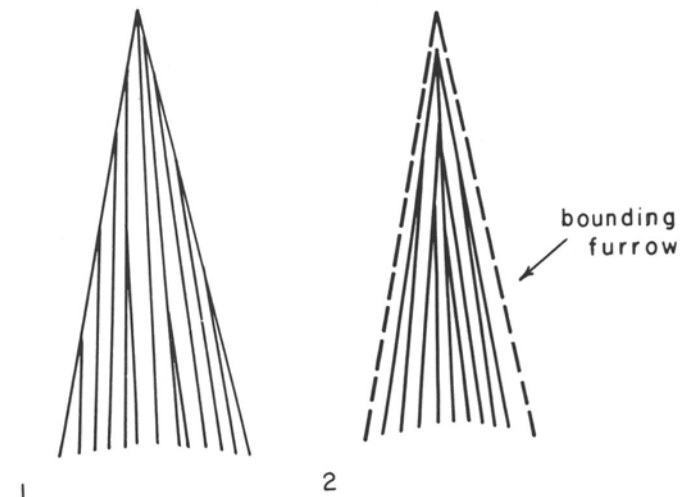


Figure 28

PLICATIONS ON *Unispirifer vernonensis*; 1, pattern on pedicle sinus, 2, pattern on brachial fold

The pedicle valve is strongly convex, but becomes slightly compressed near the cardinal extremities. The umbo region is prominent. The beak is strongly incurved, and the cardinal area is of moderate height and arched towards the beak. The curvature of the pedicle valve is smooth from the anterior margin to the middle of the shell. There is a series of growth lamellae on the anterior margin of the shell, which lamellae become more numerous and pronounced toward the line of commissure. The outline of the anterior and lateral margins of the shell is a semicircle, which meets the cardinal area at an angle of about 90 degrees. The cardinal margin slopes at a very low angle to the cardinal extremities. Each lateral slope is marked by 16 or 18 simple, rounded plications, which become progressively fainter toward the cardinal extremities.

The sinus begins as a sharp depression at the apex of the beak, widens rapidly anteriorly, causing a wide, round depression, which in turn produces a linguloid extension at the anterior margin. The sinus is marked at the apex of the beak by a simple, median plication which extends to the anterior margin of the shell without bifurcation. Each half of the sinus at the anterior margin contains 3 to 4 plications, which arise from the bounding plications by bifurcation (fig. 28).

The brachial valve is almost as convex as the pedicle valve, with the greatest convexity anterior to the middle. The cardinal margin has a very slight deflection toward the cardinal extremities. The beak is very small. The fold originates as a small elevation on the beak, and rises and broadens anteriorly.

The median plication develops on the beak, progressively bifurcating until at the anterior margin 6 to 8 plications are present. The bounding furrows of the fold are slightly deeper than those on the lateral slope. Each lateral slope has 17 to 19 simple plications.

The interior (fig. 29) of the pedicle valve is thickened in the umbonal region. The dental lamellae are present in the posterior region at first as a stout "V" imbedded in thickened umbonal material. The dental lamellae are anteriorly free and anklose, and are present for approximately one-fourth the length of the valve.

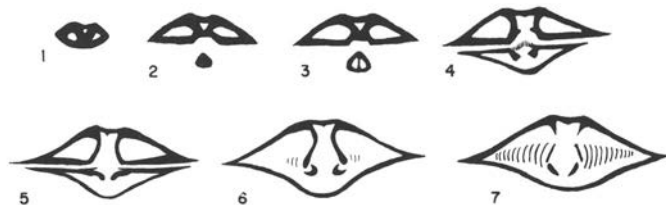


Figure 29

SERIAL SECTIONS OF *Unispirifer vernonensis*

The brachial valve has long dental sockets which reach into the umbo. The inner edge of each socket is thickened and anteriorly develops into a crus which is attached to the descending lamellae of a spire. Each spire appears to have 2 to 15 volutions, which are directed toward the cardinal extremities. The cardinal process in the umbonal region is divided into about 20 vertical plates.

Horizon. This spirifer is the most common brachiopod in the lower half (lower Osage) of member B, Keating formation, Escabrosa group. It is present from the Dragoon Mountains, Arizona, eastward to the Klondike Hills in New Mexico.

Remarks. The examples of this species collected from the Escabrosa formation are conspecific with Weller's (1914, pl. 37, fig. 8-17) examples of *S. vernonensis* from the Fern Glen formation of Missouri. The Escabrosa forms differ in that the anterior margins have a slightly more rounded outline, are not so broad, and have a wider and more rounded sinus. They agree closely with the forms from Missouri in general overall contour, in lateral plications, and particularly in the type and number of plications on the fold and sinus.

It is likely that many of the *Spirifer centronatus* s. I. reported in the literature on the Escabrosa group may belong to this species. *Spirifer centronatus* Winchell s. s. differs from *Unispirifer vernonensis* in having fewer and coarser lateral plications, fewer plications on the sinus and fold, a larger linear cardinal area, a shallower fold, and a less-pronounced linguloid extension.

Unispirifer lateralis (Hall)

Pl. 7, fig. 13-17

Spirifer lateralis, Hall, J., 1858, Iowa Geol., v. 1, pt. 2, p. 661, pl. 23, fig. 7a-7c.

Spirifer lateralis, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 330-331, pl. 43, fig. 11-15.

Spirifer lateralis, Cooper, G. A., 1944, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 325, pl. 24, fig. 1-5.

Diagnosis. Spiriferoid, greatest width at hinge line, sinus with simple median plication bounded by 2 to 4 plications

which arise by bifurcation; 24 to 29 plications on each lateral slope; brachial valve marked by abrupt, high, angular fold.

Description. Shell is of medium size, much wider than long, with the greatest width along the hinge line. The dimensions of one disassociated but mature specimen are: width 42 mm, length 14 mm, height 10 mm.

Pedicle valve has its greatest convexity posterior to the middle. Umbonal region is broad and not pronounced; beak is small and incurved. Lateral margins are compressed.

Sinus appears at the apex of the beak as a faint, shallow depression, widening anteriorly but remaining shallow and ill defined. A simple median plication is present in the sinus from the umbonal region to the anterior commissure. On each side of the sinus 2 to 4 plications arise by bifurcation from the bounding plications. Each lateral slope is marked by 24 to 29 simple, rather fine plications, which become progressively more indistinct on approaching the cardinal extremities.

Brachial valve slightly less convex than pedicle, greatest convexity posterior to the middle. Lateral slopes and cardinal extremities somewhat compressed, except near the cardinal area, where marked curvature occurs. Beak small and incurved. Fold originates abruptly at beak, becoming highly elevated, angular, and widening anteriorly. Lateral margins of beak are obscure and curve gently into the lateral slope. The anterior margin of the fold is marked by 54 to 18 plications, which arise by successive bifurcation from the median plication. Plications on the lateral slopes are similar to those of the opposite valve.

The cardinal area, delthyrium, and internal structure were not preserved in any of the material collected.

Horizon. *U. lateralis* is present in the *Syringothyris subcuspidatus* zone near the top of the Hachita formation at Blue Mountain, Chiricahua Mountains, Arizona, and at the same zone in the Big Hatchet Mountains, New Mexico.

Genus **IMBREXIA** Nalivkin, 1937

Imbrexia, Nalivkin, A. V., 1937, Trans. Cent. Geol. Prosp. Inst., U.S.S.R., v. 99, p. 157.

Type *Species.* (Original designation) *Spirifer imbrex*, Hall, J., 1853, Iowa Geol. Surv., v. 1, pt. 2, p. 601, pl. 13, fig. 2. Burlington limestone, Osage, Iowa.

Remarks. *Imbrexia* is similar in all respects to *Unispirifer* Campbell except for its surface ornamentation. *Unispirifer* is characterized by a finely striated surface, and *Imbrexia* has ornamentation which is lamellose and non-striate.

Imbrexia forbesi (Norwood and Pratten)

Pl. 7, fig. 18-2,

Spirifer forbesi, Norwood, F. G., and Pratten, H., 1855, Phila. Acad. Nat. Sci. Jour., v. 2, p. 73, pl. 9, fig. 3a-c.

Spirifer forbesi, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 600, pl. 13, fig.

Spirifer forbesi, Keyes, R. R., 1894, Missouri Geol. Surv., v. 5, p. 80, pl. 40, fig. 3.

Spirifer forbesi, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 37, fig. 18.

Spirifer forbesi, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 331-333, pl. 42, fig. 1-3; pl. 43, fig. 16; pl. 83, fig. 1, 2.

Diagnosis. Spiriferoid shell, much wider than long, greatest width along the hinge line, sinus with median plication and 2 or 3 lateral plications, fold with 4 to 7 plications; each lateral slope has 22 to 30 simple plications. Surface of shell lamellose.

Description. Shell of medium size, very much wider than long, greatest width along the hinge line.

Pedicle valve strongly convex, but becomes flattened progressively toward the cardinal extremities. The umbo is pronounced, beak small and incurved.

Sinus begins at apex of beak, is rather weakly defined, becoming wider anteriorly, but is shallow with a flat surface. A median plication (fig. 30) arises in the sinus at the apex of the beak, and continues without division to the anterior margin. The sinus may contain 2 or 3 lateral plications, which arise by bifurcation from the bounding plications. Each lateral slope of the valve has 22 to 30 simple, rounded plications, which become progressively fainter toward the cardinal extremities.

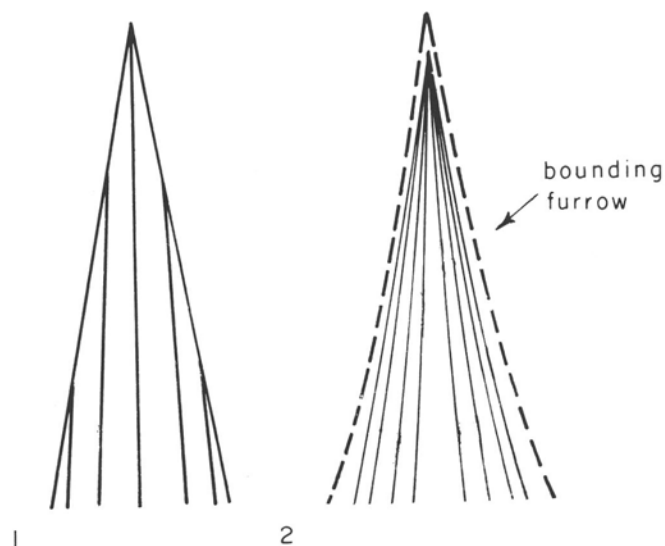


Figure 30

PLICATIONS ON *Imbrexia forbesi*; 1, pattern on pedicle sinus, 2, pattern on brachial fold

Brachial valve is equal to or slightly less convex than pedicle. Surface of valve curves rather abruptly to the cardinal margins. Curvature becomes rapidly and progressively weaker toward the cardinal extremities. The umbo is extended into a rather broad beak, which is incurved. The fold begins at the apex of the beak as an elevated plication, rapidly widening anteriorly. The median plication of the sinus bifurcates on the beak, giving rise to 2 or 3 lateral plications. The bounding furrows to the fold are broader and deeper than those on each lateral slope. About 22 to 28 plications are present on each lateral slope. Surface of the shell is lamellose and non-striate.

Horizon. *I. forbesi* is found in the upper half of member B, Keating formation. At this horizon this species is by far the most abundant brachiopod, occurring at times in large numbers as broken and disassociated valves. It is common in the Klondike Hills, Big Hatchet, Animas, and Peloncillo Mountains of New Mexico, and the Chiricahua and Dragon Mountains of Arizona.

Remarks. Campbell (1957, p. 68) considered *I. forbesi* as a typical American representative of his genus *Unispirifer*. The lamellose surface ornamentation clearly indicates this species belongs to *Imbrexia* Nalivkin.

The Escabrosa forms compare very well with the described Midcontinent examples, except that in the southwestern pop-

ulation the sinus appears to be more shallow and less distinct. This species, which is one of the most conspicuous brachiopods in the upper horizons of member B, Keating formation, has been reported as a diagnostic fossil of Burlington age in the Rundlian series of Alberta (Harker and Raasch, 1958, p. 223, 224). *I. forbesi* in the Cordilleran region may prove to be an excellent index fossil to strata of Burlington age.

J. T. Dutro (personal communication, 1961) considers this species to be widespread in the lower Mississippian of New Mexico and Arizona.

Genus **TYLOTHYRIS** North, 1920

Tylothyris, North, F. J., 1920, Quart. Jour. Geol. Soc. London, V. 76, p. 197.

Tylothyris, Cvcancara, A. M., 1958, Jour. Paleont., v. 32, p. 876.

Type *Species.* (Original designation) *Cyrta laininosa* McCoy emend, North, 1844, Synopsis of the Carboniferous fossils of Ireland, p. 137, pl. 21, fig. 4. Lower *Canina* zone, Tournaisian, Mitcheldean district, England.

Range. In North America the genus ranges in age from upper Devonian through the Osage. In Europe and Australia, through the lower Carboniferous.

Tylothyris cf. *T. novamexicana* (Miller)

Pl. 6, fig. 26

Spirifer novamexicana, Miller, S. A., 1881, Cincinnati Soc. Nat. Hist. Jour., v. 4, p. 314, pl. 7, fig. 10-oB.

Spirifer magnicostatus, Weller, S., 1909, Geol. Soc. Am. Bull., V. 20, p. 307, pl. 13, fig. 2-15.

Delthyris novamexicana, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 304, 305, pl. 36, fig. 15-24.

Delthyris novamexicana, Croneis, C., 1930, Arkansas Geol. Surv. Bull. 3, pl. II, fig. 21-23.

Delthyris novamexicana, Branson, E. B., 1938, Missouri Univ. Studies, v. 13, p. 58-59, pl. 6, fig. 8-10.

Description. The only example of this species found is a poorly preserved, exfoliated, brachial valve. The shell is much broader than long; greatest width is along the hinge line. The dimensions of the valve are: width 14 mm, length 5 mm; thickness at the brachial valve is 3.5 mm. Greatest convexity of the valve is posterior to the middle. The surface of the valve is compressed toward the cardinal extremities. Beak is small, incurved. Fold begins on beak, widens and is elevated above the surface of shell at the posterior margin. Four clearly defined, rounded plications and furrows are present on each lateral slope and they become weaker towards lateral extremities. The shell structure is impunctate.

Horizon. Coral zone, member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. Although only the exterior of the pedicle valve is represented, the genus can be determined by the nature of the fold and plications and the impunctate shell structure. The shape of the shell and plications are clearly diagnostic of the species *T. novamexicana*. The specimen from member A, Keating formation, compares in all respects to individuals from the Nunn member, Lake Valley formation.

Subfamily BRACHYTHYRINAE Fredericks, 1924

Genus **BRACHYTHYRIS** McCoy, 1844

Brachythyris, McCoy, R., 1844, Synopsis of the characters of the Carboniferous fossils of Ireland, p. 28.

Brachythyris, Buckman, S. S., 1908, Quart. Jour. Geol. Soc. London, v. 64, p. 30.

Brachythyris, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 37⁰-37¹.

Brachythyris, George, T. N., 1927, Geol. Mag., v. 64, p. 107.

Brachythyris, Chao, Y. T., 1929, Paleontologica Sinica, ser. B, v. 1 r, fasc. 1, p. 54-55.

Ovalia, Nalivkin, A. V., 1937, Cent. Geol. Prosp. Inst. Trans., U.S.S.R., v. 99, p. 107.

Brachythyris, Muir-Wood, H. M., 1948, Malayan Lower Carboniferous fossils, British Museum, P. 44.

Brachythyris, Maxwell, W. G. H., 1954, Queensl. Univ. Papers, v. 4, n. 5, p. 26-27.

Type Species. (Original designation) *Spirifer ovalis* Phillips, J., 1836, Geol. of Yorkshire, v. 2, p. 219; pl. 10, fig. 5, Lower Carboniferous, England.

Range. *Brachythyris* is restricted in North America to horizons which range in age from Kinderhook, Mississippian to Morrow, Pennsylvanian.

Diagnosis. The shell is small to large and spiriferoid. Hinge line is straight, shorter than greatest width of shell. Cardinal area is small, curved and triangular. Fold and sinus are weak to well developed. Lateral slopes of valves have simple plications, whereas those of sinus and fold increase by bifurcation. In the pedicle valve the lamellae are absent, but are frequently represented by a ridge-like thickening on the inner surface of the valve on each side of the delthyrium. Brachial valve is similar to that of *Spirifer*.

Brachythyris peculiaris (Shumard)

Pl. 8, fig. 37

Spirifer? peculiaris, Shumard, B. F., 1855, Missouri Geol. Surv., 1st and 2nd Ann. Repts., p. 202, p. 202, pl. C, fig. 7a-7c.

Spirifer peculiaris, Keyes, R. R., 1894, Missouri Geol. Surv., v. 5, p. 79.

Brachythyris peculiaris, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 381, 382; pl. 57, fig. 2; pl. 58, fig. 9'20; pl. 83, fig. 3-5.

Brachythyris peculiaris, Branson, E. B., 1938, Missouri Univ. Studies, v. 8, n. 3, p. 66, pl. 6, fig. 37-43.

Description. A mature pedicle valve has the following dimensions: width 18 mm, length 16 mm, height 7 mm. The shell is subrhomboidal in outline, the greatest width anterior to hinge line. The pedicle valve is very convex, the greatest convexity posterior to the middle. The beak is small, incurved. The cardinal area is high and incurved. The sinus is present at the apex of the beak as a faint, shallow depression, widening at the anterior margin, rounded at the bottom, continuous to the beak without plication. Bounding plications are rounded and much more pronounced than those on the lateral slope. The lateral slopes are marked by 5 to 6 simple plications, which become very faint towards the cardinal extremities. Internal structures were not preserved on the specimens available for study.

Horizon. This species has been found in the coral zone, member A, Keating formation, Escabrosa group, at Blue Mountain, Chiricahua Mountains, Arizona, and in the Klondike Hills and Big Hatchet Mountains of New Mexico.

Remarks. The shape, contour, and plications of these disassociated pedicle valves from the Escabrosa are characteristic

of *B. peculiaris* from the Chouteau limestone of Missouri. Brachial valves were not found.

Brachythyris suborbicularis (Hall)

Pl. 8, fig. 4²-45

Spirifer suborbicularis, Hall, J., 1858, Iowa Geol. Surv. Rept., v. 1, pt. 2, Paleont., p. 64.

Spirifer suborbicularis, Meek, F. B., and Worthen, A. H., 1875, Illinois Geol. Surv., v. 6, p. 523-524, pl. 30, fig. 1 a-d.

Brachythyris suborbicularis, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 374-376, pl. 61, fig. 1-8; pl. 62, fig. 1-2.

Brachythyris suborbicularis, Armstrong, A. K., 1958, N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Mem. 5, p. 24-25, pl. 3, fig. 10-11.

Description. The pedicle valve is suborbicular to subrhomboidal in outline. The cardinal' extremities are rounded or obtusely angular. The dimensions of an incomplete pedicle valve are: width 23 mm, length 20 mm, height 9 mm. The pedicle valve is strongly convex, the greatest convexity posterior to the middle. The surface of the shell curves abruptly to the cardinal area, much more gently to the anterior and anterolateral margins. The cardinal extremities are slightly compressed. The delthyrium is large, and slightly wider than high. The sinus begins at the apex of the beak as a shallow ill-defined depression and at its anterior margins is a shallow depression which is almost obsolete. The sinus of the anterior half may have one very faint median plication. Each lateral slope is marked by 10 to 13 simple, almost indistinct, plications. Those near the lateral slope are weakly developed.

Brachial valves were not available for study. Internal features were not preserved.

Horizon. *B. suborbicularis* is one of the few fossils found in the sparsely fossiliferous lower 150 feet of the Hachita formation of the Escabrosa group.

Remarks. The *B. suborbicularis* from the Hachita formation is smaller and the plications are much weaker and less defined than the average described specimens from the Burlington and Warsaw limestones of the Midcontinent region. The almost obsolescent nature of the plications may be due in part to the mode of preservation. The examples of *B. suborbicularis* from the Escabrosa group compare very favorably in size and number of plications to those described by Armstrong (1958, p. 24, pl. 3, fig.) from the Kelly formation of Keokuk age in west-central New Mexico.

Brachythyris subcardiiformis (Hall)

Pl. 8, fig. 6

Spirifer subcardiiformis, Hall, J., 1858, Iowa Geol. Surv. Rept., v. 1, pt. 2, p. 660, pl. 23, fig. 6a-6b.

Spirifer subcardiiformis, White, C. A., 1880, U.S. Geol. Surv. 2th Ann. Rept., Cont. to Inv. Paleont., n. 8, p. 165, pl. 41, fig. 2a'2c.

Spirifer subcardiiformis, Beede, J. W., 1906, Indiana Geol. Surv. 30th Ann. Rept., p. 1313, pl. 21, fig. 2-2b.

Brachythyris subcardiiformis, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 376-377, pl. 60, fig. 1-15.

Description. Pedicle valve is subrhomboidal in outline. Its dimensions are: width 29 mm, length 24 mm, height 15 mm. The valve is very convex, the greatest convexity posterior to the middle. The beak is large and incurved. The surface of the valve curves abruptly to the cardinal area and more gently

to the anterior and anterolateral margins. The surface of the cardinal extremities is compressed. The faint sinus begins on the umbo, and is broad but shallow at the anterior margin. The sinus is bound by two plications which are perceptibly stronger than those on the lateral slopes. Bounding plications give rise by bifurcation to 4 plications in the sinus. A faint, simple median plication is present in the sinus. The lateral slopes are marked by 10 simple, rounded plications which are distinct throughout their course from the posterior to the anterior margin of the shell. The cardinal area is high but narrow. The delthyrium and internal structures were not preserved on the specimens available for study. Brachial valves were not found.

Remarks. The strong plications and furrows and the presence of plications in the sinus are the distinguishing characteristics of this species.

Horizon. The upper 100 feet of the Hachita formation (Meramec), Escabrosa group at Blue Mountain in the Chiricahua Mountains, Arizona, and at the same horizon in the Big Hatchet and Animas Mountains in New Mexico. This species is a rare form in the Escabrosa group.

Brachythyris ozarkensis Snider

Pl. 8, fig. 38-41

Brachythyris ozarkensis, Snider, L. C., 1915, Oklahoma Geol. Surv. Bull. 24, p. 90-91, pl. 5, fig. 3-6.

Brachythyris chesterensis, Butts, C., 1926, Alabama Geol. Surv. Spec. Rept. 14, pl. 61, fig. 9-2.

Brachythyris chesterensis, Herson, R. M., 1935, Jour. Paleont., v. 9, n. 8, p. 688.

Diagnosis. Hinge line less than greatest width, length about equal to width, ventral valve much more convex than dorsal, broad, shallow, indistinct sinus, 8 to 10 flat, indistinct lateral plications on each slope.

Description. Shell is medium size, semielliptical in outline. The hinge line is shorter than the greatest width of the shell. The cardinal extremities are rounded. The dimensions of two disassociated valves are: pedicle length 25 mm, width 23 mm; brachial length 39 mm, width 38 mm. Pedicle valve is strongly convex with its greatest convexity posterior to the middle. Umbo is prominent, surface of valve curving abruptly to the cardinal margin and more gently to the anterolateral margins. The sinus is shallow and poorly defined and is little more than a flattening of the valve along its median line. It is bounded by plications which are faintly stronger than those of the lateral slopes. The median plication arises at the apex of the beak, which bifurcates towards the anterior margins. Each lateral slope has 8 to 10 simple, flattened plications which become indistinct on the cardinal extremities.

The brachial valve is much less convex than the pedicle valve, with its greatest convexity posterior to the middle. The surface of the shell curves abruptly to the cardinal margins and becomes somewhat flattened at the cardinal extremities. The fold is defined at the beak as a flattened ridge, which broadens anteriorly, but is not strongly elevated above the surface of the shell.

Surface ornamentation on the material available for study is absent because of the nature of preservation, but faint, concentric lines of growth were observed.

Range. *B. ozarkensis* is moderately abundant in the lower and middle parts of the Paradise formation at Blue Mountain, Chiricahua Mountains, Arizona, and in the Big Hatchet Mountains of New Mexico.

Remarks. The illustrations of the type specimens of *B. ozarkensis* by Snider (1915, pl. 5, fig. 3-6) are very poor, and using them as a comparison with the Paradise forms is hazardous. The writer borrowed Snider's type specimens from the Walker Museum. The type specimens *B. ozarkensis* from the Fayetteville formation of Oklahoma differ from the Paradise formation examples in having a broader shell and a less well-developed fold on the brachial valve. The specimens from the Fayetteville and Paradise formations agree in relative size, number, and mode of plications which are present on the fold, sinus, and lateral slopes. Butts' (1926, p. 188, pl. 61, fig. 9-2) description of his species *Brachythyris chesterensis* consists of four photographs and no written description. Butts' species compare favorably with Snider's *B. ozarkensis* except that the former apparently has slightly stronger developed plications.

Family SPIRIFERINIDAE Davidson, 1884

Subfamily SYRINGOTHYINAE Schuchert and LeVene, 1929

Genus SYRINGOTHYRIS Winchell, 1863

Syringothyris, Winchell, A., 1863, Phila. Acad. Nat. Sci. Proc. v. 3, 2d ser., p. 6-8.

Syringothyris, Davidson, T., 1880, Palaeont. Soc., v. 4, pt. 3, p. 278-280.

Syringothyris, Schuchert, C., 1890, New York State Geologist 9th Rept., p. 28-37.

Syringothyris, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., V. 8, pt. 2, p. 47-51.

Syringothyris, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 384-386.

Syringothyris, North, F. J., 1920, Quart. Jour. Geol. Soc. London, v. 76, p. 162-182.

Syringothyris, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 363.

Syringothyris, Roger, J., 1952, in Piveteau, J., Traite de Paleontologie, p. I 10.

Syringothyris, Holland, F. D., Jr., 1958, Cincinnati Univ. Ph. D. thesis (*in press*, Paleont. Res. Inst., 1959), P. 275-294.

Syringothyris, Sass, D.B., 1960, Paleont. Res. Inst. Bull., V. 41, n. 192, p. 337-350.

Type *Species.* (By subsequent designation; International Commission on Zoological Nomenclature, Opinion 100, 1928): *Syringothyris typa*, Winchell, 1863, Phila. Acad. Nat. Sci. Proc., v. 15, p. 6-7. Burlington limestone, Osage, Mississippian; Burlington, Iowa.

Range. Mississippian. Glenister (1955, p. 47) discounted Maxwell (1951, p. 41-42) reports of *Syringothyris* in beds of Permian age in India, Spitzbergen, and Australia. Sass (1960) and Holland (1958, p. 77-78) believed *Syringothyris* s. s. is not present in rocks older than Mississippian. The writer believes the genus in North America ranges from Kinderhook into Meramec time.

Diagnosis. The shell is spiriferoid in shape. The brachial valve is convex with a small, straight beak. The pedicle valve is acutely pyramidal because of a high cardinal area, cardinal extremities rounded or alate; greatest width along the hinge line. Cardinal area high, straight, concave, or, in a few cases, convex. The lateral slopes of each valve are marked by simple

plications. The rounded fold and sinus are devoid of plications. Delthyrial plate covers part of the apical end of the delthyrium. Separated from this plate and the syrinx is a pseudodeltidial plate which covers the delthyrium. Shell structure punctate (see *Remarks*) except in the central, vertically-striated region of the cardinal area.

Pedicle valve with well-developed divergent dental lamellae which rest upon the floor of the valve and extend about one-third the length of the shell. Posteriorly they are united by the apical delthyrial plate. Attached to the inner side of this plate is a tube-like extension, formed by two nearly parallel lamellae, which curve toward each other. As the distance from the apex becomes greater, this tube becomes thinner, finally toward the middle of the valve resulting in only an inverted open "U" attached to the shell by a median ridge. Earliest formed stages of the syrinx tend to be obscured by deposition of shell material (apical callosity). In well-preserved specimens a pseudodeltidial covering is present.

The interior of the brachial valve is similar to that of *Spirifer*. Brachial valve has a long, low, median septum, which extends half or more than half the length of the shell. Cardinal process is broad; spirals are large.

Remarks. *Pseudosyrinx* Weller (1914), a homomorph of *Syringothyris* Winchell, can be differentiated from the latter by the absence of a transverse plate bearing a syrinx and by its shell structure. Although Weller (1914, p. 404) in his original description of the genus *Pseudosyrinx* believed it had a punctate shell structure similar to *Syringothyris*, later workers-Cooper (1944, p. 332), Vandercammen (1955, p.), and Campbell (1957, p. 81)-have observed that *Pseudosyrinx* is impunctate. *Septosyringothyris* Vandercammen (1955, p. 1-5) is separated from *Syringothyris* by the presence in the pedicle valve of a very strong, median septum, which may bifurcate. This euseptum or pillar connects the syrinx to the roof of the valve. *Asyrinxia* Campbell (1957, p. 80-81), a lower Mississippian *Syringothyrinae* from New South Wales, is characterized by the absence of a syrinx, development of costae on the fold and sinus, and a much lower cardinal area than *Syringothyris*.

Holland (1958) and Sass (1960) demonstrated that when Winchell (1863) erected the genus *Syringothyris* he believed the shell to be impunctate. Subsequent workers, Hall and Clarke (1894, p. 47), North (1920, p. 221), Vandercammen (1955, p. 391), and Glenister (1955, p. 70) believed the shell of the genus was punctate and that this trait was one of the distinctive features of *Syringothyris*. (For a full, detailed review of the nature of punctate in the genus the reader is referred to Sass, 1960).

Sass (1960, p. 343), after a very detailed study, believed the distinctive features of the genus *Syringothyris* s. s. to be:

1. Shell structure punctate or impunctate, except in the perideltidial region which is never punctate.
2. Faint plicae may occur on the fold and sulcus, particularly along their lateral margins. This distinction is apparently more common in the sulcus than in the fold.
3. An unsupported syrinx developed from a transverse subdelthyrial plate, modifications of which take place concomitant with increasing age and the correlated disposition of adventitious shell material.
4. Textile-like ornamentation of the lateral plicae on both valves.
5. High interarea with a vertically-striated perideltidial region.

Syringothyris subcuspidatus (Hall)

Pl. 8, fig. 1-5

Spirifer subcuspidatus, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 646, pl. 20, fig. 6a-6b.

Syringothyris subcuspidatus, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 30.

Syringothyris subcuspidatus, Hall J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 26, fig. 8, I 1; pl. 27, fig. 18.

Syringothyris subcuspidatus, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 401-403, pl. 71, fig. 3-7.

Diagnosis. Punctate syringothyrid, strongly convex pedicle valve with 18 to 22 plications on each lateral slope; high convex cardinal area; brachial valve less convex than pedicle, 18 to 21 simple plications on each lateral slope; sinus and fold devoid of plications.

Description. The shell is large, wider than long, greatest width being along the hinge line.

Pedicle valve is strongly convex with the convexity most prominent on the umbo, surface of shell sloping with a convex curvature to the cardinal extremities, and a greater curvature to the anterior and anterolateral margins. Sinus begins at apex of beak as a narrow, shallow depression, widening and deepening anteriorly, rounded in the bottom, producing a linguloid extension on the anterior margin. The beak is erect and small. Cardinal area is high, broadly triangular, gently concave. The apex of the cardinal area meets at the beak of the shell at an angle of about 65 degrees. The surface of the cardinal area meets the line of commissure between the valves at an angle of 100 degrees. The base of the delthyrium is about one-third the width of the cardinal area; outline of delthyrium is triangular. Each lateral slope is marked by 18 to 22 simple plications, those toward the cardinal extremities becoming progressively more imperceptible.

Brachial valve is not quite as convex as the pedicle, greatest convexity anterior to the middle of valve. From the umbo region the surface of the valve curves toward the cardinal area and the surface of the valve becomes more compressed towards the cardinal extremities. The beak is small, and at its apex the fold is present; it becomes rapidly more rounded and very broad anteriorly. The fold is devoid of plications. Each lateral slope is marked by 18 to 21 simple plications, which become progressively fainter towards the cardinal extremities.

Each valve towards the anterior margin is marked by progressively more and stronger concentric lines of growth. The shell structure is punctate.

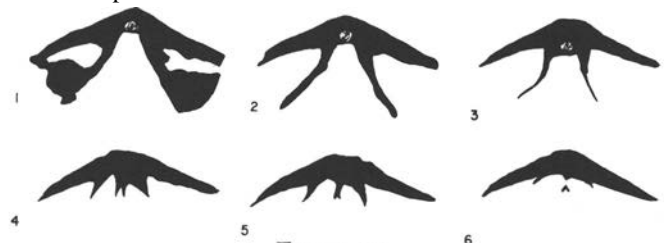


Figure 31
SERIAL SECTIONS OF *Syringothyris subcuspidatus*

The pedicle valve interior (fig. 31) has well-developed dental lamellae, which diverge at an angle of about 70 degrees. At the apex of the delthyrium is a deltidial plate with a syrinx attached to its inner side. The syrinx, which is calci-

fled and embedded in shell material at its posterior end, extends past the mid-point of the valve. The syrnix becomes progressively thinner anteriorly, and near the midpoint of the shell is reduced to an inverted "U," supported by a pillar to the top of the shell. At its most anterior position the syrnix appears not to be attached to the shell.

Horizon. The upper third of the Hachita formation (Warsaw age), Escabrosa group, Big Hatchet and Animas Mountains of New Mexico, and Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. *Syringothyris textus* (Hall) is closely related to *S. subcuspidatus* (Hall). The latter possesses a wider shell in relation to length, and a straight cardinal area, which intersects the plane of the valve at an acute angle. *S. subcuspidatus* possesses a convex cardinal area, which makes an obtuse angle with the plane of the shell. The cardinal area is also lower than in *S. textus*.

The *S. subcuspidatus* from the upper part of the Hachita formation, Escabrosa group, agrees at the specific level in all respects with described specimens from the Keokuk and Warsaw limestone of the Midcontinent region.

Superfamily ROSTROSPIRACEA Schuchert and
LeVene, 1929

Family ATHYRIDAE Davidson, 1884 (non Phillips
1841)

Genus CLEIOTHYRIDINA Buckman, 1906

Cleiothyris, King, W., 1850, Palaeont. Soc. (Permian fossils of England), p. 137, pl. 10, fig. 1-10.

Cleiothyris, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, p. 90-91.

Cleiothyridina, Buckman, S. S., 1906, Ann. Mag. Nat. Hist. (ser. 7), V. 18, p. 323-324.

Cleiothyridina, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 47²-473.

Cleiothyridina, Dunbar, C. O., and Condra, G. E., 1932, Nebraska Geol. Surv. Bull. 5, p. 359.

Cleiothyridina, Cooper, G. A., 1944, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 333.

Cleiothyridina, Dresser, H., 1954, Am. Paleont. Bull., v. 35, p. 38-39.

Cleiothyridina, Dunbar, C. O., 1955, Meddel. om Grønland, bd. I 10, nr. 3, p. 23-124.

(*Non*) *Cleiothyris*, Phillips, J., 1841, Paleozoic fossils of Cornwall and Devon, p. 55.

Type Species. (Original designation) *Athyris roysii* Davidson, 1857, Palaeont. Soc., p. 84, pl. 18, fig. 1-11. The lower Carboniferous limestones of England.

Range. Mississippian-Pennsylvanian.

Diagnosis. After King (1850, p. 137-138), Dunbar and Condra (1932, p. 359), and Dunbar (1955, p. 23-24). Shell subcircular to transversely subelliptical in outline. Fold and sinus well developed to obsolete. Surface at valve has lamellar extensions divided to their base into long flat spines. Brachial valve has short, stout dental lamellae. Pedicle valve with short hinge plate perforated by a round foramen. Hinge plates bordered by deep dental sockets, giving rise anteriorly to the crural plates, which arch forward and ventrally. Spiralia primary, lamellae recurved abruptly from the crural plates. Spiralia run dorsoanteriorly and then curve ventrally to give rise to a pair of spiral cones whose apices are directed laterally.

Cleiothyridina hirsuta (Hall)

Pl. 6, fig. 27

Spirigera hirsuta, Hall, J., 1857, Albany Inst. Trans., v. 4, p. 8.

Athyris hirsuta, Hall, J., 1883, Indiana Geol. Surv. 12th Ann. Rept., p. 328, pl. 29, fig. 18-21.

Athyris hirsuta, Walcott, C., 1884, U.S. Geol. Surv. Mon. 8, p. 222, pl. 18, fig. 5.

Cleiothyris roysii, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 46, fig. 23 (*non* fig. 24).

Cleiothyridina hirsuta, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 479-480, pl. 80, fig. 13-24.

Cleiothyridina hirsuta, Cooper, G. A., 1944, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 333, pl. 28, fig. 1-2.

Cleiothyridina hirsuta, Armstrong, A. K., 1958, N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Mem. 5, p. 26, pl. 3, fig. 12-13.

Description. Shell outline is subpentagonal and lenticular in side view. Greatest width is about the middle of the shell. Cardinal extremities are rounded. The posterolateral margins are straight and meet at the beak at an angle of about 90 to 100

degrees. The anterolateral margins are curved, and the anterior margin is slightly truncated. The dimensions of two typical specimens are:

Specimen	Length	Width	Thickness
1.	8.5 mm	9.5 mm	5.5 mm
2.	7.0 mm	7.5 mm	3.5 mm

The pedicle valve is more convex posterior to the middle than elsewhere. 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 broad, obscure, almost obsolete sinus is present near the anterior margin on most specimens.

The brachial valve is as convex as the pedicle. The surface curves abruptly from the umbo to the cardinal margins, sloping much more gently to the lateral and anterior margins. The fold is generally obsolete. The brachial beak is incurved beneath that of the opposite valve.

All specimens examined were either almost or completely exfoliated. Small areas of the shell surface did reveal the characteristic, flat, imbricating lamellose extensions which are divided into flattened spines. Four or five of these spines occupy a space of 1 mm.

Horizon. *C. hirsuta* is found in beds of Meramec age in the Escabrosa formation from Blue Mountain in the Chiricahua Mountains, Arizona, eastward to the Big Hatchet Mountains, New Mexico.

Remarks. Immature specimens of *Perditocardinia dubia* (Hall), which occur in the same horizon as *Cleiothyridina hirsuta* (Hall), have the same general contour as *C. hirsuta*. The same difficult relationship exists in the upper Mississippian Valley, where immature forms of *Cleiothyridina sublamellosa* can be confused and placed with a population of *C. hirsuta* (Weller, 1914, p. 480). *C. hirsuta* is characteristic in New Mexico and Arizona in horizons of Keokuk (upper Osage) and Meramec age. It has been found in the Kelly formation of Keokuk age in west-central New Mexico (Armstrong, 1958) and is common in the lower Meramec part of the Escabrosa formation.

Cleiothyridina cf. *C. incrassata* (Hall)

Pl. 6, fig. 15-16

Athyris incrassatus, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 600, pl. 2, fig. 6.

Athyris incrassata, Hall, J., and Clarke, J. M., 1894 (*pars*), New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 46, fig. 21.

Athyris incrassata?, Girty, G. H., 1899, U.S. Geol. Surv. Mon., V. 32, p. 562.

Description. The shell is of medium size, subovate in outline, and slightly longer than wide. Anterolateral and anterior margins form a semicircle. Outline of posterolateral margin is perceptibly concave. The dimensions of one specimen are length 33 mm, width 30 mm, and thickness 16 mm.

The pedicle valve is moderately convex with the greatest convexity on the umbonal region. The surface curves abruptly from the umbonal region to the cardinal margins and progressively more gently to the lateral and anterior margins. The sinus begins at the midregion of the valve as a broad, ill-defined depression. The sinus at the anterior margin is a broad, rounded, laterally, ill-defined depression, which projects as a linguloid extension into the plane of the opposite valve. The beak is small and incurved.

The brachial valve was poorly preserved but appears to be about as convex as the opposite valve. Fold originates on the umbo, rapidly becoming larger anteriorly, but is ill defined laterally. The beak is very small, slightly curved beneath the beak of the opposite valve.

Concentric lines of growth are present at the anterior and lateral margins of the shell.

Horizon. *C. cf. incrassata* is found in the lower Meramec part of the higher horizons in the Hachita formation on the south end of Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. This species is represented by one specimen from near the top of the Escabrosa formation, and it is smaller than the examples figured by Hall and Clarke (1894) or Weller (1914). The Escabrosa example did not have preserved on the surface of the shell the imbricating lamellae, which are divided into thin spines. This is the only diagnostic trait which separates the genus *Cleiothyridina* from the genus *Athyris*, which does not have its imbricating lamellae divided into spines. Thus, there exists a possibility that the specimen identified as *C. cf. incrassata* is an *Athyris* and a different species. The specimen exhibits remarkably well the characteristic shape and contour of described and illustrated *C. incrassata* from the Midcontinent region.

C. incrassata has been reported by Moore (1928) in the Midcontinent region, in beds ranging in age from the Burlington limestone to Keokuk limestone. In the Escabrosa formation it is associated with a fauna characteristic of lower Meramec (Warsaw and Salem) age.

Genus **COMPOSITA** Brown, 1849*Composita trinuclea* (Hall)

Pl. 8, fig. 9-24

Terebratula trinuclea, Hall, J., 1856, Albany Inst. Trans., v. 4, p. 7.

Terebratula trinuclea, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 659, pl. 23, fig. 4a-4c, 5.

Athyris trinucleus, Whitfield, R. P., 1882, Am. Mus. Nat. Hist. Bull., v. I, n. 3, p. 50, pl. 6, fig. 22-27.

Athyris trinucleus, Hall, J., 1883, Indiana Geol. Surv. 2th Ann. Rept., p. 329, pl. 29, fig. 22-27.

Seminula trinuclea, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 35, fig. 11-2, **14**.

Seminula subquadrata, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 35, fig. 13, 15.

Athyris trinuclea, Keyes, R. R., 1894, Missouri Geol. Surv., **V**, 5, p. 92.

Seminula trinuclea, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 47, fig. 5-6, 10-14.

Seminula subquadrata, Hall, J., and Clarke, J. M., 1895, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 47, fig. 7-9, 15, 16, pl. 84, fig. 30-31.

Athyris subquadrata, Whitfield, R. P., 1895, Ohio Geol. Surv., **V**, 7, p. 472, pl. 10, fig. 1-3.

Seminula subquadrata?, Girty, G. H., 1903, U.S. Geol. Surv. Prof. Paper 16, p. 296, pl. 1, fig. 5.

Seminula subquadrata, Bassler, R. S., 1909, Virginia Geol. Surv. Bull. 2A, pl. 29, fig. 6-8.

Composita trinuclea, Weller, S., 1914, Illinois Geol. Surv. Mon. I, p. 486-488, pl. 81, fig. 16-45.

Composita trinuclea, Snider, L. C., 1915, Oklahoma Geol. Surv. Bull. 24, p. 97-98.

Composita deltooides, Hernon, R. M., 1935, Jour. Paleont., v. 9, p. 689, pl. 82, fig. 6a-6d.

Composita cf. ozarkana, Hernon, R. M., 1935, Jour. Paleont., v. 9, p. 689-690.

Composita trinuclea, Hernon, R. M., 1935, Jour. Paleont., **V**, 9, p. 690.

Description. Shells of larger individuals subquadrate in outline; immature individuals tend to be subovate. The dimensions of 22 specimens* are:

Specimens	Length	Width	Thickness
1.	12.0 mm	12.5 mm	7.0 mm
2.	12.0	11.0	7.0
3.	11.0	10.0	6.5
4.	10.0	10.5	6.0
5.	10.0	9.5	5.5
6.	10.0	10.0	5.0
7.	9.5	9.0	6.0
8.	9.0	8.0	6.0
9.	8.0	7.0	5.5
10.	7.0	8.0	4.0
11.	12.0	12.0	7.0
12.	12.0	9.0	7.0
13.	11.0	11.5	—
14.	14.0	12.0	7.0
15.	11.0	11.0	8.0
16.	10.5	10.0	5.0
17.	9.0	9.0	5.0
18.	9.0	10.0	4.5
19.	11.0	10.0	7.0
20.	10.0	10.5	7.0
21.	9.0	8.0	5.0
22.	10.5	11.0	9.0

Pedicle valve is convex, greatest convexity posterior to the middle. Surface of the shell curves abruptly from the um-

* Specimens are from a zone 60 to 80 feet above the base of the Paradise formation, Blue Mountain, Arizona.

bonal region to the cardinal margins, somewhat more gently to the lateral margins. Surface curves rather gently to the anterior margin. On most specimens a shallow sinus is present at the beak, which widens anteriorly and may produce a slight linguloid extension at the anterior margin. Some examples show a poorly defined, simple furrow on each side of the sinus. The beak is small, incurved. Foramen is large, semi-circular. Cardinal area is absent.

Brachial valve is as convex as pedicle. Beak is small and incurved beneath that of opposite valve. Sinus originates on umbo as a low, rounded ridge, which widens anteriorly and may become more conspicuous because of the development of two shallow, bounding lateral furrows. The mesial fold and bounding furrows produce a trilobed brachial valve in some individuals.

The shell structure is impunctate. Surface of hntli valves is marked by regular concentric lines of growth.

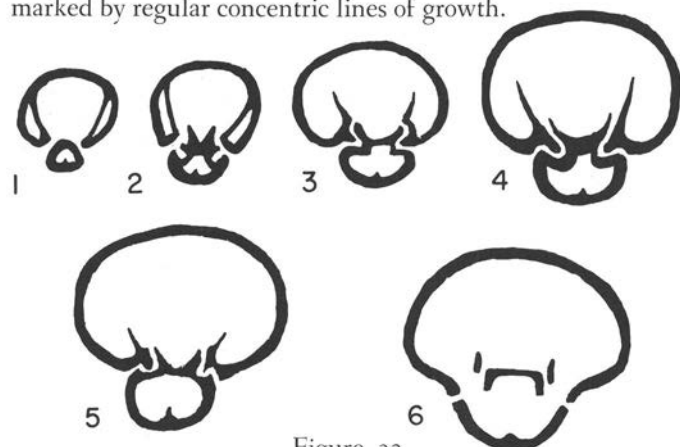


Figure 32
SERIAL SECTIONS OF *Composita trinuclea*

Interior. The hinge teeth (fig. 32) are supported by dental lamellae, which are continuous from the hinge plate to the roof of the valve only in the posterior part of the valve. Brachial valve has deep sockets bounded by socket plates. The hinge plate is subquadrate and gives rise anteriorly to the crura. A faint median septum is present on the floor of the dorsal valve.

Horizon. The species is sparse in the upper 50 feet of the Escabrosa formation in the Big Hatchet Mountains, and abundant in the lower 100 feet of the Paradise formation throughout the area of outcrop. It is less common in the higher zones of the Paradise formation in southeastern Arizona and southwestern New Mexico.

Remarks. The determination of species of *Composita* is dependent upon critical examination of a series or population of these organisms from a given horizon, and upon using the average or mean individual as the specific example (fig. 33). The necessity for this method lies in the extreme degree of variability shown by individuals in one population. Such variation, if viewed separately and without appreciation of the gradation between forms, would result in the erection of a multitude of species which were in reality an interbreeding population. Since these end members of the population do not appear to have any stratigraphic significance as yet, the more conservative attitude is warranted. In this country, Weller (1914, p. 485-486) first evaluated species of *Composita* from a population. His findings were reaffirmed by Dunbar and Condra (1932, p. 363) and Stehli (1954, p. 352).

Populations of *Composita* collected from the various hori-

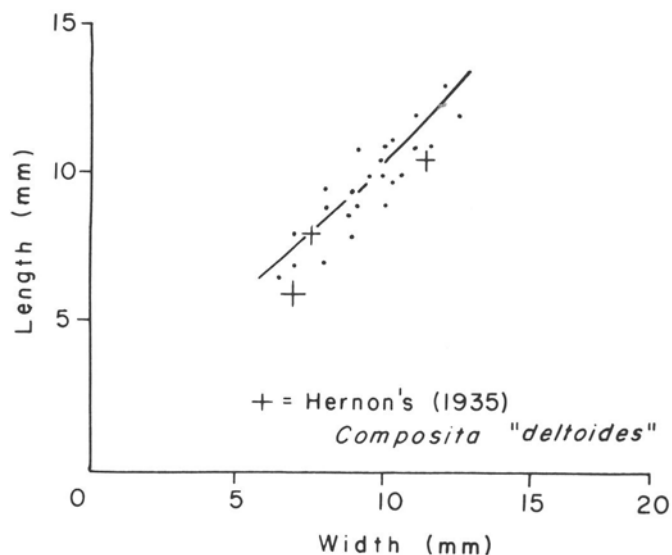


Figure 33
SCATTER PLOT OF *Composita trinuclea* LENGTH:WIDTH RATIO

zons of the Paradise formation show great variability in the individuals. Three divergent characteristics contributed greatly to individual variation: strength and size of the sinus and fold, position on the shell of the greatest width, and the degree of roundness of the anterior margin. All populations showed variations in each or a combination of these three factors, but the center or mean of each population is *C. trinuclea* Hall. Herson's (1935, p. 689) *Composita deltoides*, an end member *C. trinuclea*, is the form which has a weak sinus, the greatest width near the anterior margin, and a truncated, linear anterior. The writer believes that *C. deltoides* can be considered only as a subspecies or variant of *C. trinuclea*. Herson's (p. 689-690) *Composita cf. ozarkana* Mather is also a synonym of *C. trinuclea*. Mather (1915, p. 198, pl. 8, fig. I I- 5c) described *C. ozarkana* from the basal Morrow of Oklahoma and Arkansas as an exceedingly variable form containing individuals which could ordinarily be identified as *C. trinuclea*, but in which the average are larger and greater in breadth, and have fainter sinuses and folds. Herson (1935, p. 689-690) stated that *C. cf. ozarkana* from the Paradise formation is a dwarf form.

Composita globosa Weller

Pl. 8, fig. 25-36

Composita globosa, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 493-494, pl. 82, fig. 21-26.

Diagnosis. Shell small, wide as long, globular, compositoid shaped, fold and sinus absent or very weakly developed.

Description. The shell is small and is as wide as it is long. The average mature individual is about 10 mm long. The pedicle valve is thickest posterior to the middle. The surface of the valve curves sharply to the cardinal margins, but more gently to the anterior margins. Posterolateral margins meet at the beak and form an angle of 85 to 90 degrees; anterolateral margins from a semicircle. The beak is small and incurved. The median sinus is absent or very faintly developed on the anterior margin. The brachial valve is similar to opposite valve in outline, but it is not as convex, and it possesses a weakly developed fold on the anterior half of the shell. The surface of both valves is smooth except for the anterior mar-

gin, which may become crowded with concentric lines of growth.

The interior of the pedicle valve has two well-developed dental lamellae which unite at first at the sides of the shell by adventitious shell growth. The brachial valve is marked by deep dental sockets (fig. 34).



Figure 34

SERIAL SECTIONS OF *Composita globosa*

Remarks. *Composita globosa* belongs to a group of small, Mississippian *Composita* of which Weller (1914) described *C. laevis* from the Chester with a prominent umbo and *C. lewisensis* with an absence of a sinus on the brachial valve. *C. globosa* is distinguished primarily from the two succeeding species by its slightly more globose shell. The population of *C. globosa*, which was taken from a single outcrop, displayed a considerable range in length to width, in the absence and presence of fold and sinus, and, when present, some variation in the extent.

Horizon. Abundant in upper half of member B of the Keating formation throughout its area of outcrop; a small *Composita* which occurs in the coral zone of member A, is assigned to *C. globosa*.

Superfamily PUNCTOSPIRACEA Cooper, 1944
Family RHYNCHOSPIRINIDAE Schuchert and
LeVene, 1929
Subfamily RHYNCHOSPIRINAE Schuchert, 1894 Genus
EUMETRIA Hall, 1863

Eumetria, Hall, J., 1863, New York State Cab. Nat. Hist. 6th Ann. Rept., p. 54-55.

Eumetria, Whitfield, R. P., 1882, Am. Mus. Nat. Hist. **Bull.**, v. 1, p. 50.

Eumetria, Hall, J., 1883, Indiana State Geol. 12th Ann. Rept., p. 335.

Eumetria, Weller S., 1914, Illinois Geol. Surv. Mon. 1, p. 437.

Eumetria, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 361.

Eumetria, Campbell, K. S. W., 1957, Jour. Paleont., v. 31, p. 84-85.

Eumetria, Elias, M. K., 1957, Jour. Paleont., V. 31, p. 522-523.

Type Species. (Original designation) *Retzia vera* Hall, J. (1858, Iowa Geol. Surv., V. I, pt. 2, p. 704, pl. 27, fig. 3a): *Kaskaskia* limestone, Chester, Illinois.

Range. Mississippian.

Eumetria verneuiliana (Hall)

Pl. 9, fig. 21-23

Retzia verneuiliana, Hall, J., 1856, Albany Inst. Trans., v. 4, p. 19.

Retzia verneuiliana, Hall, J., 1858, Iowa Geol. Surv., v. 1, pt. 2, p. 657, pl. 23, fig. ia-id.

Eumetria verneuiliana, Whitfield, R. P., 1882, Am. Mus. Nat. Hist. Bull., v. I, p. 50, pl. 6, fig. 28-30.

Eumetria verneuiliana, Hall, J., 1883, Indiana State Geol. 12th Ann. Rept., p. 335, pl. 29, fig. 28-30.

Retzia verneuiliana, Walcott, C. D., 1884, U.S. Geol. Surv. Mon. 8, pl. 7, fig. 5-5a.

Eumetria verneuiliana, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 37, fig. 14, 6, 10.

Eumetria verneuiliana, Hall, J., and Clarke, J. M., 1895, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 51, fig. 13-26, 34, 35, pl. 83, fig. 26-27.

Eumetria verneuiliana, Girty, G. H., 1899, U.S. Geol. Surv. Mon. 32, p. 560, pl. 68, fig. 12a-12b.

Eumetria marcyi? Shumard, Girty, G. H., 1904 (pars) U.S. Geol. Surv. Prof. Paper 21, p. 49, pl. 10, fig. 15 (non fig. 16, 17).

Eumetria marcyi Shumard, Beede, J. W., 1906, Indiana Geol. Surv. 30th Ann. Rept., p. 1319, pl. 22, fig. 28-30.

Eumetria verneuiliana, Weller S., 1914, Illinois Geol. Surv. Mon. I, p. 442-444, pl. 86, fig. 18-24.

Eumetria marcyi Shumard, Girty, G. H., 1915 (pars) U.S. Geol. Surv. Bull. 593, p. 75-77, pl. 4, fig. 18 (non fig. 19a, 9b).

Eumetria verneuiliana, Snider, L. C., 1915, Oklahoma Geol. Surv. Bull. 24, p. 94.

Eumetria verneuiliana, Weller, J. M., 1931, Kentucky Geol. Surv. Symp., pl. 38, fig. 7a-7b.

Eumetria verneuiliana, Hernon, R. M., 1935, Jour. Paleont., v. 9, p. 688-689.

Eumetria verneuiliana, Elias, M. K., 1957, Jour. Paleont., v. 31, p. 524, pl. 58, fig. 1-2.

Diagnosis. *Eumetria* with 48 to 55 costae, small to medium-size ovate shell.

Description. Three specimens, two crushed and exfoliated and one complete ephebic individual, were available for study. Their dimensions in mm are:

Length	Width
19	16
18.5	16

Shell outline is ovate, with the anterolateral margins forming a semicircle and the posterolateral margins much more linear.

Pedicle valve convex, greatest convexity posterior to the middle. Convexity decreases progressively to the anterolateral and anterior margins. Cardinal area small, foramen and delthyrium not preserved on the specimens studied. A very faint trace of the sinus is observed on the anterior margin where perceptible flattening occurs. The surface of the valve is marked by 48 to 55 simple, rounded radiating costae.

Brachial valve is slightly less convex than pedicle, the beak is small, pointed, and projecting beyond the hinge line. The surface of the shell curves abruptly from the umbo region to the cardinal area. The curvature of the shell is progressively flattened towards the anterolateral and anterior margins. The costae are similar to those of the opposite valve. Shell structure is minutely punctate.

All of the specimens of this species either had the umbonal region broken off or were badly crushed. In most specimens the crushing was restricted primarily to the pedicle valve. Grinding of selected specimens resulted in finding intact the

interior structures (fig. 35) of the brachial valve. These had the characteristic convergent plates in the beak. These plates anteriorly became discrete but were joined by a concave transverse spondyloid platform. These vertical plates are present one-third of the distance to the anterior margin.

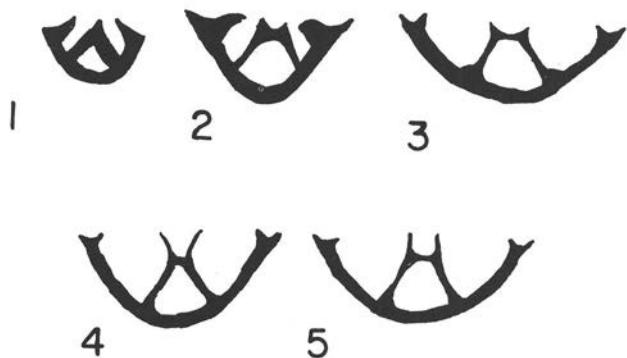


Figure 35
SERIAL SECTIONS OF *Eumetria verneuiliana*

Horizon. The Meramec part of the Hachita formation in the Big Hachet and Animas Mountains of New Mexico and Blue Mountain, Arizona. This is one of the most abundant brachiopods in the lower 80 feet of the Paradise formation (upper Meramec-lower Chester) throughout its area of outcrop.

Eumetria vera (Hall)
Pl. 9, fig. 27-30

Retzia vera, Hall, J., 1858, Iowa Geol. Surv., v. I, pt. 2, p. 704, pl. 27, fig. 3a.

Eumetria vera, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 37, fig. 8, I2.

Eumetria vera, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pl. 51, fig. 36, 37.

Eumetria vera, Bassler, R. S., 1909, Virginia Geol. Surv. Bull. 2A, pl. 29, fig. 4, 5.

Eumetria vera, Snider, L. C., 1915, Oklahoma Geol. Surv. Bull. 24, p. 94.

Eumetria marcyi, Girty, G. H., 1915 (pars) U.S. Geol. Surv. Bull. 593, p. 75-77, pl. 4, fig. 19-19b (non fig. 18).

Eumetria vera, Weller, J. M., 1931, Kentucky Geol. Surv. Symp., p. 265, pl. 38, fig. 7a-7b.

Eumetria vera, Hernon, R. M., 1935, Jour. Paleont., v. 9, p. 688.

Eumetria vera, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 361, pl. 141, fig. 38-41.

Eumetria vera, Elias, M. K., 1957, Jour. Paleont., v. 31, p. 523-524, pl. 58, fig. 6-11.

Diagnosis. *Eumetria* with 42 to 48 costae, medium-size subovate shell with greatest width near the anterior.

Description. The dimensions of two almost complete individuals are:

Length	Width	Thickness	Number of costae
15 mm	13 mm	7.5 mm	44
14 mm	11 mm	6.5 mm	42

Shell ovate with the anterolateral and anterior margins forming a semicircle, posterior lateral margins forming a triangle which has its apex at the beak.

Pedicle valve convex with the greatest convexity posterior to the middle. Umbo and beak pronounced, beak strongly incurved. Cardinal area small; foramen, delthyrium, and pseudodeltidium not observed. Surface of shell curves abruptly from the umbo to the cardinal and posterolateral margins, and progressively more gently to the anterolateral margins and the anterior margin. Surface of the shell covered by 42 to 48 simple, round, radiating costae. The anterior surface of the shell does not show any such flattening as would indicate the presence of a sinus.

Brachial valve less convex than pedicle. Beak small and incurved beneath the opposite valve and extended beyond the cardinal area. The number and nature of the costae and the curvature of the surface of the shell similar to that of the opposite valve.

The interior of the pedicle valve is devoid of dental lamellae. The brachial valve has two long, vertical supporting plates, which extend from the front of the beak to almost one-third the distance to the anterior margin. These plates converge in the beak (fig. 36), but anteriorly they are discrete and are connected by a plate which gives the appearance of a spoon-shaped central process. The lamellae of the brachidium were not observed.

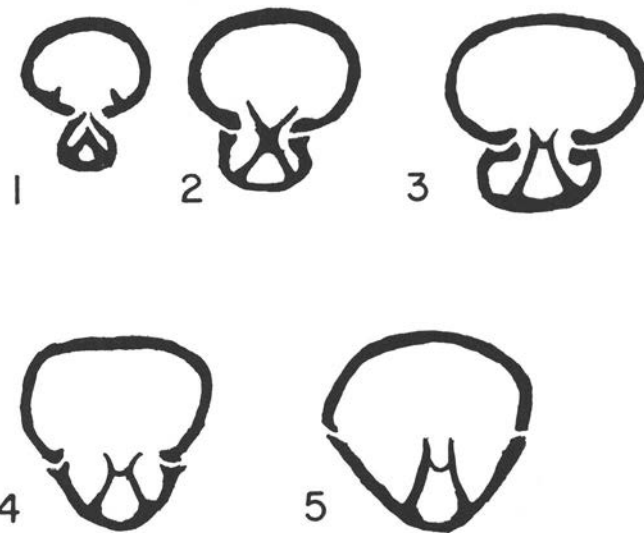


Figure 36
SERIAL SECTIONS OF *Eumetria vera*

Horizon. A common brachiopod in the Paradise formation (lower and middle Chester) throughout its area of outcrop in southwestern New Mexico and extreme southeastern Arizona.

Eumetria costata (Hall)
Pl. 9, fig. 24-26

Retzia vera var. *costata*, Hall, J., 1858, Iowa Geol. Surv. Rept., v. I, pt. 2, Paleont., p. 704, pl. 27, fig. 3a-3b.

Retzia vera var. *costata*, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, pl. 37, fig. 5-I I.

Eumetria vera var. *costata*, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 51, fig. 27-33.

Eumetria costata, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, P 444-445, pl. 76, fig. 25-29.

Eumetria costata, Snider, L. C., 1915, Oklahoma Geol. Surv. Bull. 34, pt. 2, p. 94-95.

Diagnosis. *Eumetria* with 30 to 42 costae, subovate shell, longer than wide with greatest width near the anterior.

Description. Dimensions of one pedicle valve: width 10 mm, length 11.5 mm, and thickness 3.5 mm. The shell outline is ovate with the posterolateral margins linear.

Pedicle valve convex with greatest convexity posterior to the middle. Beak small and incurved. Cardinal area small. Surface of shell curves abruptly from the umbo to the cardinal area and posterolateral margins, much more to the anterolateral and anterior margins. The surface of the shell has 30 simple, rounded radiating plications. Shell structure is minutely punctate. A few faint lines of growth can be observed near the anterior margins.

Only ventral valves were available for study which, when sectioned, showed the absence of dental lamellae.

Horizon. *E. costata* occurs only in the stratigraphically highest 60 feet of the Paradise formation (middle Chester) in the Big Hatchet Mountains of New Mexico.

Remarks. This species occurs in large numbers in the highest beds of the Paradise formation in the Big Hatchet Mountains. Although complete specimens are rare, numerous pedicle valves have been found; their contour and number of plications leave little doubt as to their generic and specific identification.

Suborder **TEREBRATULOIDE A** Muir-Wood, 1955

Superfamily **T E R E B R A T U L A C E A** Waagen, 1883

Family **DIELASMATIDAE** Schuchert and LeVene 1929

Subfamily **DIELASMATINAE** Schuchert, 1913

Genus **BEECHERIA** Hall and Clarke, 1894

Beecheria, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, p. 300.

Dielasma, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 256-257.

Dielasma, Dunbar, C. O., and Condra, G. E., 1932, Nebraska Geol. Surv. Bull. 5, p. 303-304.

Dielasma, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 364.

Beecheria, Stehli, F. S., 1956, Jour. Paleont., v. 30, n. 2, p. 302.

Type Species. (Original designation) *Beecheria davidsoni*, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, p. 300, fig. 223-224; Carboniferous limestone (Mississippian) of Windsor, Nova Scotia.

Range. Abundant in the Mississippian and Pennsylvanian, rare in the lower and middle Permian.

Diagnosis. Shell is terebratuliform. Pedicle valve with or without sinus. Pedicle valve has a large foramen. The beak is strongly incurved. Internally the dental lamellae are well developed. Brachial valve generally without mesial fold; interior with the cardinal plates medially sessile and divided into two discrete plates laterally supported by crural plates. The cardinal plates obsolete between crural plates and socket plates. The loop is dielasmoid and the transverse band moderately recurved.

Remarks. Hall and Clarke's (1894, p. 300) genus *Beecheria*

was revived by Stehli (1956, p. 300-301) for those dielasmoids which have a pedicle interior, as in *Dielasma*, and which have in the brachial interior the cardinal plates medially sessile and divided into two discrete plates laterally supported by crural plates. Hall and Clarke (1894) introduced into the American literature the above condition in their conception of the genus *Dielasma*. The type species of *Dielasma*, *Terebratula elongatus* Schlotheim, has the cardinal plates in the brachial valve connecting the inner margins of the socket plates to the floor of the valve.

Beecheria formosum (Hall)

Pl. 9, fig. 17-19

Terebratula formosa, Hall, J., 1856, Albany Inst. Trans., v. 4, p. 6.

Terebratula formosa, White, C. A., 1877, Indiana Geol. Surv. 11th Ann. Rept., p. 361, pl. 39, fig. 6-7.

Terebratula formosa, Whitfield, R. P., 1882, Am. Mus. Nat. Hist. Bull. I, p. 55, pl. 6, fig. 59-64.

Terebratula formosa, Hall, J., 1883, Indiana Geol. Surv. 12th Ann. Rept., p. 337, pl. 29, fig. 59-64.

Dielasma formosa, Hall, J., and Clarke, J. M., 1894 (*pars*) Introduction to the study of brachiopods, pt. 2, pl. 53, fig. 15-17 (*non* fig. 18-19).

Dielasma formosa, Hall, J., and Clarke, J. M., 1894 (*pars*) New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 81, fig. 18-23, 25-26 (*non* fig. 12-17, 24).

Dielasma obovata, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 81, fig. 38-40.

Dielasma obovata, Hall, J., and Clarke, J. M., 1897, New York State Geol. 14th Ann. Rept., p. 372, pl. 14, fig. 12-14.

Dielasma formosa, Weller, S., 1911, Jour. Geol., v. 19, p. 44⁰, pl. 33, fig. I a-in.

Dielasma formosum, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 265-267, pl. 33, fig. 12-17.

Dielasma formosum, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 364.

Diagnosis. Terebratuliform shell, elongate, sinus and fold absent, beak incurved, punctate shell.

Description. Shell is terebratuliform, elongate subovate in outline, with greatest width towards the anterior. Anterior margin is rounded. The dimensions of an almost perfect specimen are: length 22.5 mm, width 9.5 mm, and thickness 7.0 mm. Pedicle valve convex, particularly so in the umbo region. Surface curves abruptly from umbo to cardinal area and posterior lateral margins. Surface more gently curved to anterior margin. Sinus absent. Deltidium and foramen were not preserved on the specimens.

Brachial valve less convex than pedicle, greatest convexity posterior to the middle. Medial portion of shell not differentiated into a fold or sinus. Beak incurved beneath that of the opposite valve. Shell structure finely punctate.

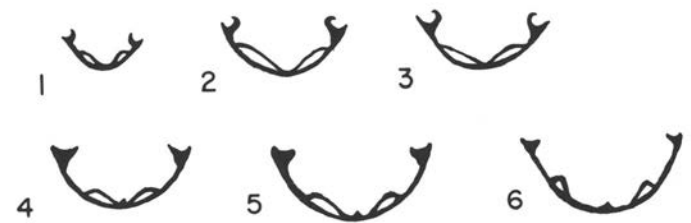


Figure 37

SERIAL SECTIONS OF *Beecheria formosum*

A brachial valve was sectioned (fig. 37) which showed the cardinal plate not connecting with the socket plate. A faint median septum was present in the anterior part of the umbonal region.

Horizon. Rare in the highest 100 feet of the Hachita formation, Escabrosa group, Blue Mountain, Arizona; Animas Mountains and Big Hatchet Mountains, New Mexico.

Remarks. Positive identification for the genus *Beecheria* can be made only upon internal structures of the brachial valve. The ovate outline of the shell, rounded in the front, and the absence of a sinus or fold on either valve are traits highly characteristic of the species *B. formosum*.

Beecheria cf. *B. chouteauensis* (Weller)

Pl. 9, fig. 20

Dielasma formosa, Hall, J., and Clarke, J. M., 1894, New York Nat. Hist. Paleont., v. 8, pt. 2, pl. 81, fig. 24 (*non* fig. 12-23 or 25-26).

Dielasma chouteauensis, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 257-259, pl. 32, fig. 1-17.

Dielasma chouteauensis, Branson, E. B., 1938, Missouri Univ. Studies, v. 8, p. 55-56, pl. 5, fig. 28-30.

Dielasma chouteauensis, Armstrong, A. K., 1958, N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Mem. 5, p. 26-27, pl. 2, fig. 1-7, 11-14, 17-28, 31.

Description. The species is represented by broken and disassociated valves. One exfoliated, immature, brachial valve was studied in detail. Its dimensions are: length 15 mm, width 10.5 mm, and thickness 3.5 mm. The brachial valve is subovate in outline and is strongly convex posterior to the middle. The surface arched strongly to the posterolateral margins, much more gently to the anterolateral and anterior margins. Fold is absent. Faint concentric lines of growth are present. Shell structure is finely punctate.

Although the specimen was recrystallized, traces of the internal structure could be observed. The pedicle valve has dental lamellae which are well developed but do not meet the socket plate. Cruras absent. Median septum faint.

Horizon. Member A, Keating formation, some 60 to 70 feet above the Devonian-Mississippian contact in the Big Hatchet Mountains, New Mexico, and Blue Mountain, Chiricahua Mountains, Arizona.

Remarks. Although the specimens studied were extremely poorly preserved, the contour of the shell and particularly the nature of the interior of the brachial valve are diagnostic of *Beecheria chouteauensis*. This species is apparently widespread throughout the Cordilleran region in beds of upper Kinderhook and lower Osage age. In west-central New Mexico it is abundant in the lower Osage Caloso formation (Armstrong, 1958b) and has been reported by Brown (1952), and Harker and Raasch (1958) in the Banff series of Alberta, Canada.

Genus **DIELASMA** King, 1859

Dielasma, King, W., 1859, Dublin Univ., Zool. and Bot. Assoc. Proc., v. 1, pt. 3, p. 260-261.

Dielasmoides, Weller, S., 1910, Jour. Geol., v. 19, p. 443-444.

Dielasmoides, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 251-254.

Dielasma, Dunbar, C. O., 1955, Meddel. om Gronland, bd. 110, nr. 3, p. 117.

Dielasma, Stehli, F. G., 1956, Jour. Paleont., v. 30, n. 2, p. 299-302.

Non Epithyris Phillips, King, W., 1850, Palaeont. Soc., v. 3, Permian fossils of England (*Epithyris* Phillips, 1841, Geol. Soc. Great Britain Mem., p. 178; a Jurassic terebratula).

Non Dielasma, Hall, J., and Clarke, J. M., 1894, Introduction to the study of brachiopods, pt. 2, p. 295.

Non Dielasma, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 256-257.

Non Dielasma, Dunbar, C. O., and Condra, G. E., 1932, Nebraska Geol. Surv. Bull. 5, p. 303-304.

Non Dielasma, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 364.

Type Species. (Original designation) *Terebratulites elongatus*, Schlotheim, E. F., 1816 (Beitrage zur Naturgeschichte der Versteinerungen in geognostische Hinsicht: Akad. Wiss. Munchen, Denkschriften, Math.-phys. Kl., v. 6, p. 27, fig. 7a-7c). Permian Hohlen Kalkstein, Thuringia (Species type destroyed during W.W. 2, lectotype, chosen by Stehli, 1956, p. 299).

Range. Lower Mississippian-Permian.

Diagnosis. Shell is terebratuliform, with or without a pedicle sinus. Pedicle interior has well-developed dental plates. Brachial interior has an imperfect cardinal process or none at all. Cardinal plates divided into two plates which may or may not be discrete and connect without other attachment. Socket plates reach to the floor of the valve. Crural plates may or may not be present, but if present, they arise from the cardinal plates. The crural points are normal.

Remarks. Stehli (1956) conclusively demonstrated by a detailed study of the pertinent literature and by sectioning neotype material of *Terebratula elongatus* Schlotheim, the type species of *Dielasma* King, that the genus had been incorrectly understood by Hall and Clarke (1894, p. 295) when they introduced it into the American literature. They used as their example of the genus *Dielasma*, *Terebratula bovidens* Morten, in which the cardinal plates are obsolete between the socket plates and the floor of the valve. This misconception of the genus *Dielasma* was followed by Weller (1914, p. 256-257), who further restricted the genus by excluding all forms which did not show the internal characteristics of *Terebratula bovidens*. Forms having the internal characteristics of *Terebratula elongatus* were placed by Weller (1910, p. 443-444) in his new genus *Dielasmoides*. Dunbar and Condra (1932, p. 303-304) followed Weller's misconception of the genus *Dielasma* King. Weller used his new species *D. bisinuata* as the type species for his genus *Dielasmoides*. *D. bisinuata* differs from the type species of *Dielasma*, *D. elongatus* (Schlotheim) in not possessing a cardinal process. Sanders (in Easton et al., 1958, p. 50) recognized *Dielasma* King as restricted by Stehli (1956, p. 299) on the basis of the absence of a cardinal process in *Dielasmoides*. Stehli (personal communication, 1960) found that the presence or absence of a cardinal process in the Dielasmatidae is not consistent and varies within a genus or a species. The writer agrees with Stehli, that the presence or absence of a cardinal process can at best be a specific trait.

Dielasma bisinuata (Weller)

Pl. 9, fig. I-15

Dielasmoides bisinuata, Weller, S., 1911, Jour. Geol., v. 19, p. 443, fig. 3a-3g.

Dielasmoides bisinuata, Weller, S., 1914, Illinois Geol. Surv. Mon. 1, p. 254-255, pl. 31, fig. 19-24.

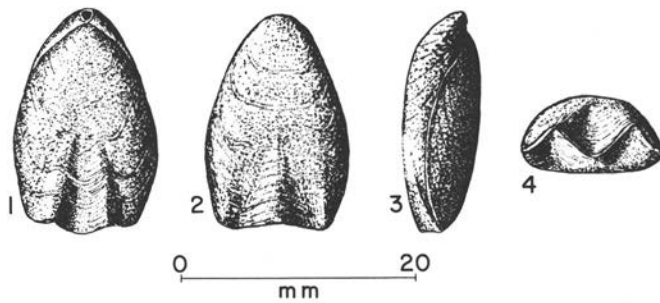


Figure 38

INKED DRAWING OF *Dielasma bisinuata*; 1, brachial, 2, pedicle, 3, lateral, 4, anterior views

Dielasmoides bisinuatus, Hernon, R. J., 1935, Jour. Paleont., v. 9, n. 8, p. 684.

Diagnosis. Terebratuloid shell of ovate to subtriangular shape, greatest width towards anterior margin, anterior portion of pedicle valve with ventral biplication (intraplicate), brachial valve with two folds.



Figure 39

SERIAL SECTIONS OF *Dielasma bisinuata*

Description. Shell (fig. 38) medium size, ovate to subtriangular in outline; the greatest width near the anterior third of the shell. The dimensions in mm (fig. 40) of a suite of complete but somewhat crushed specimens are:

Specimen	Length	Width	Thickness
1.	18.0	13.5	7.5
2.	18.0	12.0	8.0
3.	18.0	12.0	7.0
4.	14.0	12.5	7.5
5.	13.5	9.0	6.5
6.	15.0	11.0	6.0
7.	14.0	10.5	6.0
8.	12.0	9.0	5.5
9.	15.0	11.0	7.0
10.	21.5	15.0	8.5
11.	12.0	9.0	5.0
12.	12.5	10.0	6.0
13.	11.0	8.0	9.5
14.	10.5	10.0	5.5
15.	11.0	8.0	5.0
16.	10.0	7.0	5.0
17.	9.0	6.5	9.5

Pedicle valve moderately convex, greatest convexity posterior to the middle. At umbo and median area, valve is gently curved except along posterolateral margins where shell sur-

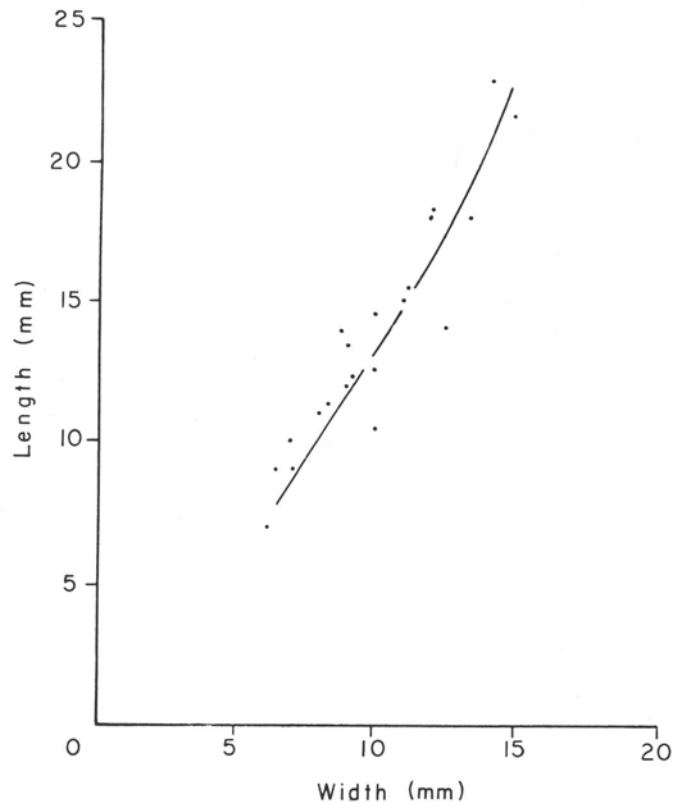


Figure 40

SCATTER PLOT OF *Dielasma bisinuata* LENGTH:WIDTH RATIO

face is strongly curved to meet opposite valve. Near middle of the shell there begin two broadly rounded sinuses, which strengthen anteriorly.

Brachial valve equal to or slightly more convex than pedicle, with greatest convexity posterior to the middle. Median portion of valve in anterior one-half depressed into a shallow rounded sinus. Both sides of the sinus are marked by broad bounding folds which are slightly elevated above the surface of the shell. The beak is pointed and incurved beneath that of the opposite valve.

Pedicle valve has well-developed dental plates which are present in the posterior one-fifth of the valve. Brachial valve (fig. 39) has the socket plates lying at the plane of valve with its inner margins joined by the cardinal plates. These join at the floor of the valve. Cardinal process or diductor muscle attachment and crura absent.

Remarks. The *Dielasma bisinuata* from the Paradise formation differs from those shown by Weller (1914, pl. 31, fig. 19-24) in that it possesses an anterior margin which is much less rounded and more linear, also the folds and sinuses are better developed. Stehli (1956, p. 301) noted that adult neotype material of *D. bisinuata* which he had examined shows a uniplicate more often than it shows a sulcinate anterior commissure. The majority of mature specimens from the Paradise formation possessed the sulcinate condition.

Horizon. Highest part of the Hachita formation and lower part of the Paradise formation at Blue Mountain, Chiricahua Mountains, Arizona, and the Big Hatchet Mountains of New Mexico. Also abundant in the Chester-age Helms formation in the southern Sacramento Mountains, New Mexico.

Phylum **ECHINODERMATA**

Class **BLASTOIDEA** Say, 1825

Order **EUBLASTOIDEA** Bather, 1899

Suborder **SPIRACULATA** Jackel, 1896

Family **ORBITREMITIDAE** Bather, 1960

Genus **CRYPTOBLASTUS** Etheridge and Carpenter, 1886

Cryptoblastus, Etheridge, R., and Carpenter, P. H., 1886, British Mus. Catalogue Blastoidea, p. 229-232.

Cryptoblastus, Cline, L. M., 1937, Jour. Paleont., v. 11, n. 8, p. 634-636.

Cryptoblastus, Cline, L. M., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 137.

Cryptoblastus, Bergouniour, F. M., 1953, Traite de Paleontologie, pt. 3, p. 647.

Type Species. (Original designation) *Pentremites melo*, Owen, D. D., and Shumard, B. F., 1850, Phila. Acad. Nat. Sci. Jour., v. 2, pt. 1, p. 65, pl. 7, fig. 14a-14c, Burlington limestone.

Range. The genus is known only from Mississippian beds of North America, from strata of upper Kinderhook to lower Meramec age.

Diagnosis. The following are those traits cited as characteristic of the genus *Cryptoblastus* by Etheridge and Carpenter (1886, p. 229-232) and Cline (1937, p. 634-635). Calyx subglobose with flattened or hollow base. Basal plates small. Radials long, deeply incised. Deltoid plates small, inconspicuous. Four anterior deltoidal plates are each pierced by two spiracle openings; posterior deltoidal plates have the two spiracles coalescing with the anus. Ambulacra narrow, linear, almost reach length of calyx. Lancet plates separated from the radials by a hydrospire plate which does not extend above the radial deltoid suture, but above this line lancet plate meets the deltoids without leaving any hydrospire pores. Four hydrospire folds beneath each ambulacrum grouped in pairs, 2 to each side.

Remarks. *Cryptoblastus* can be distinguished from *Orbitremites*, which has only four spiracles that pierce the apices of the deltoids, and only two hydrospire folds under each ambulacra. *Cryptoblastus* differs from *Schizoblastus* which may have slightly protruding basals, radials which generally reach less than half the length of the calyx, and deltoids which extend half or more the length of the calyx. *Schizoblastus*, like *Cryptoblastus*, has four hydrospire folds under each ambulacra.

Cryptoblastus melo (Owen and Shumard)

Pl. 9, fig. 31-40

Pentremites melo, Owen, D. D., and Shumard, B. F., 1850, Phila. Acad. Nat. Sci. Jour., v. 2, pt. 1, p. 65, pl. 7, fig. 14a-14c.

Cryptoblastus melo, Hambach, G., 1903, St. Louis Acad. Sci. Trans., v. 13, p. 40.

Cryptoblastus melo, Etheridge, R., and Carpenter, P. H., 1886, British Mus. Catalogue Blastoidea, p. 232-234, pl. 7, fig. 14-15.

Cryptoblastus melo, Keyes, R. R., 1894, Missouri Geol. Surv., p. 139, pl. I 8, fig. 7a-7b.

Cryptoblastus melo, Cline, L. M., 1937, Jour. Paleont., v. I 1, n. 8, p. 636-637.

Cryptoblastus melo, Cline, L. M., 1943, in Shimer, H. W., and Shrock, R. R., Index fossils of North America, p. 137, pl. 51, fig. 32-34.

For a complete bibliography of the species the reader is referred to Cline (1937, p. 636).

Diagnosis. The calyx is melon-shaped and is higher than wide. There are basal plates within the columnar cavity. The radial plates are very large. The deltoids are small. Ambulacra are narrow and reach almost full length of the calyx. There are eight spiracles and a large oval anal opening with a star-shaped mouth. Four hydrospire folds are under

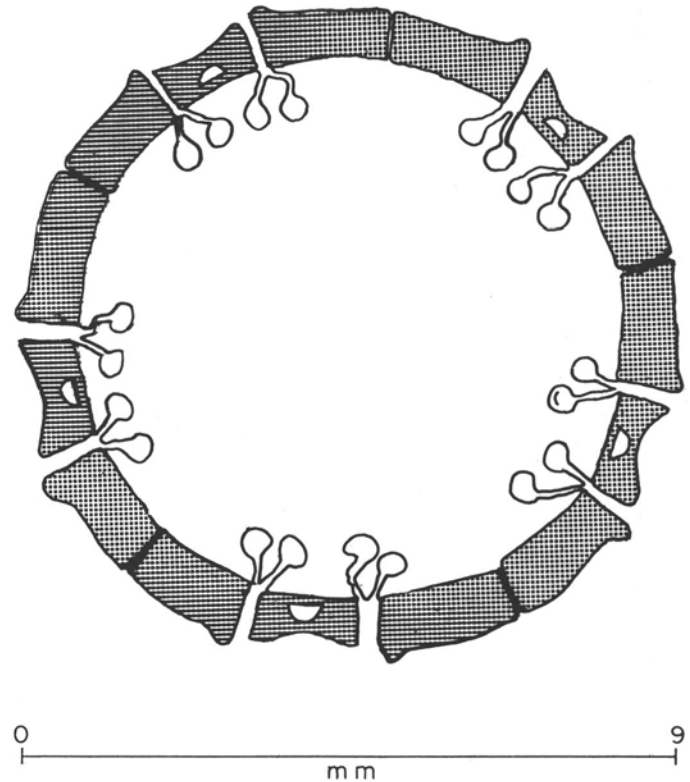


Figure 41
TRANSVERSE SECTION OF *Cryptoblastus melo*

each ambulacra.

Description. The calyx is (fig. 41) melon-shaped (prolate), slightly higher than wide. The dimensions of nine specimens in mm are:

Height	Width
10.0	9.0
10.0	8.5
9.5	9.5
9.0	9.0
9.0	8.5
8.5	8.0
8.0	7.0
7.0	6.5
5.5	5.0

The basal plates rest within and are completely hidden in a columnar cavity. Columnar cavities are rays 2.0 mm to 2.5 mm in diameter. Size and shape of stem column are unknown. Radial plates are large and form almost all of the calyx. Radials reach almost the full length of the calyx but at their apex are

truncated by the deltoids. Surface of the radial bounding the ambulacra is produced into a ridge which is progressively stronger aborally. Deltoids are very small and are almost invisible from the side. Ambulacra expand slightly to radial deltid suture, then contract gently aborally. Ambulacra reach almost the full length of the calyx. Average specimen has ambulacra which are 8.5 mm long and near the mouth are 1.6 mm wide. Silicification had destroyed the surface ornamentation and the finer details of the ambulacra on the specimens studied. Eight spiracles pierce deltoids near their apex. The mouth is large and star-shaped. The anal spiracle is large, oval. Part of the deltoidal plate is modified and projected into a hood over the anal spiracle. Hydrosfire folds are stalked and are sac-like in section; four are present in each ambulacrum.

Horizon. *Cryptoblastus melo* is one of the first identifiable fossils found in the basal horizons of the Escabrosa group, in the Chiricahua Mountains of Arizona and the Klondike Hills and Big Hatchet Mountains of New Mexico. It is found most frequently in the encrinites beneath the coral zone of member A, Keating formation. Poorly preserved specimens of a blastoid with the hydrosfire folds of *Cryptoblastus* have been found in the lower part of the Hachita formation at Blue Mountain, Chiricahua Mountains, Arizona. These specimens appear to have the general shape and plate arrangement of *Cryptoblastus melo*. Because some doubt exists as to their exact taxonomic position, they are considered in this report as *Cryptoblastus?* aff. *C. melo*.

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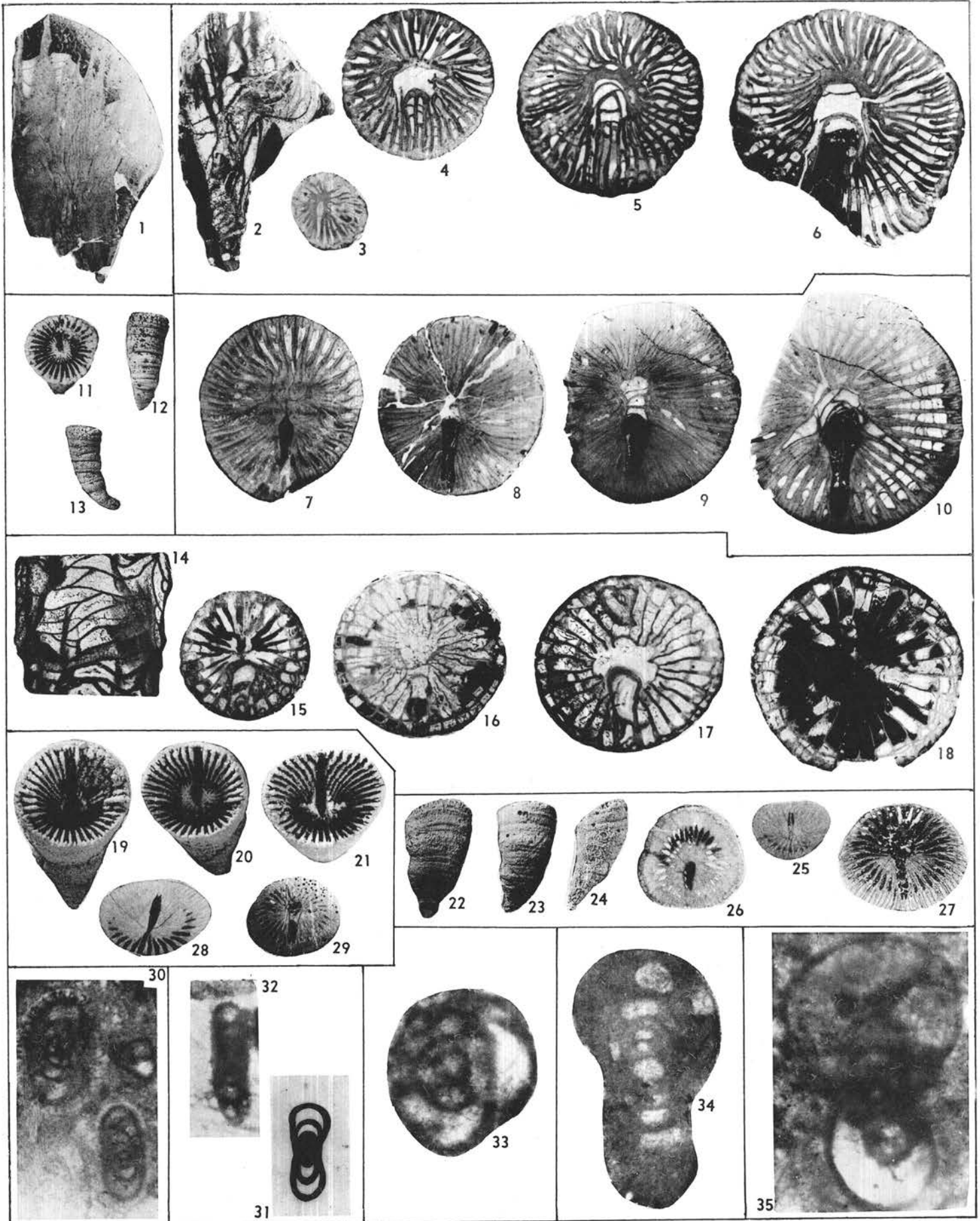
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PLATES 1-12

WITH EXPLANATIONS

PLATE 1

- 2-6. *Hapsiphyllum nunnensis*, n. sp. $\times 2$, 2. longitudinal section; 3-6 transverse sections from middle neamic stage to late ephebic; note in 5 and 6 the fusion of minor septa to major. Nunn member, Lake Valley formation, Lake Valley, New Mexico.
- 1, 7-10 *Amplexizaphrentis northropi*, n. sp. $\times 2$, 7. transverse section at early ephebic state; 1. longitudinal section; 8-10. series of transverse sections from very early to late ephebic stage. Top of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.
- 11-13. *Homalophyllites circularis* Easton. $\times 1$, 12-13. side views of corallite; $\times 2$, 11. view of calyx. Member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
- 14-18. *Caninia cornicipiae* Michelin. $\times 2$, 15-18. transverse sections from the early to late ephebic stages; 14. longitudinal section, late ephebic stage. Nunn member, Lake Valley formation, Lake Valley, New Mexico.
- 19-29. *Homalophyllites calceolus* (White) $\times 2$, 19-21. view of calyx of three etched specimens; 22-24. cardinal side of corallite; 19-24. from the Klondike Hills, New Mexico. 25-27. Transverse sections from neamic to ephebic stages; 28, 29. transverse sections of early ephebic stages.
30. *Paramillerella tortula* D. Zeller. $\times 50$, somewhat oblique vertical axial section; middle of the Paradise formation, Big Hatchet Mountains, New Mexico.
- 31, 32. *Millerella*(?) sp. $\times 50$, 31. an inked drawing made from observations through the microscope; 32. a photomicrograph of the same individual; upper Hachita formation (Meramec age), Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
33. *Paraendothyra* sp. $\times 50$, oblique section; member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
34. *Endothyra symmetrica* E. J. Zeller. $\times 50$, vertical axial section; upper Hachita formation (Meramec age), Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
35. *Endothyra* sp. $\times 50$, vertical axial section; member A, Keating formation (Fern Glen age), Escabrosa group, Klondike Hills, New Mexico.



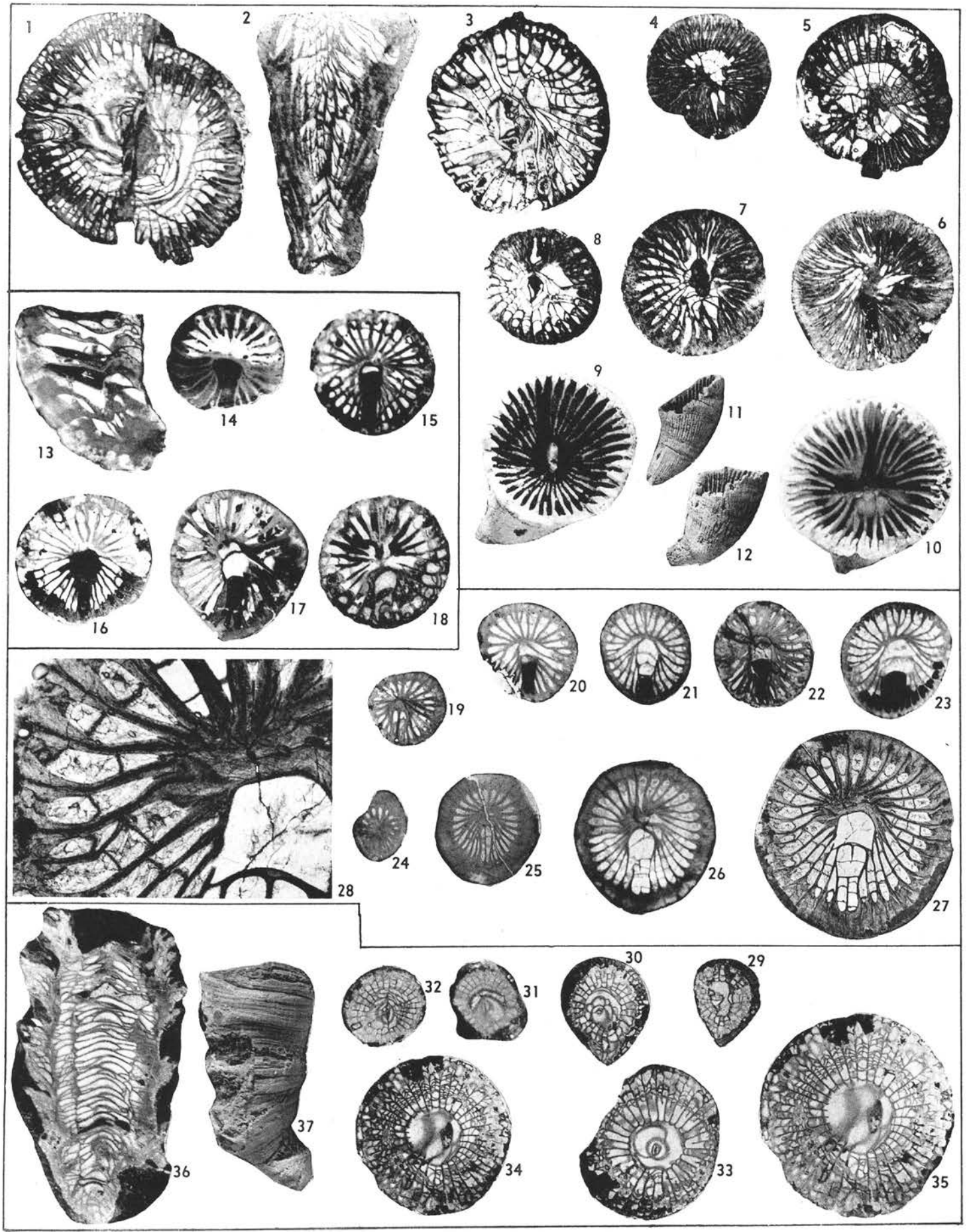
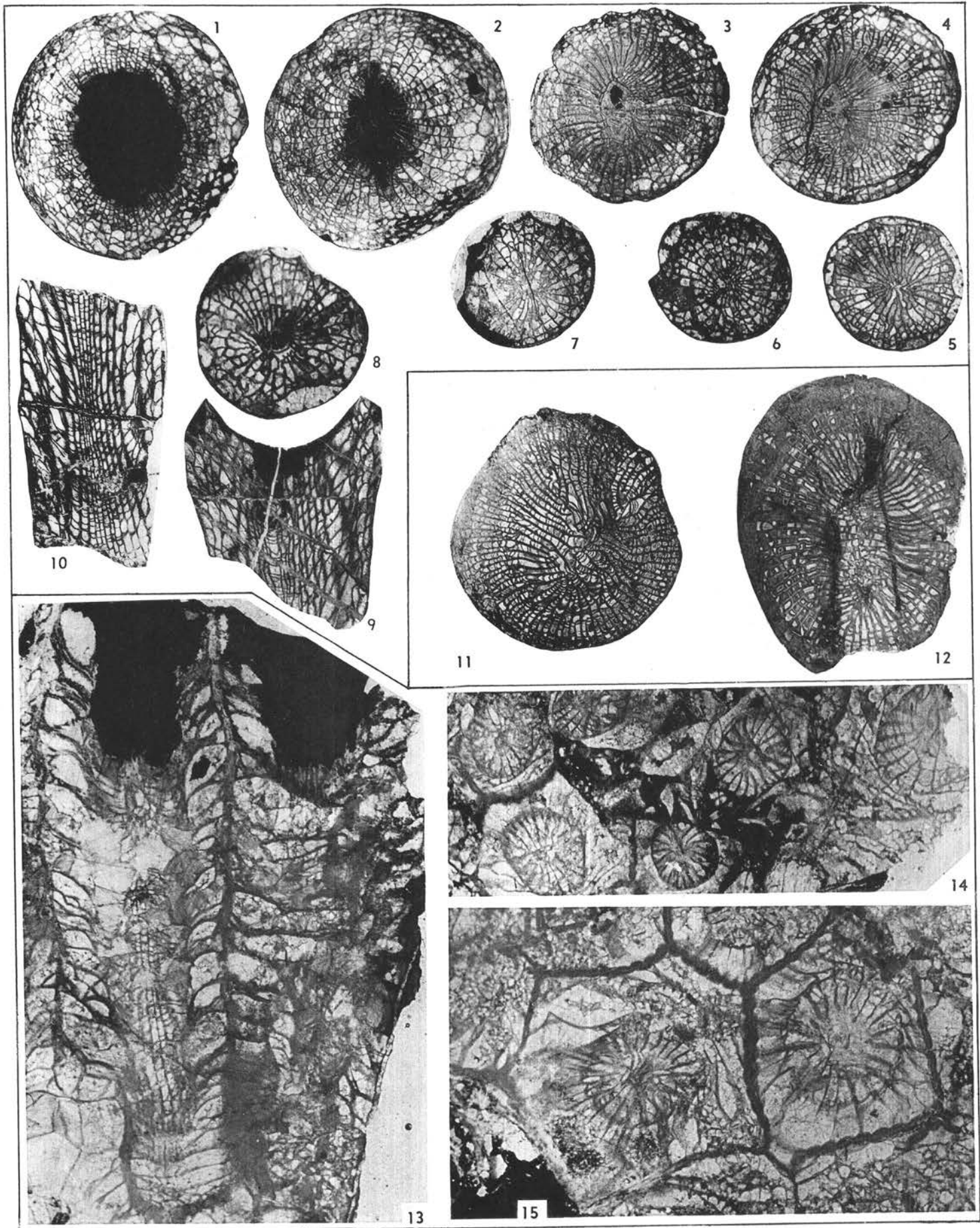


PLATE 2

- 1-8. *Rylstonia teres* Girty. $\times 2$, 1. transverse section of late ephebic stage; 2. longitudinal section illustrating the columella and the tabulae; 3. transverse section at the ephebic stage with a weakly developed columella; 5. transverse section at the ephebic stage with thickened septa in the dissepimentarium; 4. transverse section at the early ephebic stage; 6-8. transverse sections at the late to early ephebic stages, note thickening of septa and fusing of minor septa to major.
- 9-12. *Rylstonia teres* Girty. $\times 2$, 9, 10. view of calyx of two mature etched specimens; $\times 1$, 11, 12. Side view of corallites. Member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
- 13-18. *Amplexizaphrentis hespere* (Grove) $\times 2$, specimens are silicified; 13. longitudinal section; 14. transverse sections in the early ephebic stage; 15, 16. holotype, transverse sections in ephebic and late ephebic stages; 17, 18. transverse section in ephebic stage.
- 19-28. *Amplexizaphrentis sonoraensis*, n. sp. $\times 2$, 19-28. transverse sections from early to late ephebic stage; sections are from various individuals. 24-26. transverse sections of the holotype from late neamic to late ephebic stages; $\times 3$, 27. transverse section of a well-preserved mature specimen; $\times 6$, 28. enlargement of 27 showing the nature of the septal tissue and the fusion of the septa above the cardinal fossula.
- 29-37. *Koninckophyllum elpasoensis*, n. sp. $\times 2$, 29-35. series of transverse sections from late ephebic to late neamic stage; 36. longitudinal section; $\times 1$, 37. side view of weathered corallite. Helms formation (Chester age), Franklin Mountains, Texas.

PLATE 3

- 1-10. *Vesiculophyllum sutherlandi*, n. sp. $\times 2$, 1. transverse section in the calyx illustrating the nature of the dissepimentarium; 2. section at base of calyx; 3, 4. sections in the late ephebic stage; 5-7. sections of an immature individual illustrating the nature of the septa and the gradual disappearance of the dissepimentarium in earlier growth stages; $\times 3$, 8. early ephebic stage illustrating the withdrawn septa and weak dissepimentarium; $\times 2$, 9. longitudinal section of the calyx in the late ephebic stage; 10. longitudinal section in the early ephebic stage. Member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
11. *Vesiculophyllum* sp. A. $\times 2$, transverse section; note the absence of the epitheca. Hachita formation, Tombstone Hills, Arizona.
12. *Vesiculophyllum* sp. B. $\times 2$, transverse section; Hachita formation, Big Hatchet Mountains, New Mexico.
- 13-15. *Lithostrotionella shimeri* (Crickmay) $\times 2.5$, 13. longitudinal section of a corallite, illustrating the weakly developed columella and the dissepimentarium; 14. transverse section of the corallum, specimen has been fractured; 15. transverse section of ephebic corallites. Black Prince limestone, Gunnison Hills, Arizona. United States Geological Survey Collection No. 13844.



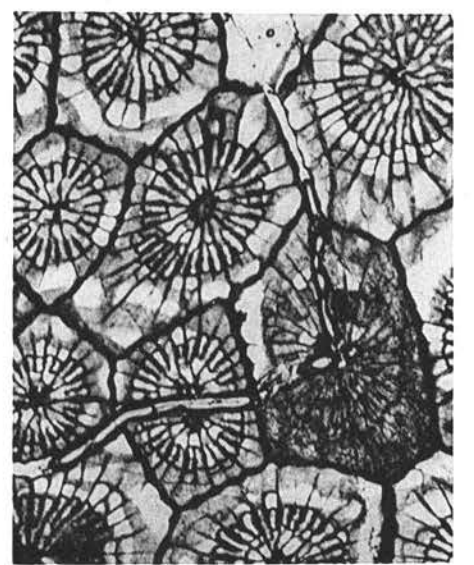
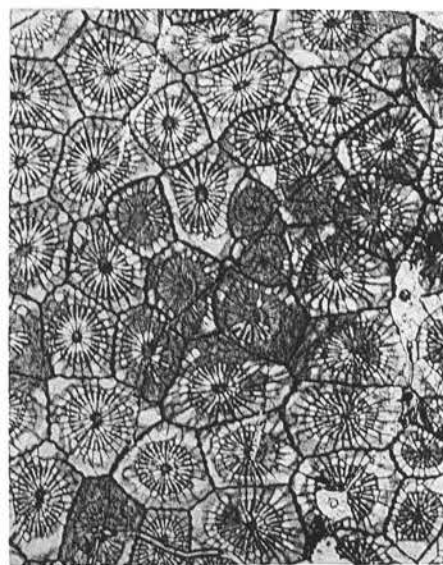
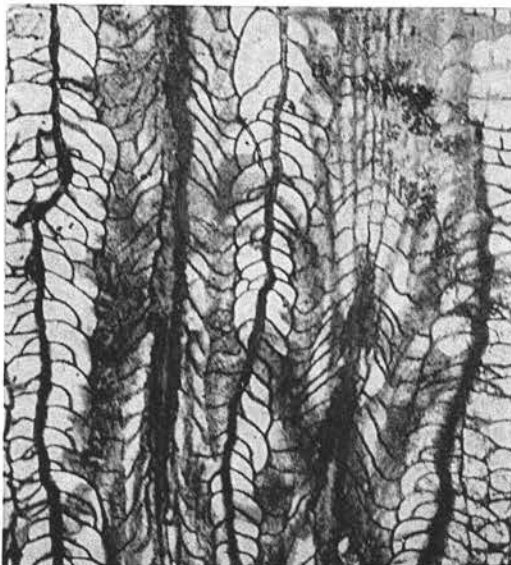
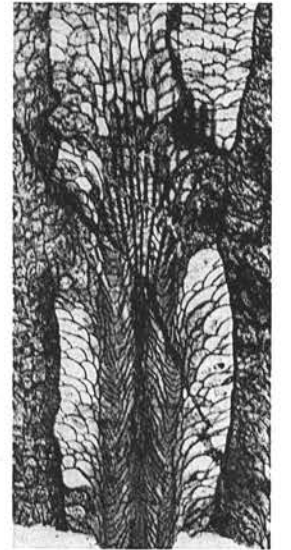
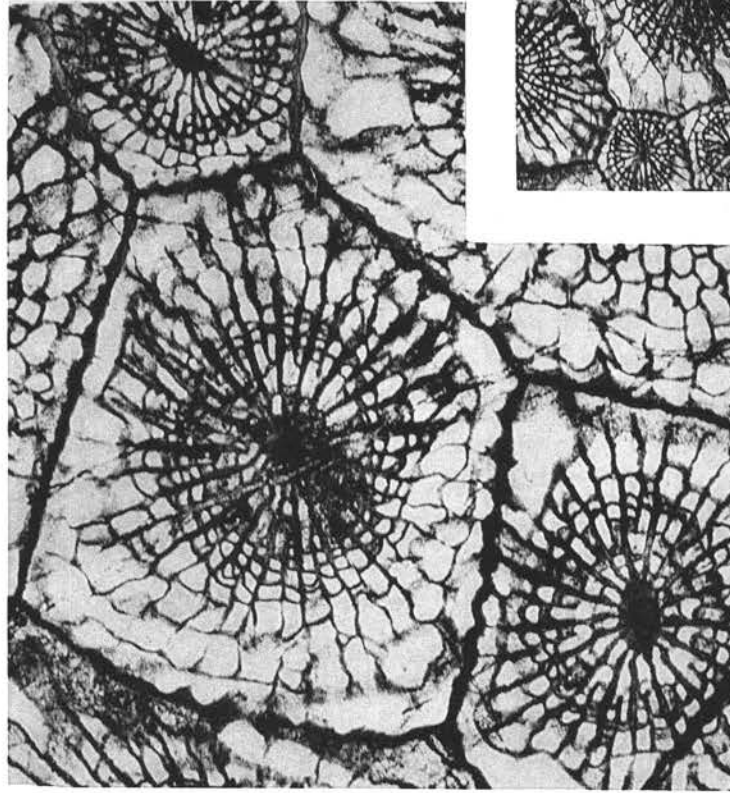
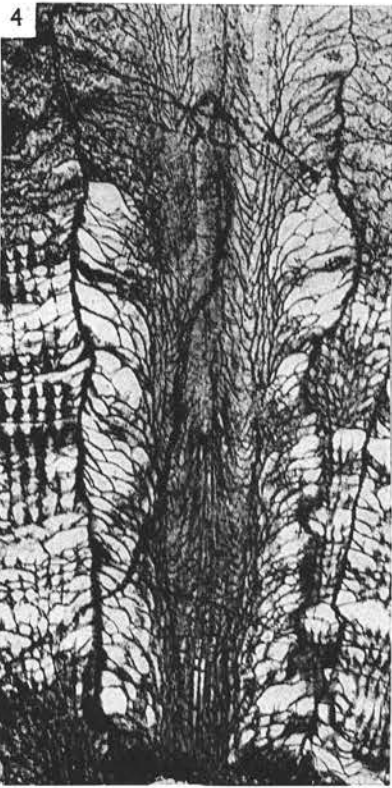
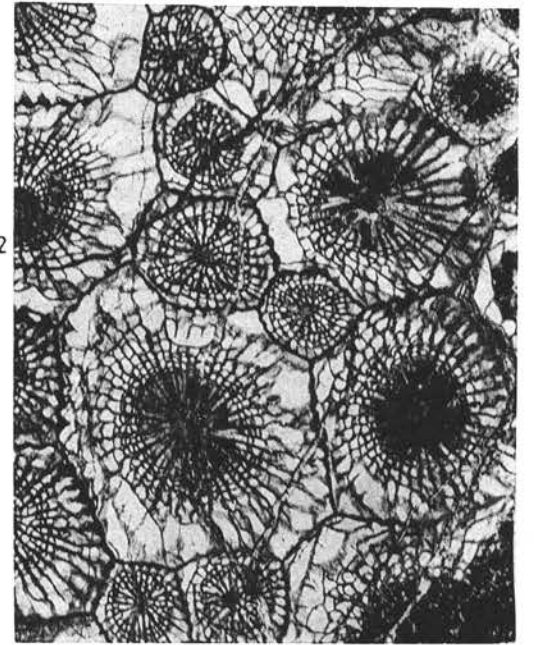
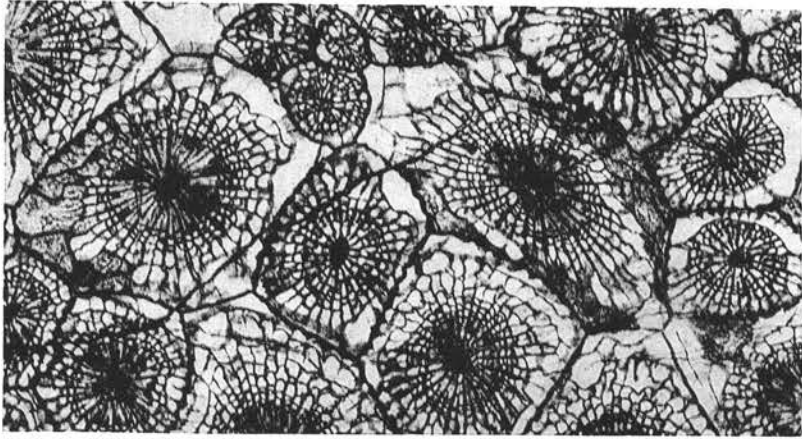
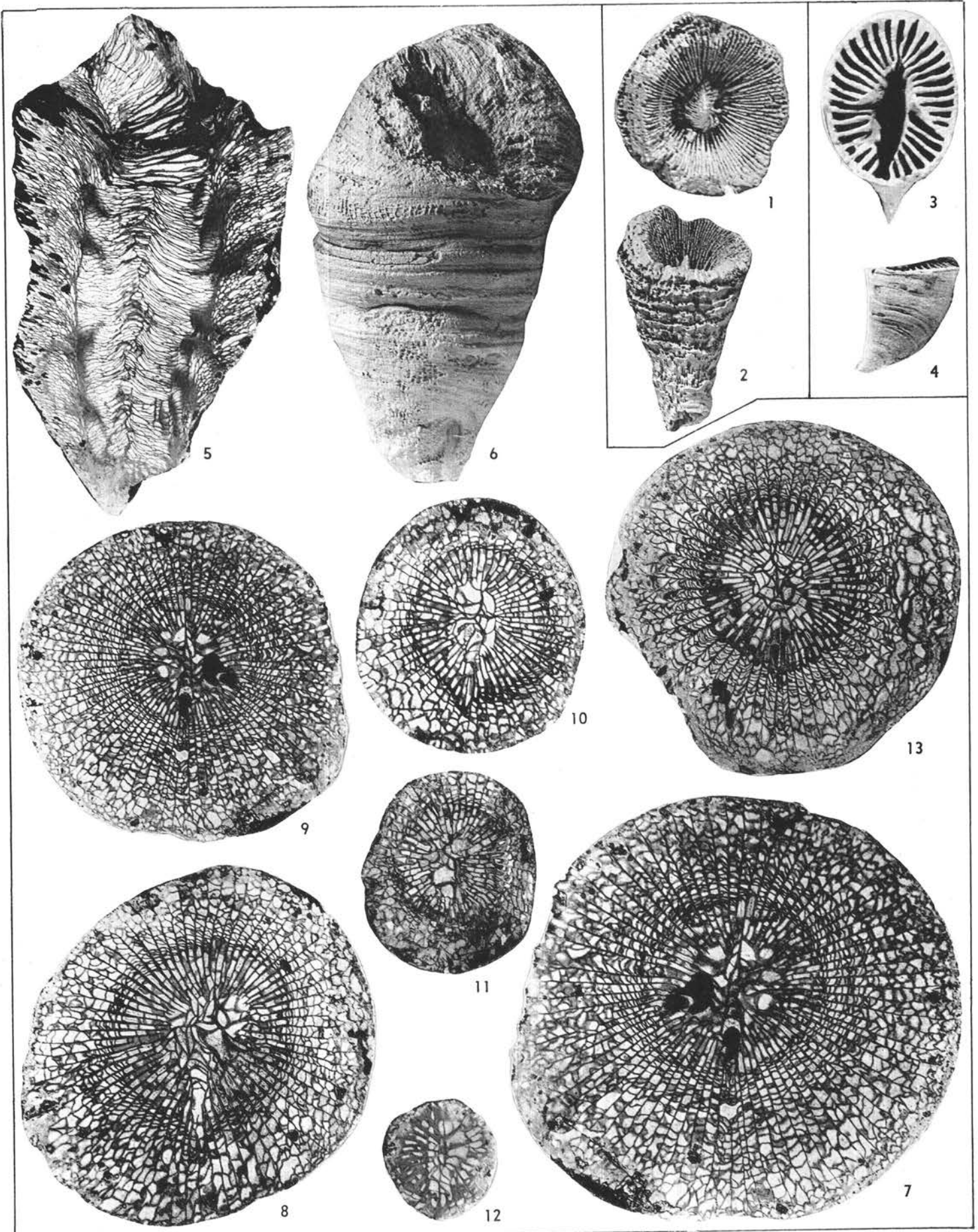


PLATE 4

- 1-5. *Lithostrotionella confluens* Easton, $\times 3$, 1, 2. transverse section of corallum; $\times 6$, 3. transverse section of corallum illustrating nature of columella; $\times 6$, 4. longitudinal section illustrating the columella, strongly up-arched tabulae and the well developed dissepimentarium; $\times 3$, 5. longitudinal section. Member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 6-8. *Lithostrotionella lochmanae* n. sp. one colony, $\times 3$, 6. transverse section of corallum; $\times 5$, 7. horizontal section illustrating nature of major and minor septa, and columella; $\times 5$, 8. longitudinal section illustrating the columella, strongly up-arched tabulae and the dissepiments. Member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.

PLATE 5

- 1-2. *Amygdalophyllum* sp. $\times 1$, 1. view of calyx, showing columella and absence of cardinal fossula; $\times 1.5$, 2. side view of corallite. Member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
- 3-4. *Amplexizaphrentis clinatus* (Greene) $\times 1$, 4. side view of corallite; $\times 2$, 3. view of calyx. Lower part of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.
- 5-6. *Dibunophyllum bipartitum konincki* (Milne-Edwards and Haime) $\times 1$, 6. view of weathered corallites; 5. longitudinal section of a mature specimen, note rejuvenescence. Helms formation (Chester age), Franklin Mountains, Texas.
- 7-13. *Dibunophyllum bipartitum konincki* (Milne-Edwards and Haime) $\times 1.5$, 7-12. transverse serial sections of holotype from late ephebic to neamic stage, figure 12 is $\times 2$; $\times 1.5$, 13. transverse section of another individual at the ephebic stage of growth; Helms formation (Chester age), Franklin Mountains, Texas.



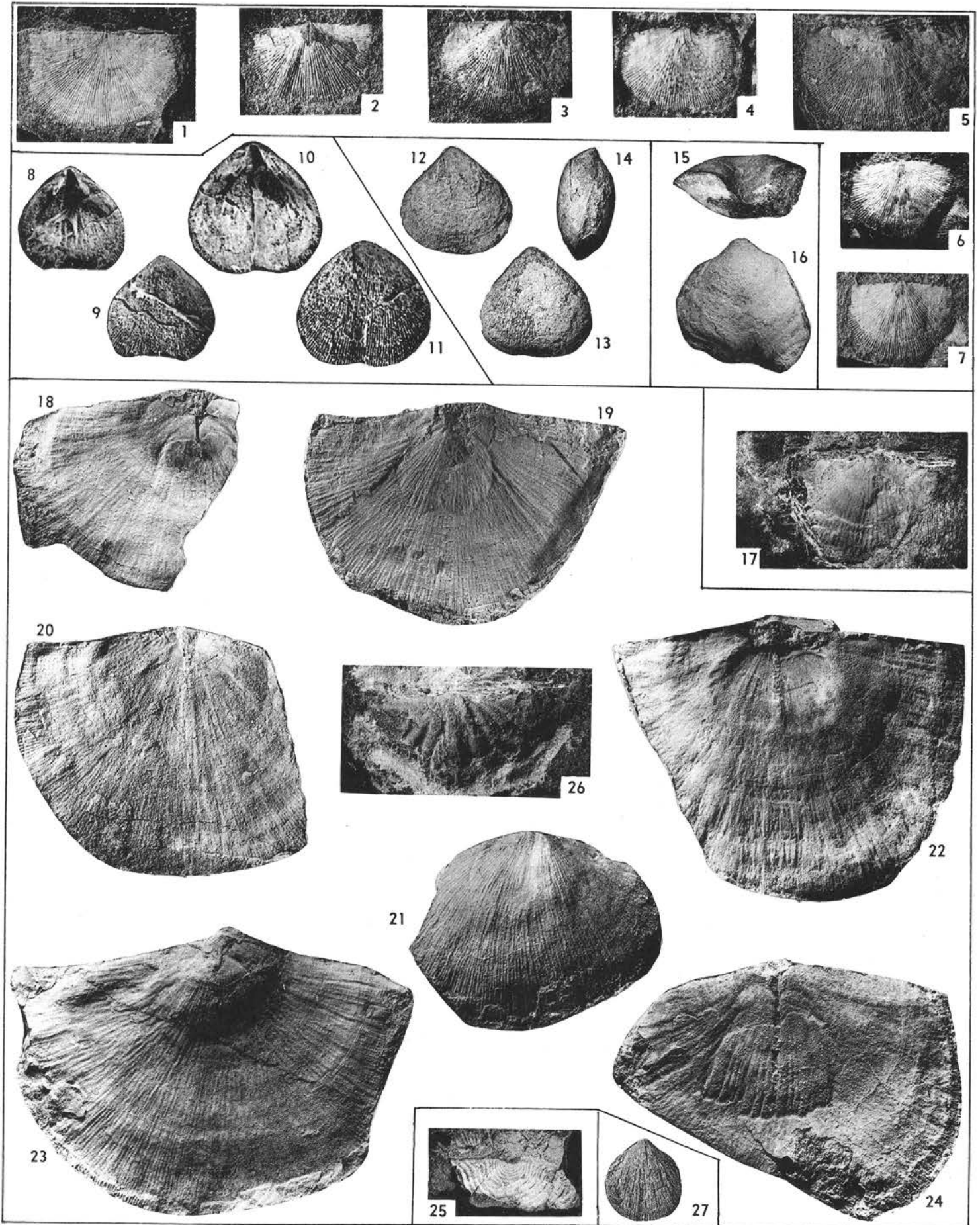
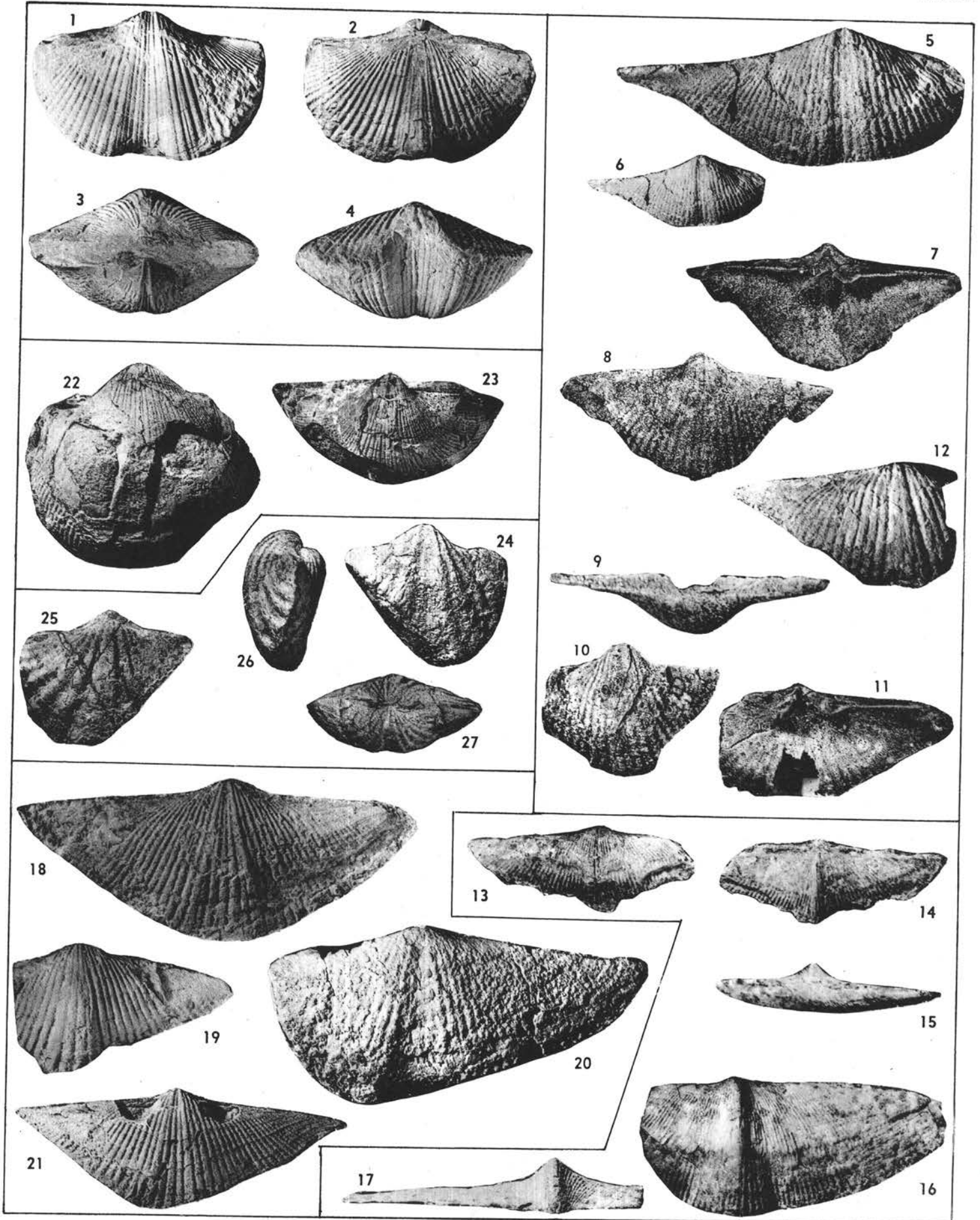


PLATE 6

- 1-7. *Chonetes klondikia* n. sp. $\times 2$, 1. brachial valve exterior; 2, 3. exfoliated pedicle valve; 4. pedicle valve interior; 5-7. pedicle valve exterior; upper part of member A, Keating formation, Klondike Hills, New Mexico.
- 8-11. *Rhipidomella jerseyensis* Weller $\times 2$, 8, 9. interior and exterior of an etched pedicle valve; 10, 11. interior and exterior of an etched pedicle valve. Top of member B, Keating formation, Big Hatchet Mountains, New Mexico.
- 12-14. *Perditocardinia dubia* (Hall) $\times 2$, 12. brachial; 13. pedicle; 14. lateral view of one individual. *Syringothyris subcuspidatus* zone (lower Meramec), Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 15-16. *Cleiothyridina* cf. *C. incrassata* (Hall) $\times 1$, 15. anterior; 16. pedicle view of an incomplete specimen. Highest beds of Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
17. *Chonetes* cf. *C. glenparkensis* Weller $\times 2$, incomplete pedicle valve; member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 18-24. *Werriea keokuk* (Hall) $\times 1$, 18. exfoliated pedicle valve; 19. exterior view of a pedicle valve; 20. interior of a pedicle valve; 21. exterior of a poorly preserved and immature brachial valve; 22. interior of a pedicle valve illustrating the median septum and the muscle scars; 23. exterior of a pedicle valve; 24. incomplete mold of a pedicle valve showing the median septum and dental lamellae. *Syringothyris subcuspidatus* zone (lower Meramec), Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
25. *Leptaena analoga* Phillips $\times 1$, pedicle valve of an incomplete specimen; member A, Keating formation, Blue Mountains, Arizona (no text description).
26. *Tylothyris* cf. *T. novamexicana* (Miller) $\times 2.5$; exfoliated pedicle valve; member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
27. *Cleiothyridina hirsuta* (Hall) $\times 2.5$, pedicle valve of an exfoliated individual. *Syringothyris subcuspidatus* zone (lower Meramec), Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.

PLATE 7

- 1-4. *Unispirifer vernonensis* (Swallow) \times 1.5, 1. pedicle; 2. brachial; 3. posterior; 4. anterior views of an almost complete specimen. Lower part of member B, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 5-12. *Unispirifer balki*, n. sp. All \times 2 except 6; 5. exterior of pedicle valve, holotype; 6. same as 5 but natural size; 7-9. interior, exterior, and posterior view of an etched pedicle valve; 10. exterior of an incomplete pedicle valve; 11. interior of pedicle valve; 12. exfoliated brachial valve. Specimens 5 and 12 from member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona. Specimens 7-11, member A, Keating formation, Klondike Hills, New Mexico.
- 13-17. *Unispirifer lateralis* (Hall) \times 2, 13-15. pedicle, brachial, and posterior views of an immature individual; 16, 17. pedicle and posterior views of one valve of a typical specimen. Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 18-21. *Imbrexia forbesi* (Norwood and Pratten) \times 2, 18. exfoliated pedicle valve; 19. incomplete brachial valve; 20. poorly silicified pedicle valve; 21. pedicle valve, illustrating lamellae. 18, 19. from top of member B, Keating formation, Big Hatchet Mountains, New Mexico; 19, 20. from top of member B, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 22-23. *Spirifer* cf. *S. gregeri* Weller. \times 1, 22. view of a badly exfoliated pedicle valve; 23. posterior view of pedicle valve. Member B, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 24-27. *Spirifer bifurcatus* Hall. \times 2, 24. pedicle; 25. brachial; 26. lateral; 27. posterior views of an exfoliated specimen. *Syringothyris subcuspidatus* zone (lower Meramec), Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.



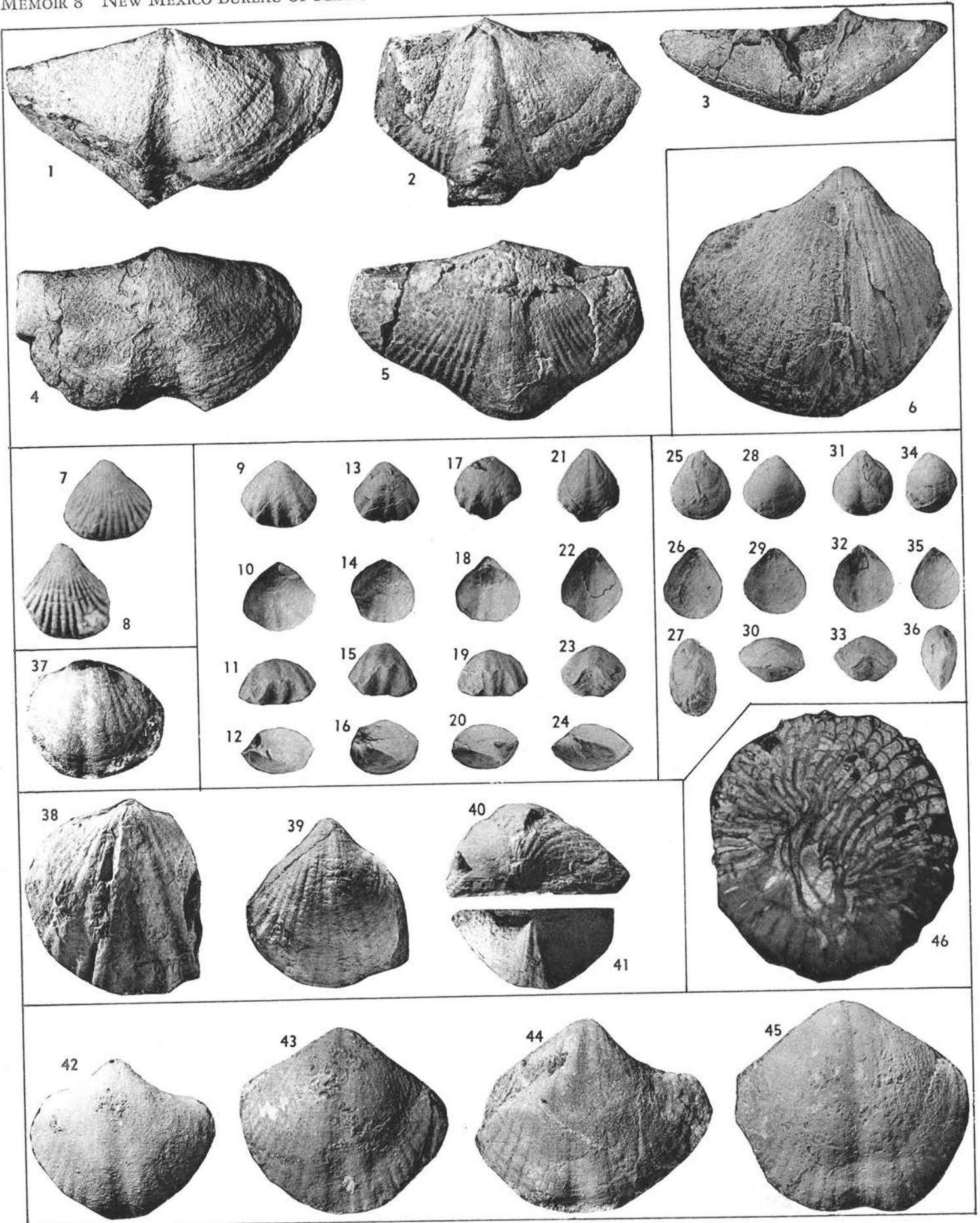
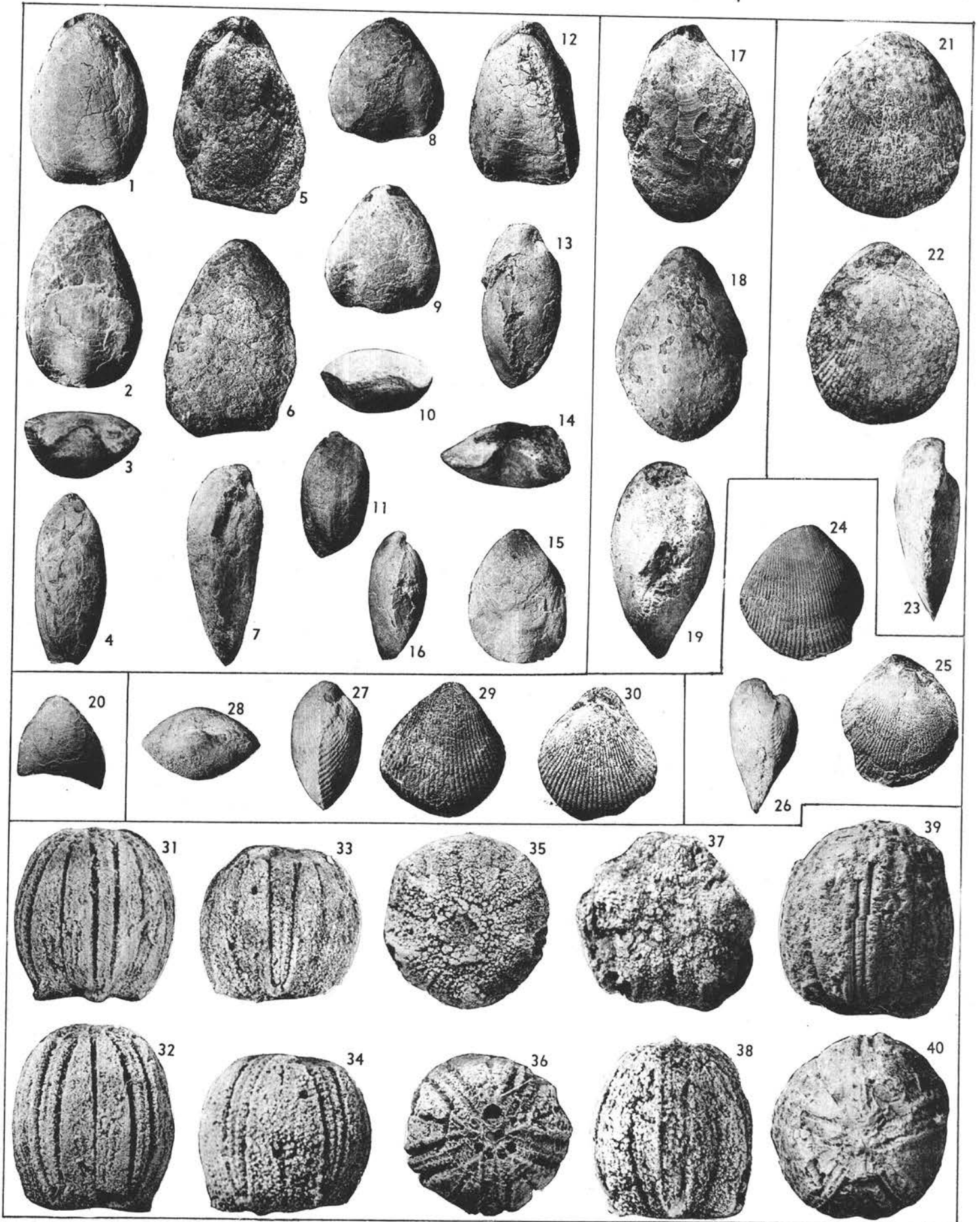


PLATE 8

- 1-5. *Syringothyris subcuspidatus* (Hall) \times 1, views of disarticulated valves. 1, 4. pedicle valves; 2, 5. brachial valves; 3. cardinal area of pedicle valve. *Syringothyris subcuspidatus* zone (lower Meramec), Hachita formation, Big Hatchet Mountains, New Mexico.
6. *Brachythyris subcardiiformis* (Hall) \times 1.5, incomplete pedicle valve; *Syringothyris subcuspidatus* zone, Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 7, 8. *Camarotoechia tuta* (Miller) \times 2.5, 7, 8. pedicle valve. Base of member A, Keating formation, Big Hatchet Mountains, New Mexico.
- 9-24. *Composita trinuclea* (Hall) \times 1.3, 9-12, 13-16, 17-20. pedicle, brachial, anterior, and later views of nearly perfect individuals. 21-24. pedicle, brachial, anterior, and lateral views of an individual which approaches Hernon's (1935) *C. "deltoides."* All from the lower part of the Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 25-36. *Composita globosa* Weller. \times 1.3, 25-27, 34-36. pedicle, brachial, and lateral views of two individuals; 28-30, 31-33. pedicle, brachial, and anterior views of two individuals. All from member B, Keating formation, Klondike Hills, New Mexico.
37. *Brachythyris peculiaris* (Shumard) \times 1.5, incomplete pedicle valve; member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 38-41. *Brachythyris ozarkensis* Snider. \times 1.5, 38. brachial valve; 39. pedicle valve; 40. anterior view of brachial valve; 41. anterior view of pedicle valve. Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 42-45. *Brachythyris suborbicularis* (Hall) \times 1.5, 42-45. a series of poorly preserved pedicle valves, lower 100 feet of Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.
46. *Vesiculophyllum incrassatum* (Easton and Gutschick) \times 2.2, transverse section at ephebic stage of corallite; lower part of member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona.

PLATE 9

- 1-16. *Dielasma bisinuata* (Weller) \times 2, 1. brachial; 2. pedicle; 3, 4. anterior and lateral views of a typical specimen; 5. brachial; 6. pedicle; 7. lateral views of a crushed specimen with an originally weakly developed fold and sinus. 8. brachial; 9. pedicle; 10. anterior; 11. lateral views of a specimen which is short, wide, and has a truncated anterior margin; 12. brachial; 13. lateral; 14. anterior views of a specimen which has its greatest width near the anterior margin; 15. lateral; and 16. pedicle views of an immature specimen. Specimens are from the lower part of the Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 17-19. *Beecheria formosum* (Hall) \times 2, 17. brachial; 18. pedicle; 19. lateral views of an exfoliated specimen. *Syringothyris subcuspidatus* zone, Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
20. *Beecheria* cf. *B. chouteauensis* (Weller) \times 2, brachial valve of an incomplete specimen. Member A of the Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
- 21-23. *Eumetria verneuilliana* (Hall) \times 2, 21. pedicle; 22. brachial; 23. lateral views of a robust, crushed and flattened specimen from the *Syringothyris subcuspidatus* zone, Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
- 24-26. *Eumetria costata* (Hall) \times 2, 24. pedicle; 25. brachial; 26. lateral views of a nearly complete specimen. Upper fourth of the Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 27-30. *Eumetria vera* (Hall) \times 2, 27. posterior; 28. lateral; 29. pedicle; 30. brachial views of a nearly complete individual. Lower fourth of the Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
- 31-38. *Cryptoblastus melo* (Owen and Shumard) \times 4, 31-32, 36. ambulacral; interray and oral views of one specimen; 33-35. ambulacral, interray, aboral view of one specimen; 37, 38. aboral, ambulacral view of one specimen. Member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
- 39-40. *Cryptoblastus?* aff. *C. melo* (Owen and Shumard) \times 3, 39, 40, oral and ambulacral view of one specimen; Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.



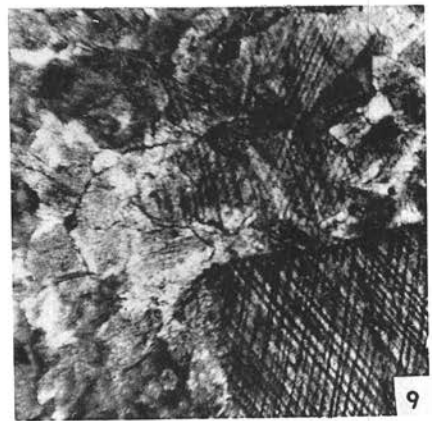
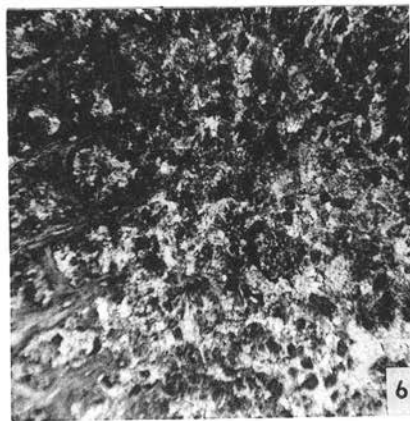
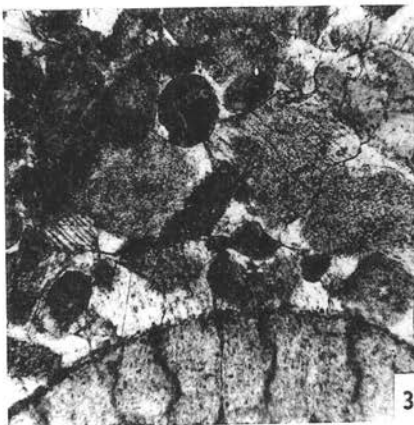
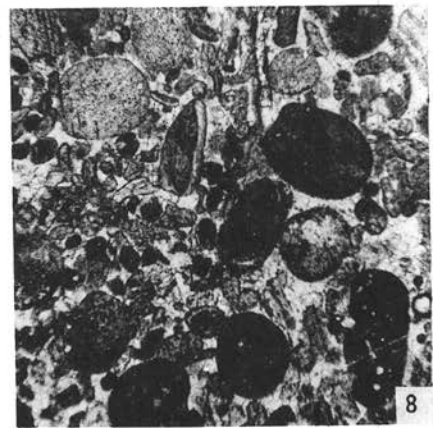
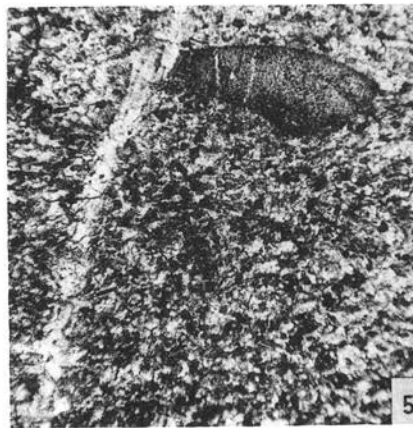
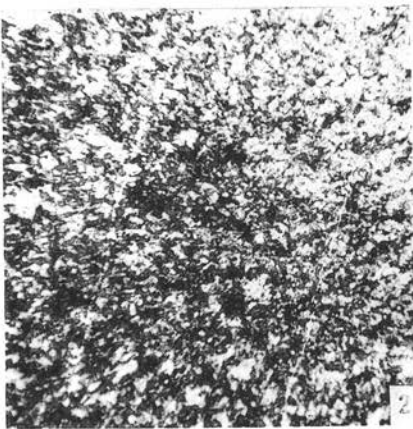
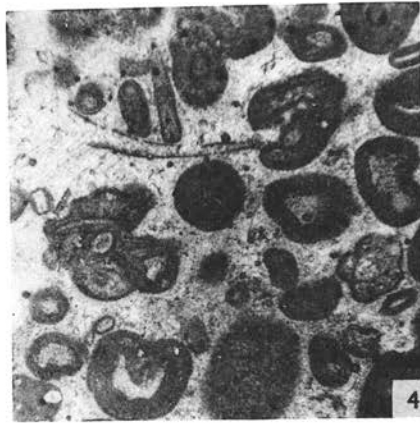
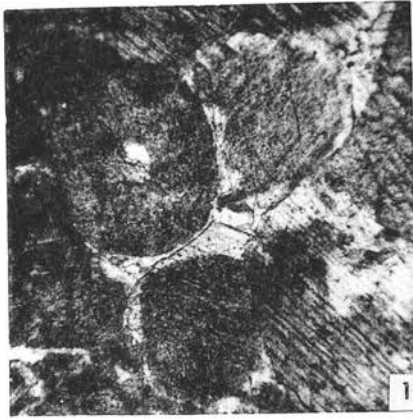


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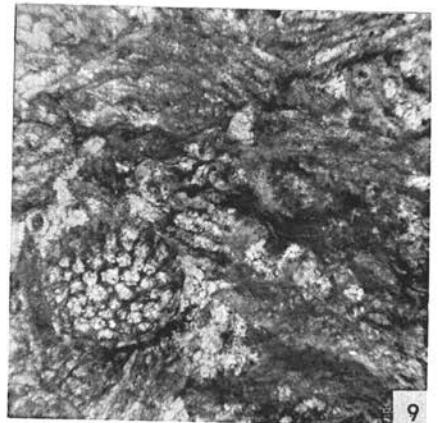
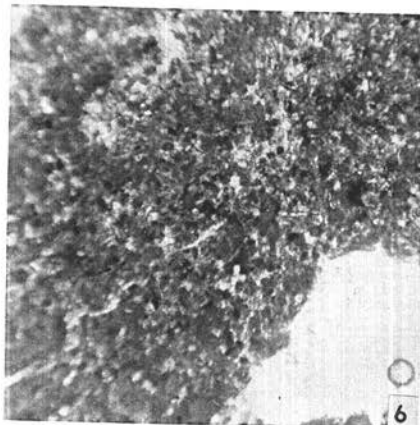
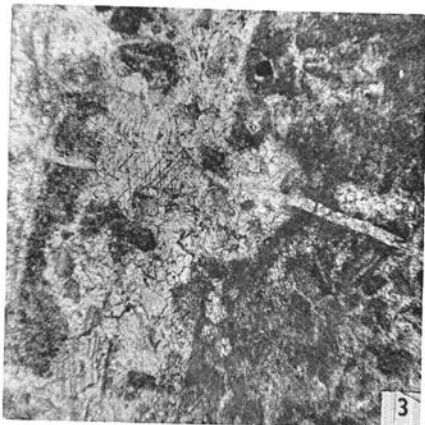
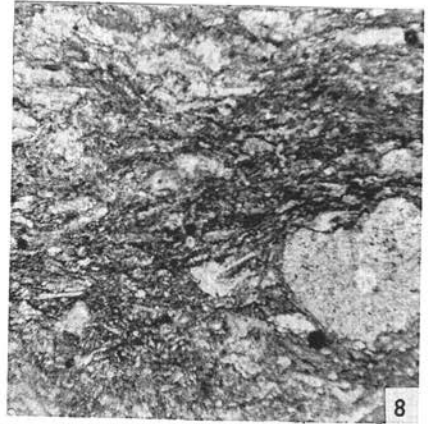
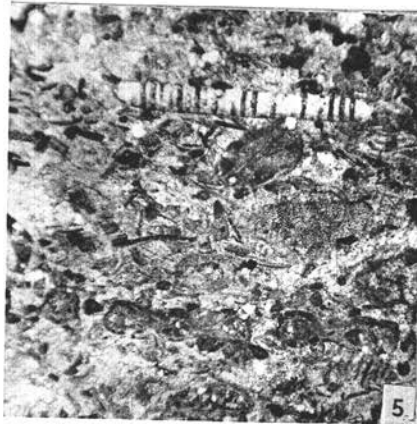
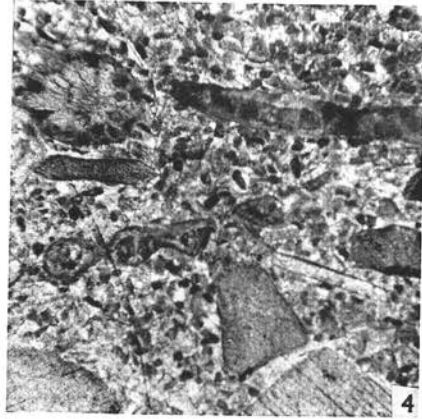
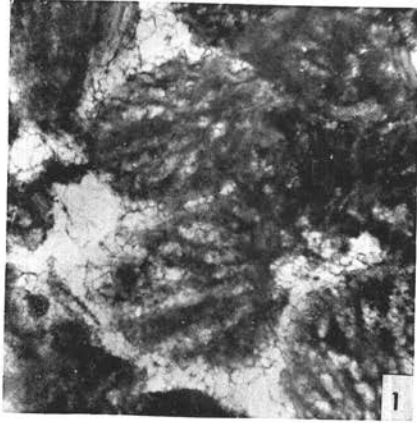
All photomicrographs are $\times 40$.

1. Encrinite, abraded and broken crinoid plates in a sparry calcite cement. Basal limestone of member A, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.
2. Calcilutite, originally calcite mud and ooze. Middle of member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
3. Encrinite (calcarenite to calcirudite); the rock shows a large range in particle size, abraded corallite down to fecal pellets. The mixture of sparry calcite and calcite ooze cement also indicates poor sorting. Top of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.
4. Oolitic limestone; oolites with a sparry calcite cement. Member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
5. Pelletic limestone; brown fecal pellets comprise the major portion of the rock with a microcrystalline calcite ooze as a cement. Lower part of member B, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
6. Pelletic limestone, fecal pellets, fossil fragments, and microcrystalline calcite. Fecal pellets predominate with fossil fragments occurring occasionally. Upper part of member B, Keating formation, Escabrosa group, Klondike Hills, New Mexico.
7. Encrinite, composed of broken and abraded crinoid remains with lesser amounts of bryozoan fragments, cemented by sparry calcite. Transition beds between Keating and Hachita formations, Big Hatchet Mountains, New Mexico.
8. Coquina, composed of oolites which have as their nuclei endothyrids, fossil fragments, fecal pellets, cemented by sparry calcite and microcrystalline calcite. Meramec part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
9. Encrinite (calcarenite to calcirudite), large, broken and abraded crinoid fragments cemented by microcrystalline calcite and lesser amounts of sparry calcite. Sorting, as shown by range of size and calcite mud, was poor. Osage part of Hachita formation, Escabrosa group, Big Hatchet Mountains, New Mexico.

PLATE 11

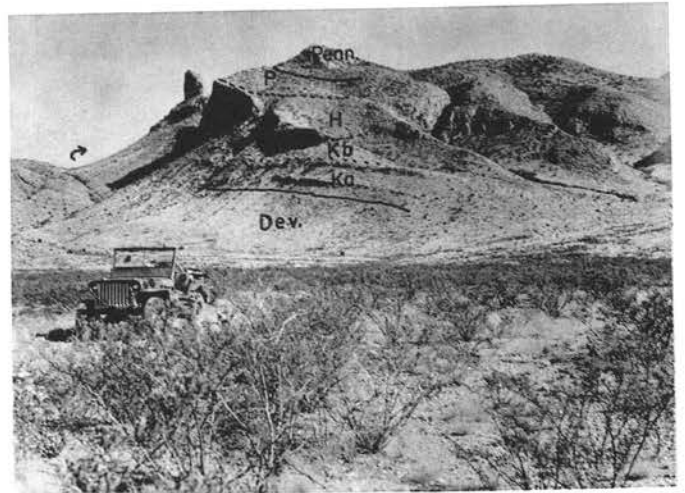
All photomicrographs are $\times 40$.

1. Bryozoan coquinite from same horizon as figure 9. This example illustrates the nature of the sparry calcite between the bryozoan fragments.
2. Coquinite fragments of crinoids, bryozoans, brachiopods, and fecal pellets cemented by microcrystalline calcite. Highest horizons of Hachita formation (Meramec), Blue Mountain, Chiricahua Mountains, Arizona.
3. Bioclastic limestone which was originally fossil fragments and microcrystalline calcite; has undergone partial recrystallization to a sparry calcite. Primarily the large fossil fragments are replaced by clear calcite. Upper Hachita formation (Meramec), Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
4. Pelletic limestone, primarily fecal pellets with subordinate amounts of bryozoans, brachiopods, and mollusca fragments. Cement is microcrystalline calcite and sparry calcite. Lower part of Paradise formation (Chester), Big Hatchet Mountains, New Mexico.
5. Limestone, composed of fecal pellets, bryozoans, brachiopods, and mollusca remains cemented by microcrystalline calcite. The poor sorting but pronounced evidence of microbedding suggest deposition in gentle but persistent currents. Middle of Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
6. Microcrystalline limestone, composed primarily of microcrystalline ooze, occasional fecal pellets. Basal limestone of Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.
7. Coquina, broken and abraded fragments of crinoids, bryozoans, and brachiopods. Meramec part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
8. Limestone, majority of rock is microcrystalline calcite containing abundant fine-grained abraded particles and occasional large pieces of crinoids. This rock type may have collected in protected quiet waters adjacent to meadows of growing crinoids. Osage part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.
9. Bryozoan coquina, rock is composed of tightly packed fragments of bryozoan zoarium and sparry calcite cement. Meramec part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.

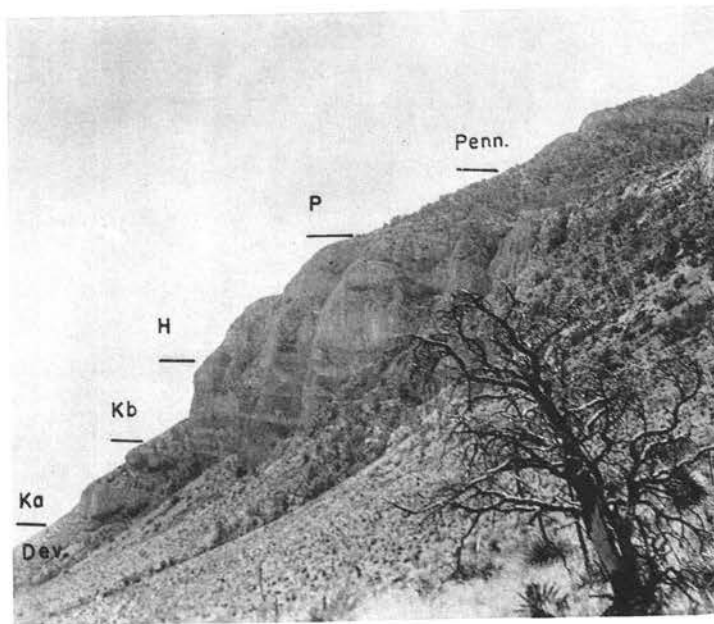




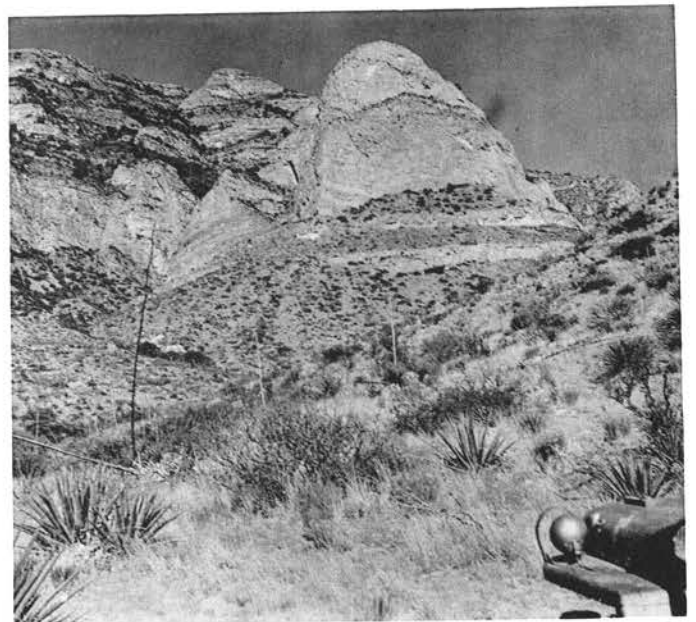
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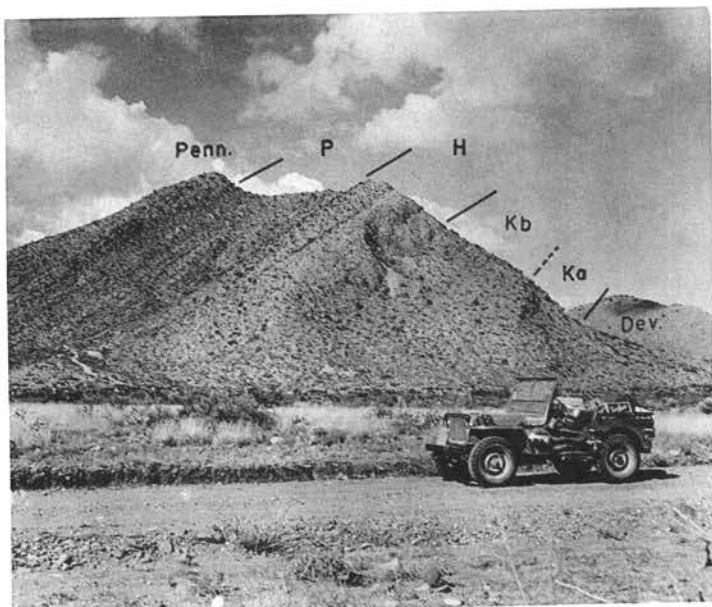
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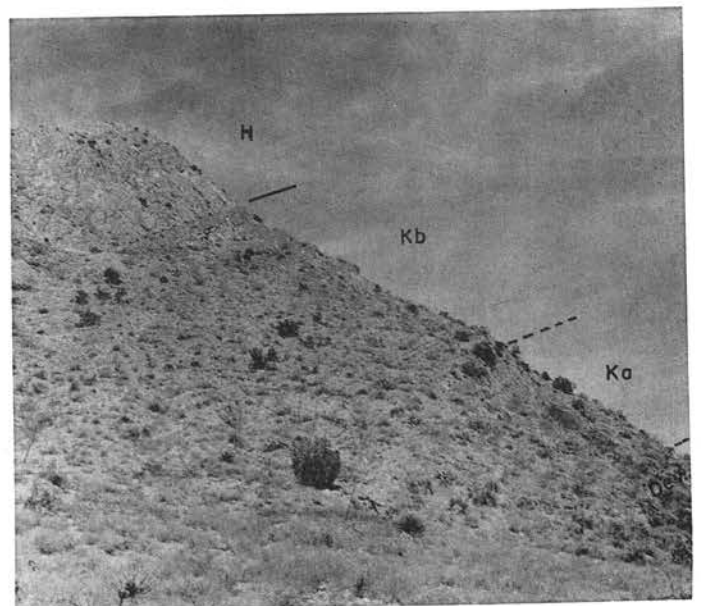
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6

PLATE 12

In all figures: Dev., Devonian Portal formation. Mississippian Escabrosa group: Ka, Keating formation, member A; Kb, Keating formation, member B; H, Hachita formation. P, upper Mississippian Paradise formation. Penn., Pennsylvanian system.

1. Klondike Hills, New Mexico; looking southward. Photograph illustrates the low-lying hills which are composed primarily of Mississippian rocks. Low hill in foreground is composed of members A and B of the Keating formation. Hachita formation is exposed south of second hill as a pediment surface. Member A of Keating formation on first knoll contains a prolific coral fauna. Mississippian section was measured in part from base of first hill over second knoll to base of the Hachita formation. Member B is repeated in the section by faulting.
2. Big Hatchet Mountains, New Mexico; viewed from the northwest side. Photograph shows the stratigraphic sequence from the Devonian Portal formation through the Escabrosa group and into the Pennsylvanian. Mississippian section was measured between the two northfacing, massive cliffs of the Escabrosa group.
3. Big Hatchet Mountains, New Mexico; photograph is a view of the northeastern side of the mountains. It was taken from the spot indicated by the arrow in the saddle in figure 2. Member B of the Keating formation is repeated by a low-angle fault.
4. Big Hatchet Mountains, New Mexico; view of massive Escabrosa cliffs on northeastern side of mountains. Photograph is a face view of the cliff profile shown in figure 3.
5. Blue Mountain, Chiricahua Mountains, Arizona; view from the southwest. The topographic and sharp contact between the various Mississippian formations and members, and the Devonian and Pennsylvanian strata are shown. The Mississippian section was measured along the profile of the hill as shown in the photograph.
6. Blue Mountain, Chiricahua Mountains, Arizona; close up view from the southeast illustrating the sharp contact between the Hachita formation and the Keating formation, and between the two members within the Keating formation.

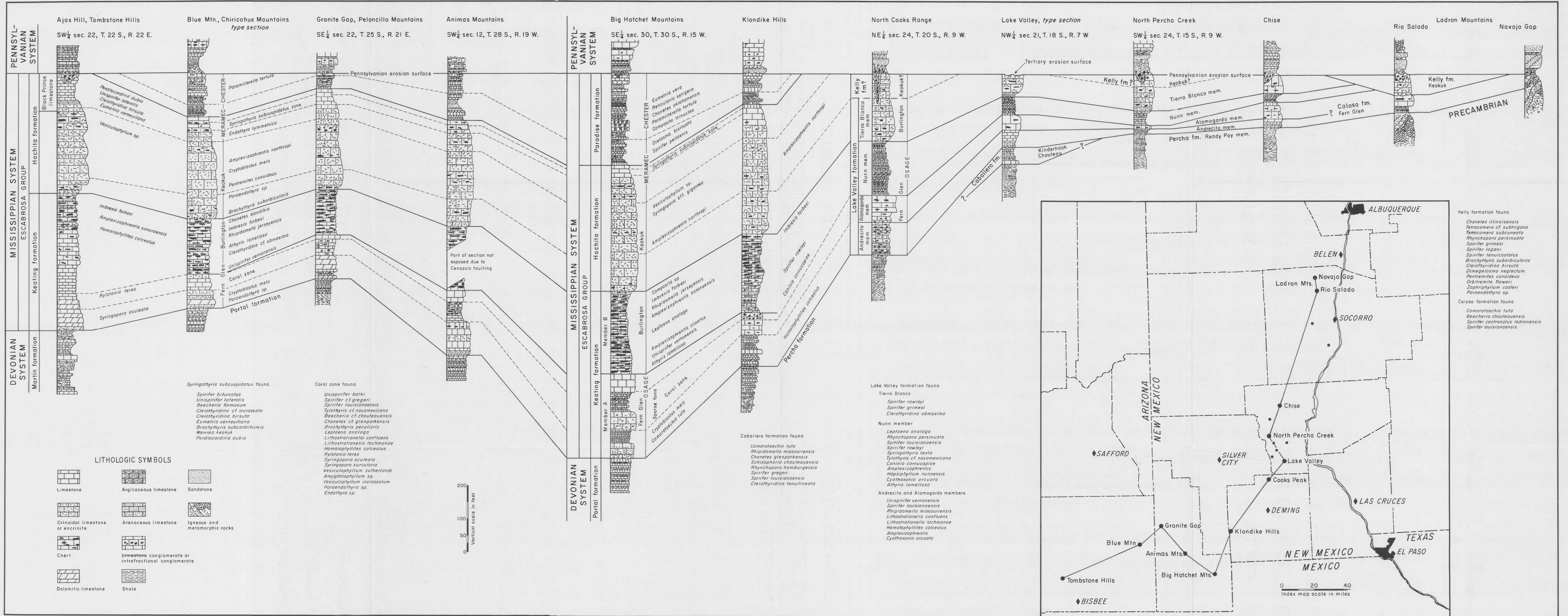
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COLUMNAR SECTIONS OF MISSISSIPPIAN ROCKS