THE PALEONTOLOGY AND STRATIGRAPHY OF THE MISSISSIPPIAN SYSTEM OF SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

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I hereby recommend that the thesis prepared under my supervision by Augustus K. Armstrong

entitled THE PALEONTOLOGY AND STRATIGRAPHY OF THE MISSISSIPPIAN SYSTEM OF SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

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ABSTRACT

The Mississippian system in western Cochise County, Arizona and in Luna, Hildalgo and Grant Counties, New Mexico, is described. The primary concern of this study is the Osage through Meramec Escabrosa limestone, its stratigraphy, paleoecology and biologic contents. The Escabrosa limestone in this report 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 1000 feet in the Big Hatchet Mountains of New Mexico. In the area of this report it is primarily an encrinite with minor amounts of microcrystalline 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 klondika, Cleiothyridina everharti, Unispirifer balki, Amplexizaphrentis sonoraensis, Amplexizaphrentis northropi, Kakwiphyllum sutherlandi, Lithostrotion lochmani,

Syringopora robusta and Michelinia leptosphragma.

The late Meramec to middle Chester Paradise formation is delineated and part of its brachiopod fauna is 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 of New Mexico. It thins rapidly to the north, and to the west and is only some 80 feet thick in the eastern Chiricahua Mountains of Arizona. The Helms formation of Chester age in the Franklin Mountains is discussed and its coral fauna described, which contains the new coral species Koninickphyllum elpasoensis.

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INTRODUCTION

The Mississippian system in southwestern New Mexico and southeastern Arizona is represented by the Escabrosa limestone which has a maximum thickness along the Mexican border of 1000 feet.

Previous published material pertaining to the Escabrosa limestone were 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 paleontologic contents of these strata are poorly known. In the past they have been correlated in broad generalities with the Mississippian type sections of the Midcontinent region. This generalized attitude was expressed in central Cochise County, Arizona, by Williams (in Gilluly, 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 or related formations in the Cordilleran region. The first problem is the poor preservation and fragmentary nature of the fossils within these rocks. In addition, fossils are not abundant and are generally difficult to extract from the

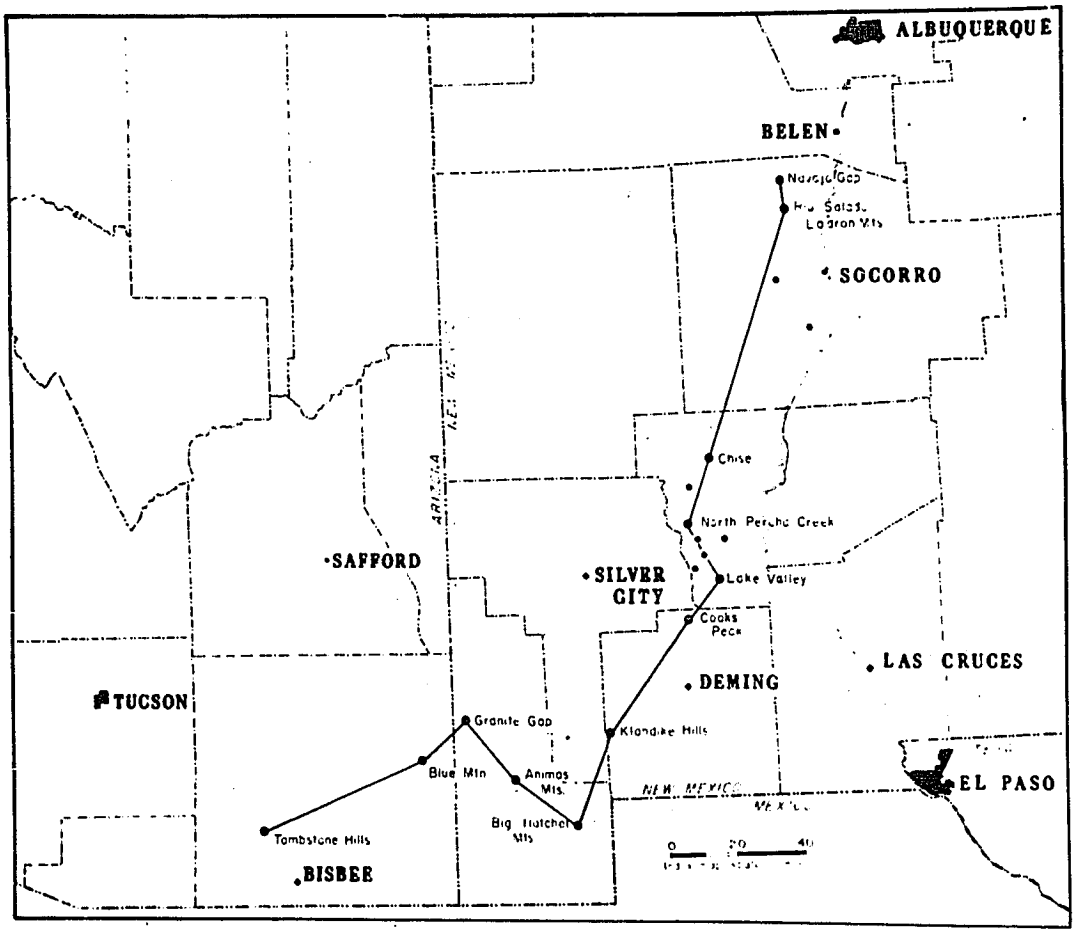

Figure 1 - Index map of area considered in this study.

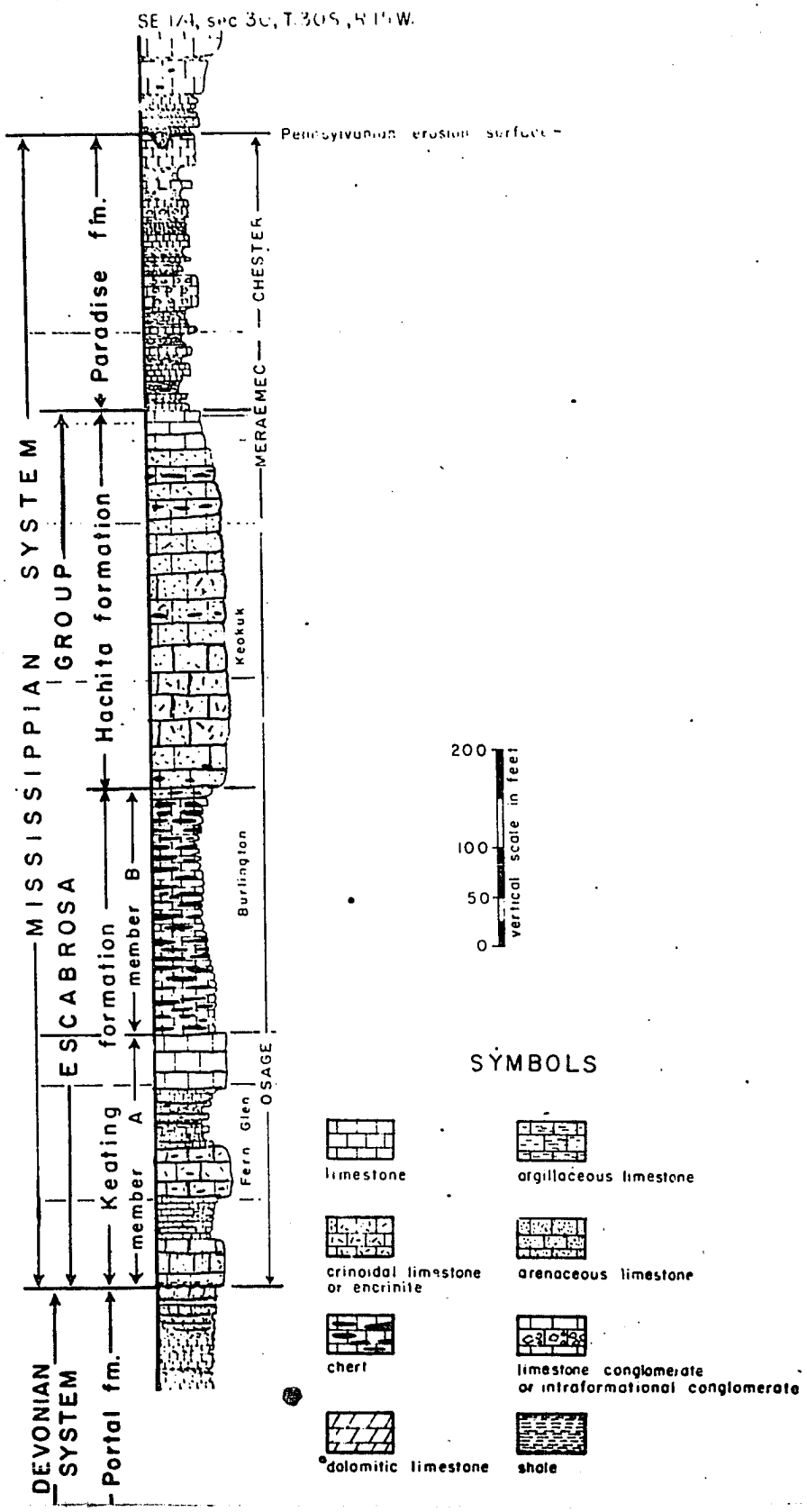

Figure 2. - Type section of the Keating and Hachita formations, Escabrosa group at Blue Mountain, Chiricahua Mountains, Arizona.

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 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 we have no assurance yet that these species have the exact same stratigraphic range as in the Mississippi Valley. Furthermore, in the Cordilleran region there was in many areas continuous deposition and a stable ecology throughout Osage and Meramec time. Within these sections the generic lineages are vertically a series of intergrading species.

This is in marked contrast to the Midcontinent Osage and Meramec column which is marked by a series of hiatuses. Each succeeding formation had a distinct ecology and a distinctive fauna.

It is now evident that the Cordilleran Mississippian coral fauna is primarily indigenous to the area and is not represented in the Midcontinent region. At present only a small part of this fauna has been described and the stratigraphic range of the various species and genera is poorly known.

In an effort to solve some of these problems a systematic paleontologic study was made of the brachiopods

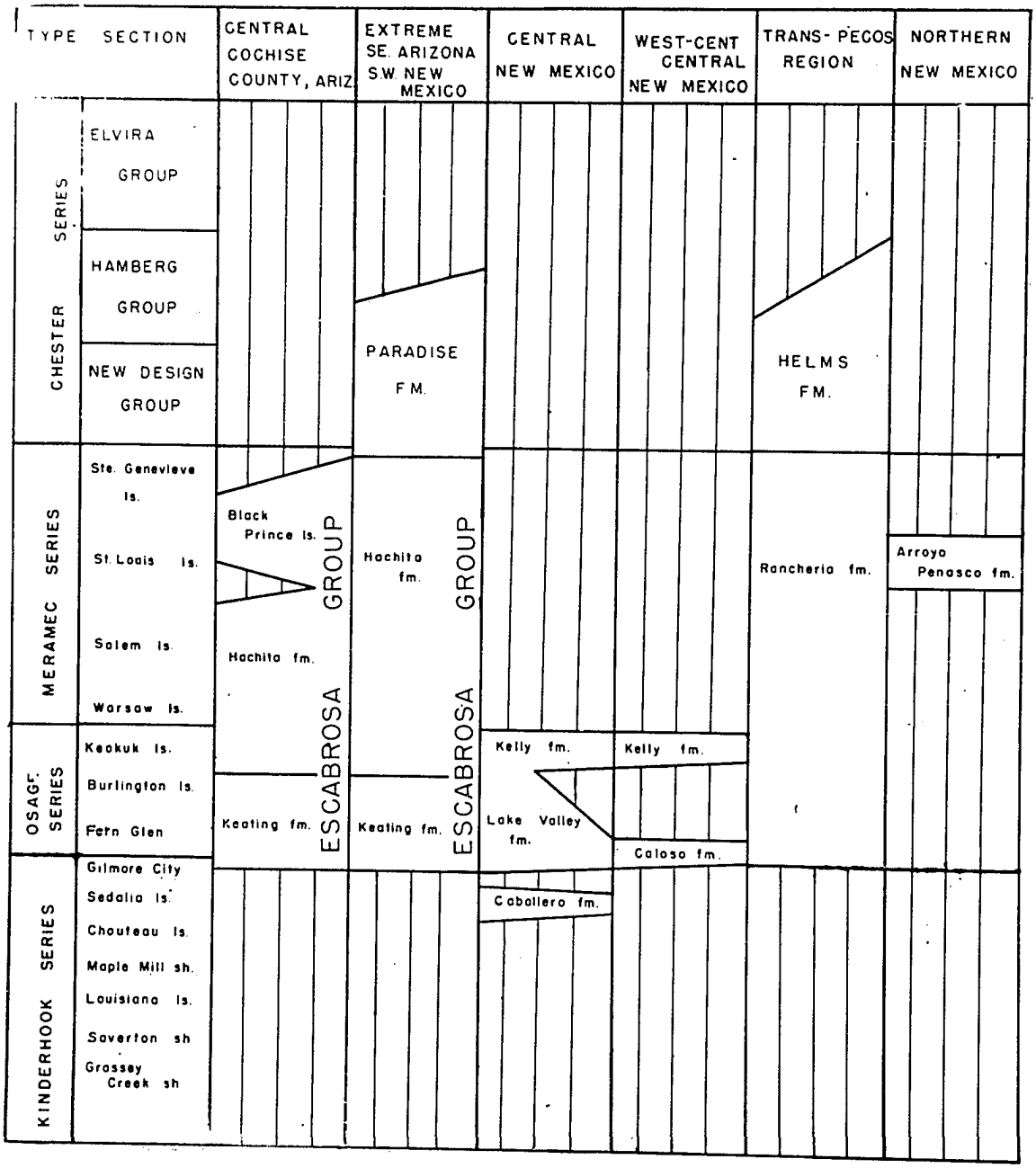

Figure 3. - Regional correlation chart of the Mississippian system.

(exclusive of productids), corals, blastoids and endothyrids from the Escabrosa limestone. These paleontologic studies were combined with petrographic and insoluble residue studies. An effort was made by combining the above evidence to deduce the paleoecology of the Escabrosa through Osage and Meramec time.

The primary area of study was in southeastern Arizona in Cochise County and in southwestern New Mexico in Luna, Hildalgo and Grant Counties.

The Escabrosa limestone in the area of this report is elevated to group status and two new formations are named. In ascending order they are, the Keating formation and the Hachita formation. The Keating formation is a series of calcilutites and crinoidal limestones which are from Fern Glen (Osage) to Burlington (Osage) age. Overlying the Keating formation without a discernable hiatus is the Hachita formation. 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. Those strata which are adjacent to and a facies of the Escabrosa group were studied in considerable detail to ascertain their biologic and lithic relationship to the Escabrosa.

Comparison is made between the brachiopod faunas of the Osagian Lake Valley and Kelly formations of west-central New Mexico and the Escabrosa group. The coral fauna from

the Lake Valley formation west of the Rio Grande River is systematically described.

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

ACKNOWLEDGEMENT

I am indebted to many persons and institutions which aided me in this study. Dr. K. E. Caster of the University of Cincinnati encouraged the writer to undertake the study, gave advice on paleontologic matters, and carefully criticized the manuscript. Dr. W. F. Jenks of the University of Cincinnati spent several days in the field in New Mexico with the writer checking complex stratigraphic and structural problems. While the writer was in New Mexico preparing the first draft of the manuscript Dr. Christina Lochman-Balk of the New Mexico Institute of Mining and Technology, spent many hours discussing paleontologic and paleoecologic problems. She also made available the use of her laboratory and dark room at the Institute in which the majority of the photographs were made.

I am indebted to Dr. Frank Kottlowski of the New Mexico Bureau of Mines and Mineral Resources who helped measure the structurally complex sections in the Klondike Hills, Tres Hermanas, and Florida Mountains. Dr. R. H. Flower, State Paleontologist at the New Mexico Bureau of Mines gave freely of his time in advising the writer on paleontologic matters, photographic techniques, and fossil preparation.

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PRIOR WORK

The first serious studies on the Mississippian system of southern New Mexico was done by Laudon and Bowsher (1941, 1949) who studied the Lake Valley and Rancheria formations in detail. They did not extend their studies into extreme southwestern New Mexico to include the Escabrosa group. To the west, in central Cochise County, Arizona, Gilluly, Cooper and Williams (1959) published a primarily lithostratigraphic study on the Escabrosa and Black Prince limestone. The readily accessible section at Blue Mountain, Chiricahua Mountains in extreme eastern Cochise County, Arizona, has over the years received considerable attention. Hernon (1935) defined the age, paleontology and stratigraphy of his Paradise formation at Blue Mountain. Sabins (1957) at the same section demonstrated the exact boundary of the Devonian-Mississippian contact and proposed the Devonian Portal formation. Zeller (1957) described species of Endothyra and Millerella from the upper part of the section at Blue Mountain.

The thick sections of Mississippian sediments in extreme southwestern New Mexico had not been lithologically or paleontologically studied.

TREATMENT AND DISCUSSION OF LIMESTONE LITHOLGIES

The stratigrapher who attempts to describe a thick sequence of limestones such as the Escabrosa group, is immediately faced with the perplexing problem of limestone nomenclature. The terminology proposed by Pettijohn (1949), which is based primarily on description and origin, is used in a modified sense in this report. The lithic terms used in this report are defined in an appendix. One of the most useful papers in deciphering limestone lithologies is that of Folk's (1959, p. 1-39). He convincingly demonstrates the origin of the various limestone petrofabrics. However, he also proposed an elaborate limestone nomenclature which does not seem to be any improvement on systems widely in use. Folk demonstrated that limestones are made of three carbonate end members: (1) allochems, evidently transported or otherwise differentiated carbonate bodies; (2) 1 to 4 micron microcrystalline calcite ooze matrix, and (3) coarser and clearer sparry calcite, which in most rocks forms as a simple pore-filling cement and only uncommonly forms by recrystallization. He recognizes only four types of allochems as volumetrically important in limestones: (a) intraclasts, reworked fragments of penecontemporaneous carbonate sediments, (b) oolites, (c) fossils, and (d) pellets (rounded aggregates of microcrystalline calcite, averaging .04 - .10 mm). Allochems provide the structural

framework of sandstones; microcrystalline calcite and sparry calcite are analogous with the clay matrix and chemical cement of sandstones.

Folks recognized three major families of limestone which are 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.

STRATIGRAPHY

ESCABROSA GROUP

The Escabrosa limestone of Mississippian age (Kinderhook-Osage boundary throughout 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 throgh Cochise County, Arizona, by the United States Geological Survey in reports dealing with various mining areas. Girty's (1904, p. 42-44) type section of the Escabrosa is an area of considerable post-Paleozoic tectonic activity. Girty's type section is probably one of the poorest Escabrosa exposures in Cochise County. Girty, as a result of the complex structure, found it impossible to determine the exact thickness of the Mississippian strata within the Bisbee quadrangle.

Lithostratigraphic and paleontologic studies of the Escabrosa limestone in western Cochise County, Arizona, and Luna, Hildalgo, and Grant Counties, New Mexico reveal the need to elevate the Escabrosa limestone to group status and divide it into two formations. These formations are, in ascending order, the Keating formation of lower and middle Osage age, and the Hachita formation of Middle Osage through upper Meramec age.

The Keating formation is a sequence of calcilutites and encrinites varying in thickness from 350 to 500 feet. The Keating formation ranges from Fern Glen (Osage) to Burlington (Osage) in age. The Hachita formation conformably overlies the Keating and is a massive encrinite 250-350 feet thick. This sequence represents continuous sedimentation from Burlington (Osage) to St. Louis (Meramec) time. The type section for these two new formations is the excellent exposures at the south end of Blue Mountain, Chiricahua Mountains, Arizona (SW $\frac{1}{4}$, Sec. 20, T. 16S, R. 30E).

Keating formation

Lithology. - The name Keating is here proposed for the basal formation of the Escabrosa group. It bears a fauna of Osage age and is divided by lithology into two members, which are for simplicity called members A and B. The name is derived from Keating Canyon, a few miles north of Blue Mountain in Chiricahua Mountains, Arizona. The type section is on the southeast side of Blue Mountain, (Sec. 20, R. 30E., T. 26S.) 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, north and east as a result of original deposition. It is some 360 feet thick south of Ajax Hill in the Tombstone Hills of Arizona. In the Klondike Hills of New Mexico it is 395 feet thick. From the Chiricahua Mountains of Arizona eastward the Keating formation lithologically is readily divisable into two members.

Member A, stratigraphically the lowest, rests with a paraconformity on Upper Devonian strata. The basal unit or bed of this member is generally some 50 feet thick and consists primarily of an encrinite. Thinsections (pl. 1, fig. 1) show a breccia of crinoidal remains which range in size from 0.2 to 9 mm. The larger fragments are worn crinoidal columnals; the smaller appear to be broken

crinoid columnals and plates. The pore space between the enchinoderm fragments is filled primarily with microcrystalline ooze and, to a lesser degree, by sparry calcite. Some thinsections from this unit have large, crinoid fragments suspended in microcrystalline ooze. The latter may comprise as much as 30 to 40 per cent of the thinsection.

Insoluble residues show that the lower 20 feet of the Keating formation in the area of study may contain a relatively high percentage of clay and fine quartz sand. The sand averages about 0.05 to 0.1 mm in diameter. The clay apparently is derived from the soil zone which must have 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 (0.01 mm) quartz sand.

A zone some 20 to 50 feet thick in the upper part of member A is characterized by a larger, diversified, coral fauna. This horizon, which is very persistent over a wide area, is called appropriately 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 which are on the surface of the rock imperfectly silicified with brown chert. Thinsections made from this horizon show

a wide range of microlithologies. In the Klondike Hills the most characteristic lithology is a limestone composed of bioclastic fragments which range in size from 0.3 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, Arizona, eastward to the Klondike Hills, has a pronounced tendency within the massive limestones to develop highly, oolitic microfacies. A typical example (pl. 1, fig. 4) contains up to 75 per cent oolites. They are generally spherical, show concentric lines of growth and are between 0.5 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 small fecal pellets about 0.2 mm in size and microcrystalline ooze. Sparry calcite composes less than 2 per cent of the total rock but in some samples it grades into conditions where 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, Arizona, and present in most of the sections to the east, is a microcrystalline ooze with occasional crinoid or brachiopod fragments suspended in it. The microcrystalline ooze typically has microbedding planes which are caused by rhythmic layers of material with a slightly higher concentration of shale and organic matter. The microcrystalline ooze grades imperceptably horizontally and vertically into oolites and encrinites with microcrystalline ooze filling the pore spaces.

Member A is distinguished topographically by the cliffs it forms 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 chertiferous. Twenty to 40 per cent of the rock is composed of chert and consists of long, lenticular bodies which frequently coalesce with adjacent chert masses above and below. The contact between members A and B is a zone some 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, Arizona (see discussion under Hachita formation and Hachita paleontology).

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 undergoing a facies change and the silica is primarily ill-defined disseminated masses of brown chert which are parallel to the bedding. The chert is scarce in the sections south of Warren, in the Tombstone and Dragoon Mountains and member A and B are not readily recognized. The lower limestones of member B are gray to dark gray and in handspecimens are lithographic. Thinsection studies reveal they are a microcrystalline calcite and limestones rich in fecal pellets. The fecal pellet limestones (pl. 1, fig. 2), are composed of small (0.2 mm), brown pellets surrounded and, in part, suspended in microcrystalline calcite. 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 are progressively replaced vertically by calcarenites and coquina limestones. These are dark gray and in thinsections are found to be composed primarily of broken crinoid plates with lesser amounts of fragments of brachiopods, corals and bryozoans. The shell hash ranges in thickness from about 0.4 to 10 mm. The pore space between the fossil fragments is filled with brown pellets, some being as large as 0.3 mm in size. The remaining space is filled with microcrystalline calcite

and minor amounts of clay. Some thinsections are devoid of microcrystalline calcite and have the pore spaces filled with sparry calcite. The stratigraphically higher beds of member B frequently have within them angular interclasts composed of similar material. These interclasts are arranged within the strata with a tendency to have their long axis parallel to the bedding. These interclasts 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 shale. 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. The chert often contains within it silicifed remains of invertebrate skeletons. Frequently a crinoid stem was observed to lie both in limestone and in the chert. The part of the crinoid stem within the chert would be silicifed, whereas the part in the limestone would not be silicified. Also chert

nodules frequently show the same textures as those in the surrounding limestone. Where the limestone is composed of crinoid remains and organic hash, the chert is 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 of the rock. Some large corals, which are completely silicified above the surface of the rock in thinsections made of the coral only incipient silicification beneath the surface. Weathering processes in arid regions can account for the selective silicification of fossils on the surface of limestone.

Fauna. - 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 without much question continuous with and equivalent to the Andercito 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 the Represo limestone of northwestern Sonora, Mexico. The fauna of member A consist of brachiopods, corals, endothyrids, blastoids, bryozoans, crinoids, and occasional trilobites

and gastropods. The state of preservation of the gastropods, trilobites and bryozoans was 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 is very persistent over a wide area in member A of the Keating formation and in the lower part of the Lake Valley formation. The coral fauna of member A seems to be part of a widespread fauna, which is unique to the lower Mississippian of the Cordillerian region. The coral fauna has not proved to be of direct value in correlating with the standard Midcontinent region, but is very valuable in intra-regional correlating in the western half of the United States and Canada. The brachiopods do give some indication as to the relationship with the standard Midcontinent type sections.

The lower part of member A is generally 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 calceola White and Whitfield. In the Midcontinent region, Cline (1936, p. 635-637) found Cryptoblastus melo to be quite abundant in the lower part

of the Burlington formation, and not to occur 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 calceola is, according to Easton (1944, 1958), primarily a lower Osage species. The paleontologic dating of the basal limestones of member A is admittedly on somewhat tenuous ground due to the paucity of the fauna. The age assignment is at the Kinderhook-Osage boundary; and, because of the presence of Cryptoblastus melo, a basal Osage age is preferred by the writer.

A decidedly Kinderhookian age for the lower part of the Escabrosa group has been repeatedly cited by many authors in the literature. 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) on a small number of specimens collected by Ransome in the area of Bisbee, Arizona. Girty thought that the lower part of the Escabrosa was of Kinderhook age. It must be remembered that at that time the Kinderhook series embraced at the type section in Illinois all Mississippian strata up to the base of the Burlington limestone. Weller et al. (1948) in the Geological Society of America Correlation chart

assigned at least half of the Escabrosa group to the Kinderhook series. Stoyonow (1936, 1948) largely influenced by Girty's earlier studies considered the Escabrosa to be in part of Kinderhook age. Williams (1954, p. 12; 1956) viewed the Escabrosa fauna as existing through both Kinderhook and Osage time. He gave no faunal evidence to support his conclusions. The assignment of parts of the Escabrosa group to the Kinderhook is based by most authors on the existence of 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 southeastern Arizona, is in all probability Spirifer 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 extent to which 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 Spirifer, is exemplified by William's (1954, p. 11) faunal list from the Escabrosa limestone of central Cochise County, Arizona. He reports S. centronatus to be present in the lower Mississippian and in younger rocks (supposed Meramec).

The coral zone in the upper half of member A at Blue Mountain, Chiricahua Mountains, Arizona, and all of

the Escabrosa group exposures to the east of this area contain in this narrow zone a relatively rich fauna which is characterized by large rugose corals. The following species of brachiopods have been identified from this zone in the upper half of member A: Leptaena analoga Phillips is a conspicuous member of the fauna. The species is characteristic of Kinderhook and lower Osage strata of North America. Chonetes glenparkensis Weller occurs both in the upper Kinderhook and in the lower Osage. It is also abundant in the Nunn and Alamorgordo members of the Lake Valley formations. Brachythyris peculiaris (Schumard) and Tylorthyris novamexican (Miller) is also present and occur in late Kinderhook and early Osage strata, and are present in the Lake Valley formation of southcentral New Mexico. Beecheria choutenauensis (Weller), which is characteristic of both the highest Kinderhook and 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 is present in the lower Osage Caloso formation of west-central New Mexico (Armstrong 1958, B). Spirifer louisianaensis Rowley is a very common spirifer in strata of Chouteau and Burlington age. It is abundant also in the Kinderhook Caballero and lower Osage Lake Valley formations of southcentral New Mexico. Spirifer 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 from member A none of the species are known to be restricted to Kinderhook strata, and the majority of the brachiopods are found in the Lake Valley formation to the east which is Fern Glen (lowest Osage) in age.

The coral fauna, if taken superficially on the generic level, would be suggestive of a Meramec age. This is due to the presence of three genera, which have been found primarily in Meramec rocks. The genus Ekvasophyllum, which is represented in member A by E, primum Armstrong, was cited in the literature by four other species (Parks, 1951; Sutherland, 1958) all of which came from the western half of North America and from strata of Meramec age.

The lithostrotionid 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 Kinderhookian-Osagian Banff formation of western Canada. Lithostrotion lochmani, n. sp. occurs with L. confluens in member A. L. lochmani 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. lochmani both occur in the Andercito and Alamorgordo members of the Lake Valley formation at Lone Mountain, south of Silver City and in the Andercito member, north of the Santa Rita mining district and in the Cooks Range.

In the Midcontinent region, Homalophyllites calceolus White 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, Kakwiphyllum sutherlandi is a large, solitary, caninid coral common to member A; but apparently it is restricted to the upper half of this unit. The only other known species of the genus, which is the type species, is K. duxi Sutherland from the Meramec Rundles formation of British Columbia. Stensaas and Langenheim (1960, p. 182-184) report K. duxi from the middle and upper parts of the Joana limestone of Nevada.

Fragments of very rare caninid coral were found in member A, and appear to be the same species as Caninophyllum incrassatum, Easton and Gutschick from the Represo limestone of northwestern Sonora and the Redwall limestone of Arizona. 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 in the Andercito and Alamogordo members of the Lake Valley formation.

In member A, foraminifera are represented by a sporadically occuring 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 endothyrid knowledge, 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 is beginning to suspect that Mississippian endothyrid 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 paleoecology must be made on this group.

Fauna. - Member B - The stratigraphically highest unit of the Keating formation, member B, contains a fauna which is distinct compared to the assemblage found in member A. The difference is believed to be due primarily to ecological conditions and also to the evolutionary changes as a result of the passage of time. The very lowest cherty beds of member B are characterized by such lower Osage brachiopods as Unispirifer vernonensis (Swallow). Leptaena analoga Phillips, and Athyris lamelosa (Leveille). 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 southcentral New Mexico. The coral fauna of member B is represented by Amplexizaphrentis sonoraensis, n. sp. from the Lake Valley formation. Homalophyllites calceolus White is occasionally found in the lower part of member B.

The middle and upper part of member B is marked by a more pronounced bioclastic nature produced by crinoidal

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, Unispirifer 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 faunas also have a distinct Osage character which consists of the following determined species: Brachythyris suborbicularis (Hall), Cleiothyridina everharti, n. sp., Chonetes klondikia, n. sp. and Composita globosa Weller. The corals are represented in the middle of member B by 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 yield Syringothyris, Schuchertella, various species of Spirifer and 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, Arizona, and eastward to the Klondike Hills of New Mexico, the bedding planes of the limestones commonly display the

problematical annelid fossil Taonorus. In the thinsections studied from member B, endothyrids were absent.

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 rest 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; S½, Sec. 20, T. 26S., R. 31E.. The Hachita formation is lithologically and topographically the most characteristic part of the Escabrosa group. It is a persistent cliff-former throughout its area of exposure. It generally forms a bold cliff along with the less resistant Keating formation. This cliff is due primarily to the massive nature of the encrinites, and in part to the weak argillaceous Devonian limestone and shale below, and 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 in color, has persistent massive bedding, and is composed to a large extent of crinoid remains, although it contains also 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, SE¼, Sec. 30, T. 30S., R. 15W., with a maximum thickness of 380 feet. The Hachita formation thins, due to original deposition, to the north and west (see correlation diagram). West of the Chiricahua Mountains in Arizona, where the Chester age Paradise formation is absent, it thins in part due

to pre-Pennsylvanian and early Pennsylvanian erosion. To the east because of sparseness of exposures, the complexity of Cenozoic faulting and thrusting, and the presence on some of the Hachita exposures of extensive Cenozoic pediment surfaces, the exact thickness of the formation is not known. Northeast of the Big Hatchet Mountains in the Klondike Hills, the Hachita formation is at least 350 feet thick and may be considerably thicker.

Laudon (1948), Laudon and Bowsher (1949), and Bowsher (1960, personal communication) maintain that the Rancheria formation of the southern San Andres and Sacramento Mountains, and the Franklin Mountains is a lower Meramec overlap northward onto an eroded Lake Valley formation surface. This concept would necessitate in the Rio Grande River and Trans-Pecos Region in southern New Mexico and eastward, an uplift in late Burlington or Keokuk time. This would result in the stripping off of earlier Mississippian sediments down to the Devonian surface and regional submergance again in earliest Meramec time. The writer is now engaged in a detailed study of the Rancheria formation. The field work and preliminary faunal studies seem to contradict Laudon's and Bowsher's concept. The field relations, petrographic data, and some paleontologic evidence now seem to indicate that the Rancheria formation was 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 Paleoecology and Paleogeography. Graphic representation of the relationships here visualized of the Escabrosa group to the above formations is shown in the lithofacies maps and the regional correlation charts enclosed in the pocket at the end of this paper.

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, encrinite limestone of white to light gray color with occasional nodules of white chert. In contrast, the top of the Keating is a medium-bedded, dark gray, in part encrinite and coquinite limestone with zones of abundant lenticular, and bedded dark gray chert. In the Klondike Hills and Big Hatchet Mountains of New Mexico there is a gradational zone, 10 to 20 feet thick, between the two distinct lithologies. The contact between the two formations at Blue Mountain, Arizona, 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, does indicate 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, Unispirifer 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, as indicated by sedimentary evidence were deposited in very shallow water (the reader is referred to the ecological and environmental section of this study). The transition zone between the two formations, at many locations such as the Big Hatchet Mountains and Klondike Hills of New Mexico and Tombstone Hills of Arizona, would suggest continuous deposition, but under very shallow water conditions. The section at Blue Mountain with its numerous interclasts and abrupt lithologic change between the two formations would suggest (at the end of Keating deposition) a region which stood at or just below sea level. 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, transported and redeposited them into newly-forming calcarenites and

calcite ooze. It is suggested that the sharp contact between the Keating and Hachita formations at Blue Mountain is the product of one of these localized short hiatuses, which happened to occur at the precise time a widespread regional ecological change began. The relatively sudden ecological and depositional change resulted in the rather marked contrast in the limestone lithologies between the Keating and Hachita formations.

The lower two-thirds of the Hachita formation is, in all of the exposures east of Blue Mountain, Arizona, a massive encrinite limestone, which is almost devoid of distinct bedding. The lower and middle units of the Hachita formation contain some white to light gray nodular chert. Detailed examination of a number of Hachita exposures was made in an effort to determine the types of limestones and primary structures present. This technique, coupled with observing the exposures from a distance, failed to reveal any biohermal or biostromal buildup within the formation.

Studies revealed the formation is composed almost entirely of crinoid fragments, to the almost complete exclusion of other detrital clastic and organic remains. When an occasional brachiopod was found, it was inevitably a broken and disassociated 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 there does exist within this massive crinoidal debris, interfingering and gradational bodies of differing textured encrinite limestone. Some lenses are composed of coarse crinoidal fragments which grade into zones made up of very finely abraded crinoid fragments and microcrystalline calcite (See pl. 2, fig. 5).

Microscopic examination of a number of thinsections reveals that the lower two-thirds of the Hachita formation does not contain any appreciable amount of fenestrate bryozoans. This is in marked contrast to Pray's (1958) discussion of the lower Osagian crinoidal bioherms of the Sacramento Mountains of New Mexico. He reported the framework of these bioherms to be fenestrate bryozoans. Microscopic examination further reveals the Hachita limestone is composed primarily of broken crinoid plates and, depending on the thinsection, cemented either by sparry calcite or microcrystalline calcite or a combination of the two (See pl. 2, fig. 3). In thinsections the crinoid fragments are more tightly packed than they could have originally been before diagenesis. This tight packing is due to the presence of numerous microstylolites between the crinoid fragments.

A limestone type of minor importance in the Hachita formation is microcrystalline calcite with suspended fragments of crinoids. Insoluble residue studies from this

part of the section throughout its area of exposure reveal the almost complete absence of detrital quartz, and very minor amounts of shale and organic residue. Some of the limestone horizons have small amounts of tiny (0.1 to 0.3 mm) doubly terminated quartz crystals. The upper third of the Hachita formation from Blue Mountain eastward is primarily an encrinital limestone, but 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. 2, fig. 2). The endothyrids are from 0.5 to 0.7 mm in diameter and have formed the nucleus of oolites. Some 20 to 40 per cent of the rock is composed of rounded fragments of brachiopods and echinoderms, some of which are also the nucleus of oolites. The pore space is primarily filled with sparry calcite and minor amounts of microcrystalline calcite. One of the more common types in the Meramec sequence is a fine-grained, relatively unfossiliferous, light gray, limestone which in thinsection (Pl. e, fig. 3) is primarily composed of fossil fragments of brachiopods, echinoderms and bryozoans. These fragments are up to 3 mm in diameter, but are present as ghosts. 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. The material ranges in size from 0.5 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 reveal the presence of a slightly higher amount of insoluble residues compared to the lower encrinites. Although detrital quartz is still rare, there is a noticeable increase in the shale fraction and organic residue. The upper third of the Hachita formation has a noticeable increase in chert. Appreciable amounts of pink to salmon-colored 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 thin brown ribbon chert. The Osage-Meramec boundary within the Hachita formation is discussed in detail in this paper under the Hachita fauna. The evidence now available indicates that continuous deposition existed between the two 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) reported that, in Cochise County, Arizona, on the top of

their Escabrosa limestone and beneath the base of the Pennsylvanian Horquilla limestone, a very sparsely fossiliferous, medium-bedded, fine-grained limestone of middle Mississippian age is present. They named this sequence the Black Prince limestone. Although they studied it primarily in the area of 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 p. 14-16) places considerable importance on a zone some 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 well represent 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. Although time was not available to adequately study the Black Prince problem, it appears from fossil collections which contain the Canadian Cordilleran index fossil, Lithostrotionella shimeri (Crickmay), 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

calcite with minor amounts of bedded calcarenite.

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

To the east, in the area where the Paradise formation is present, the top of the Hachita formation and the bottom of the Paradise formation has been arbitrarily drawn at all exposures. There appears to have been essentially continuous deposition from Meramec to Chester time. Hernon (1935, p. 656) at Blue Mountain separated the Paradise formation from the Escabrosa limestone (now 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". From observations in the field and paleontologic evidence, the bottom of Hernon's Paradise formation would extend into the top 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 first 18-inch shale zone which occurs at the 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. The limestones in the upper third of the Hachita formation are darker in color and possess progressively better-defined bedding planes than do the lower part of the formation. These higher horizons are topographically less resistant than the lower massive encrinal limestones, and form less precipitous cliffs. The Hachita formation at Blue Mountain, Arizona, and the Peloncillo, Animas, Big Hatchet Mountains, and Klondike Hills of New Mexico is overlain by the Paradise formation, which is easily weathered and forms gentle, covered slopes beneath 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 searching of the lower hundred feet of the Hachita formation has yielded a small and poorly preserved fauna consisting of Pentremites conoidesus Hall, Cryptoblastus melo (Owen and Schumard), Brachythyris suborbicularis (Hall), Amplexizaphrentis northropi, n. sp.

and occasional specimens of Paraendothyra sp.

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

The genus Cryptoblastus is restricted to Osage rocks in North America. Brachythyris suborbicularis is a typical representative of Osage rocks. In the middle part of the Hachita formation the only identifiable fossils are corals, the most frequent form being Amplexizaphrentis northropi. It is interesting to note that 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. Also found in the midportion of the Hachita formation are occasional specimens of Bothrophyllum sp. and Caninophyllum sp. and large colonies of Syringopora robusta, n. sp. In the upper two-thirds of the Hachita formation in a zone some 100 feet thick occurs the Osage-Meramec boundary. There is no physical evidence of a hiatus between the two series. The rocks throughout the suspected boundary zone are massive encrinites which show no noticeable change in lithology. Because identifiable fossils are rare, paleontologic methods cannot be used to determine the presence or absence of a hiatus or even the general location within a few score feet of the boundary between the two

series. It is believed in the area of Escabrosa deposition, in extreme southwestern New Mexico and in the Chiricahua Mountains of Arizona, that encrinite sedimentation continued from Osage well into Meramec time. Undoubtedly there exists within the Hachita formation, as in most marine deposits on the continents, small local diastems caused by short periods of non-deposition, 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 stratum that appears to be of definite Meramec age is marked by the presence of Endothyra symmetrica Zeller. This zone has been detected in the Big Hatchet Mountains of New Mexico and in the Chiricahua Mountains, Arizona. Some 30 to 40 feet above the E. symmetrica zone occurs a very diagnostic unit which is persistent over a wide area. It has been observed as far south and west as the hills south of Bisbee, Arizona. It reaches its maximum development in the Chiricahua Mountains of Arizona, and the Animas and Big Hatchet Mountains of New Mexico. It is also believed to be present in the Klondike Hills, but definite identification is obscured by selective dolomitization of the brachiopods.

The very highest beds of the Hachita formation, which are some 20 to 30 feet below the first shale of the

Paradise formation at Blue Mountain, Arizona, and the Big Hatchet Mountains of New Mexico, contain a sparse fauna consisting of Cleiothyridina hirsuta (Hall), Beecheria formosa (Hall), Eumetria verneuilana Hall, Dielasma bisinuatus (Weller) and Werriea keokuk (Hall and Whitney). This fauna, as was pointed out by Hernon (1935, p. 660) for the section at Blue Mountain, Arizona, 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 Michelinia leptosphragma, n. sp. have been found. Lithostrotion and Lithostrotionella have not been observed in the Meramec part of the Hachita formation at Blue Mountain, Arizona, or 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 ecological 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. At the base of the Black Prince limestone in the Gunnison Hills, Arizona, Lithostrotionella shimeri (Crickmay)

has been found. This species is characteristic of Meramec strata in western Canada (Nelson, 1960).

The highest beds of the Escabrosa group in the hills south of Warren, Arizona, contain a fauna characterized by Syringothyris subcuspidatus (Hall). It is overlain by an unfossiliferous series 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) 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 verneuiliana Hall from the lower part of the Black Prince limestone in the Ajax Hills. Gilluly et al. (1954, p. 16) 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). Although the Black Prince limestone is exposed in an area which represented the western periphery of the area of this study, it, therefore, was not studied in the detail it deserves. In thinsections it is a fine-grained

microcrystalline limestone, which is apparently almost devoid of megafossils and microfossils. Its exact age is uncertain, but it appears to represent lithologically and stratigraphically 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 of Arizona is not far removed lithologically from the Meramec age horizons at Blue Mountain, Arizona. The writer would treat the Black Prince as a localized member of the Hachita formation, Escabrosa group.

PALEOECOLOGY, PALEOGEOGRAPHY AND REGIONAL CORRELATIONS

Introduction. - An attempt to discuss the paleoecology through most of a geologic period and over a geographic area the size of this study, is truly a very hazardous undertaking, particularly when one considers most of the field studies were of a reconnaissance nature. Also at the present time we have a very limited knowledge as to how paleoecologically to interpret lithologies and fossils. Thus the statements made here on Mississippian paleoecology must be regarded as tentative and suggestive only.

The present interpretation of Mississippian sedimentation and paleoecology has been much influenced by the published studies of Illing (1954), Newell and Rigby (1957) and Cloud and Barnes (1957) on recent limestone sedimentation and ecology of the Bahama Bank. The concepts and interpretation of Folks (1959), pertaining to the environment in which the various limestone petrofabrics were formed, are also used in this study.

Upper Devonian. - The upper Devonian sea, which extended over southern and central New Mexico and Arizona, retreated at the close of the period. All of New Mexico and eastern Arizona is believed to have been a peneplain in earliest Mississippian time. As shown on late

Devonian paleogeologic map the southern part of the two states had exposed at their surface a variety of Devonian shales and argillaceous limestones. The rocks at the surface in central and northern New Mexico and northeastern Arizona were Precambrian metasedimentary and metaigneous rocks intruded by granitic plutons and associated rocks. At the end of the Devonian period this Precambrian terrain, referred to in this study as a craton, was a peneplain surface which had occasional low monadnocks of metaquartzite.

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. - The exact nature of the earliest Mississippian (Chouteau) Caballero formation is not clearly known. Its sedimentation, fauna, and extent of marine submergence are still somewhat enigmatic. Dr. G. A. Cooper (personal communication) is presently engaged in a study of the Caballero fauna which should appreciably help in our understanding of this poorly known time.

The present state of knowledge of the geographic extent and thickness of the Caballero sediments is shown

in the two correlation diagrams and the Kinderhook lithofacies map. Studies made on the Escabrosa group indicate strata equivalents of the 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 occurrances of Caballero age strata west of the Rio Grande River is at the mining camp of Lake Valley and the Roberto Mountains west 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 layers of gray nodular limestone, and in zones, thin beds of crinoidal limestone. The advancing Caballero sea, reworking the underlying Devonian regolith and shale, accounts for part of the shales within the formation. Streams, which flowed southward across the Precambrian craton and Devonian terrain, undoubtedly carried shales and fine sediments into the Caballero marine embayment.

Although it was not the primary object of this report to study the Caballero fauna or sediments, the following field observations were made. The fauna is marine, occurs sporadically, and is usually localized to certain stratigraphic levels. The Caballero formation is much more argillaceous than any of the succeeding

Osage or Meramec strata of the region. In conclusion, the Caballero sea was shallow, of short duration, and of restricted geographic distribution.

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

Osage. - In earliest Osage time a sedimentary pattern was initiated in the region of this study, which was to persist throughout the Mississippian. Three elements are apparent.

There was a shelf area or craton in northern and central New Mexico, which extended into northwestern Arizona. This is the southwestern part of the mid-Paleozoic Trans-Continental arch as depicted by Clarke and Stearn (1960, p. 60, figs. 2-4). It consisted of Precambrian rocks which were peneplained. This surface remained at, or near, sea level, and was occasionally submerged for short intervals of time. At the beginning of Osage time, this craton had little or no relief, and the rocks at its surface must have been deeply weathered. Through Osage and Meramec time, it contributed essentially no clastic material into the surrounding carbonate sea.

The remaining two elements were in the southern part of the state. The shelf area of the central part of the state was gently bent southward beneath sea level,

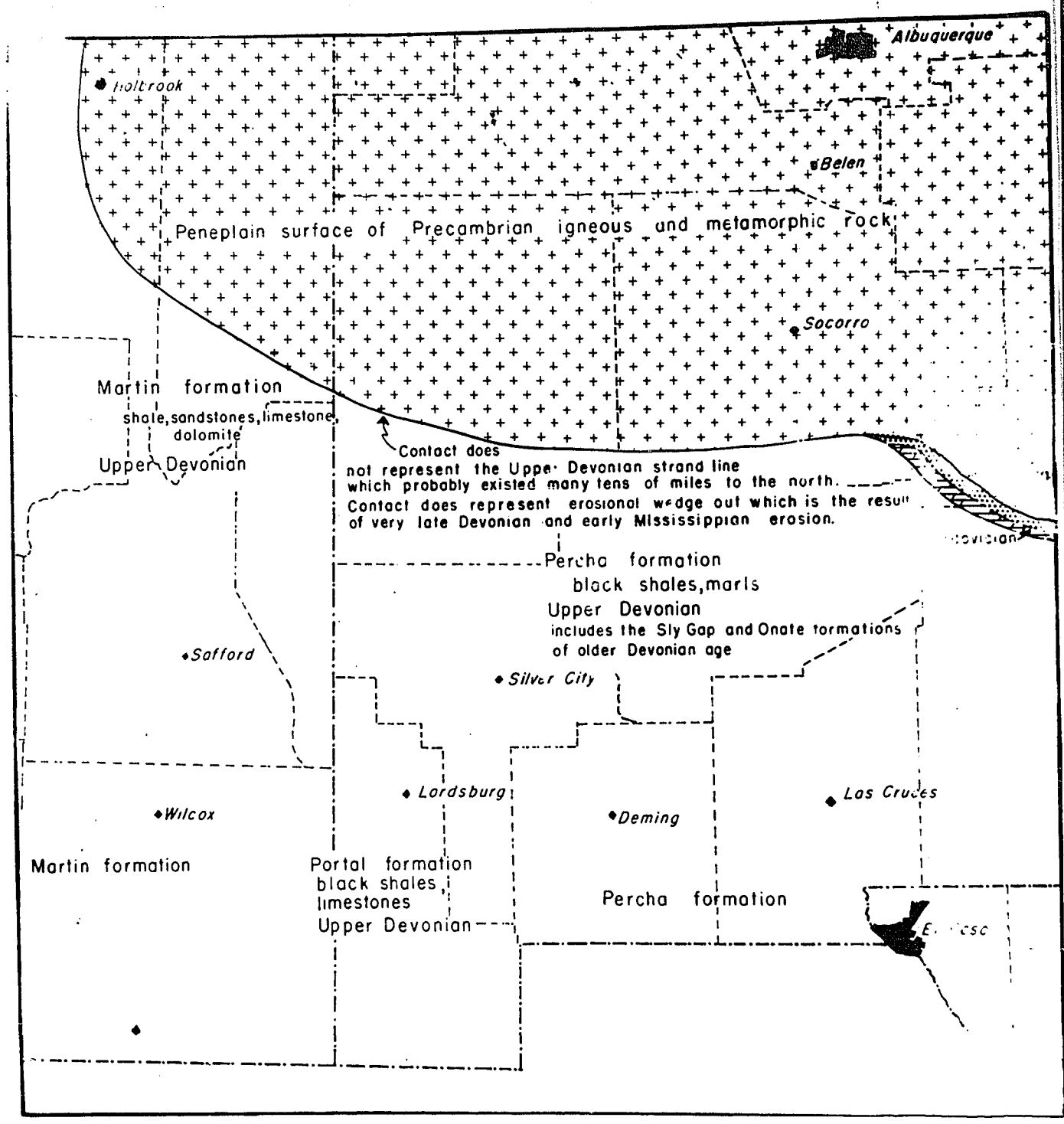

Figure 4. - Latest Devonian paleogeologic map.

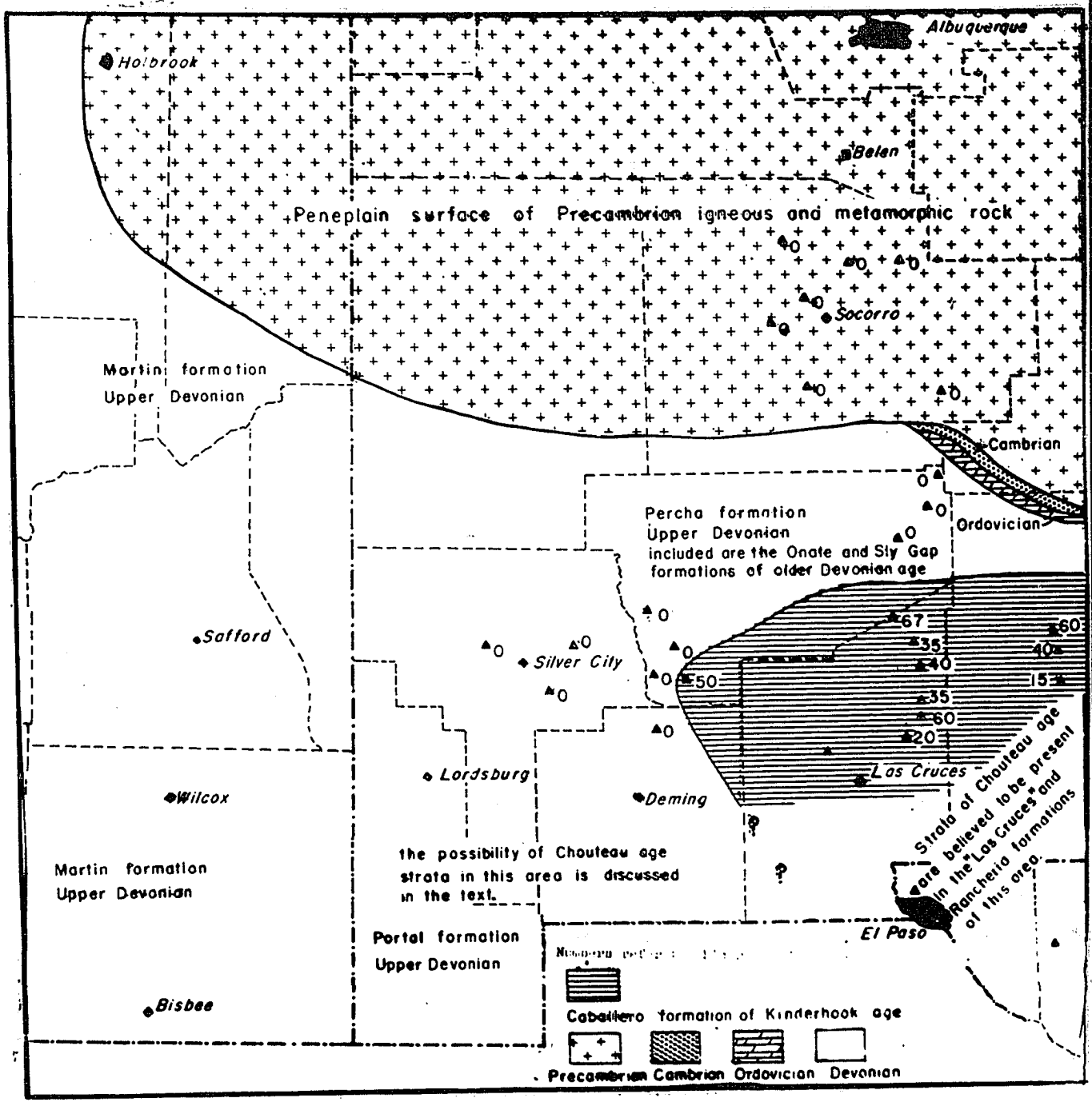

Figure 5. - End of Chouteau Kinderhook time paleogeologic map.

and continued to sink essentially at a steady and 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 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 the area of 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 to the north by reef-bearing crinoidal limestones of the Lake Valley formation and to the west by the encrinal 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 Loudon and Bowsher (1949, p. 19), was considered to be a northward overlap of lower Meramec age onto an eroded Lake Valley (Osage) surface. This interpretation is probably incorrect, and studies currently in progress indicate the Rancheria formation is a starved basin facies of the Escabrosa and Lake Valley formation.

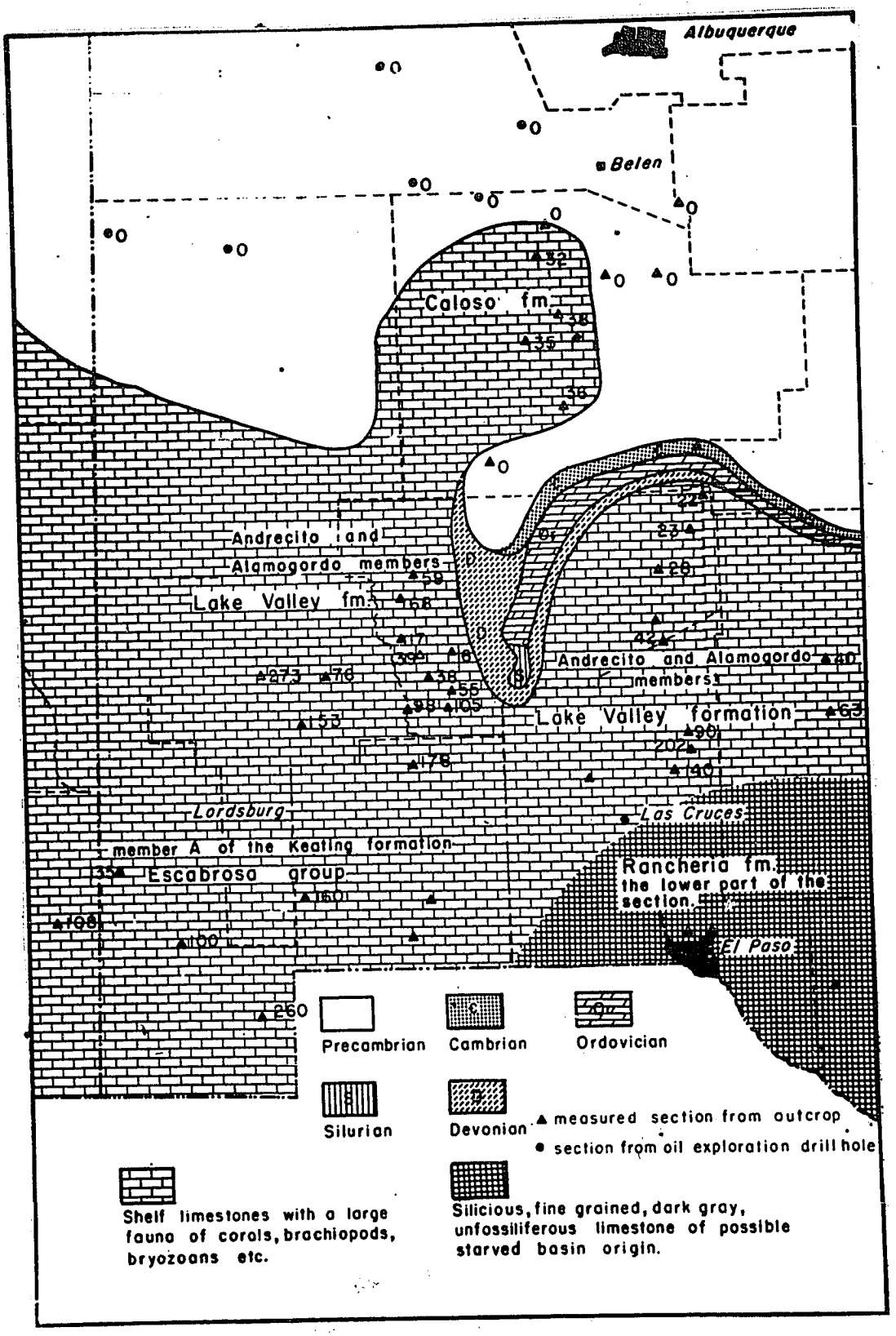

Figure 6. - Earliest Fern Glen, Osage, lithofacies map. (The northern limits of the Mississippian limestones is a function of early Pennsylvanian erosion).

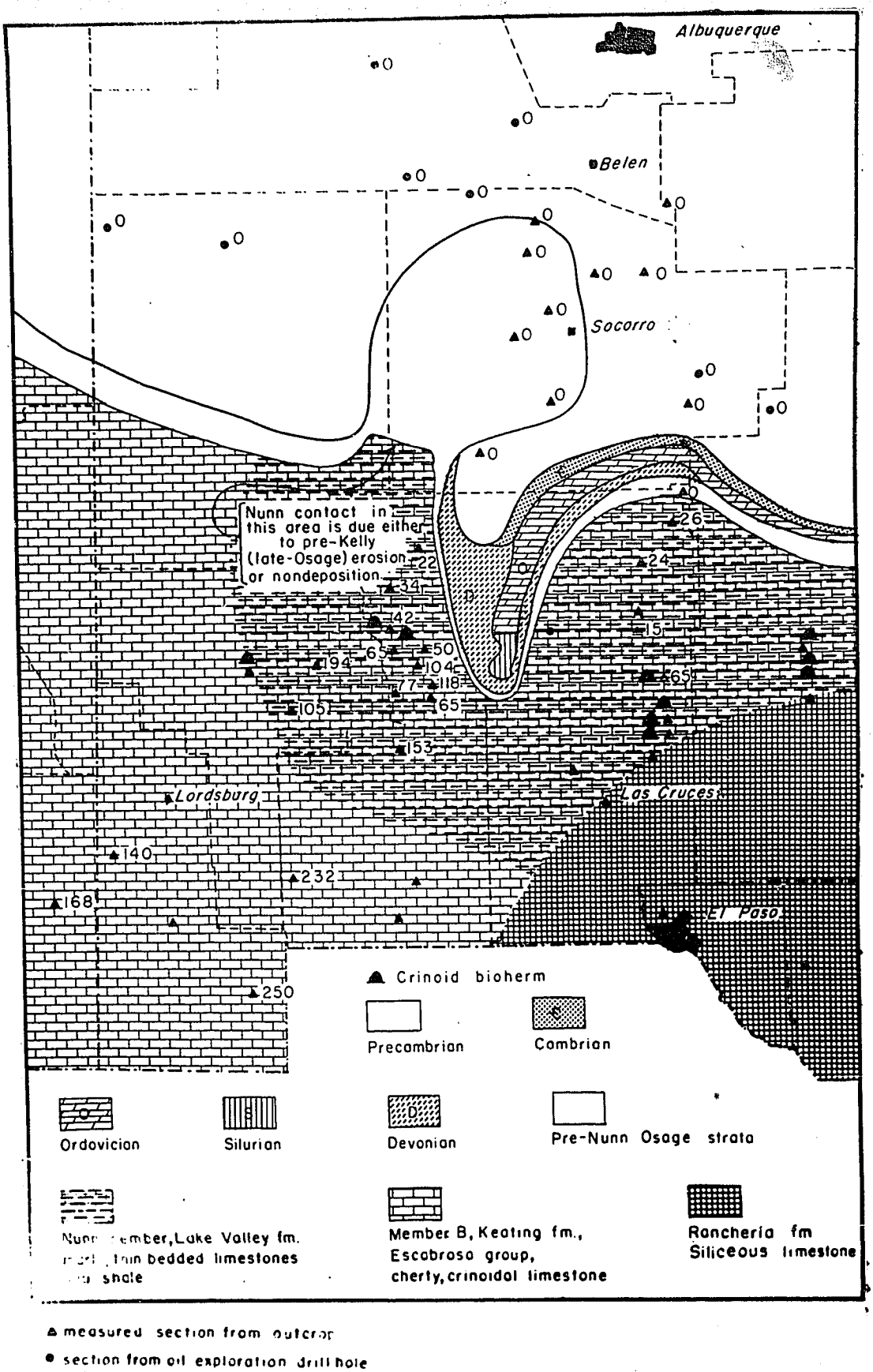

Figure 8. - Fern Glen, Nunn-Keating Lithofacies map.

In the Franklin Mountains of Texas and southern Sacramento Mountains of New Mexico field studies indicate that the facies change, between the Lake Valley and Osagian part of the Rancheria formation, is abrupt. The Rancheria facies with time advances northward over older Lake Valley facies sediments. Within the Osagian part of the Rancheria facies are long tongues of Lake Valley crinoidal limestone. These apparently represent crinoidal debris swept by turbidity 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 them back into the Lake Valley formation. A forthcoming paper now in preparation will discuss in detail the lithology and fauna of the Rancheria formation.

In southwestern New Mexico and extreme southeastern Arizona, the basal Mississippian is represented by

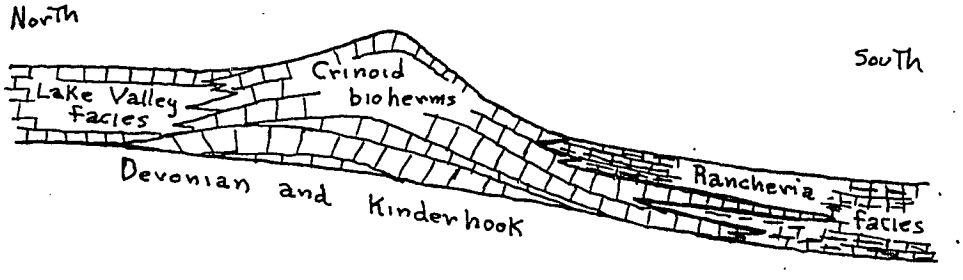

Figure 7. - Diagrammatic illustration of the relationship between the Lake Valley and Rancheria formations in the Sacramento Mountains, New Mexico.

member A of the Keating formation, Escabrosa group. Member A can be divided into two lithic units. The lowest of these is 70 to 150 feet thick and is an encrinite which may be secondarily altered to a dolomite. In the Klondike Hills, the highest Devonian is a shale and thin-bedded limestone. The basal Mississippian reflects the Devonian by containing much reworked shale. In general, where the upper Devonian is calcareous or a limestone, the basal Mississippian will be a limestone and generally an encrinite.

Wherever conditions were suitable in this early Osage sea the crinoids established themselves rapidly and were able to exclude most types of preservable invertebrates. This was apparently in areas where the waters were clean and agitated and the bottom stable. During earliest Osage time, in rather localized areas, and through a stratigraphically short section, the crinoids were able to maintain an almost exclusive hold on the environment. This early Osage dominance of the crinoids 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 was characterized during this time by a large area covered by shale and calcite ooze and 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 probably 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 a set of distinctive lithologic features which can be traced over a wide region. Deposition was again in shallow water and in a zone of high energy. Some of the lithologies indicate that deposition was at times primarily a calcite ooze in shallow but quiet water below wave base. The most characteristic limestone types of this horizon are those deposited in high energy zones. There are two types, a typical bioclastic limestone with sparry calcite, and an öolitic limestone. Recent workers (e.g., Illings, 1959; Newell and Rigby, 1957; and Folks, 1959) have indicated two important factors in the formation of öolites: 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. They believe marine waters must be swept across a shallow shelf area where the water

became warmer and supersaturated with calcium carbonate. This supersaturated marine water then must be vigorously agitated. Similar conditions to the above must have existed over wide areas during the deposition of the coral zone fauna in New Mexico and Arizona. This broad area is thought of as slowly sinking, while the calcium carbonate organisms maintain 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, terebratulas, chonetids, and productids thrived. The most conspicuous part of the fauna were the corals which throughout the area and at this time, were at their regional 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 covered much, if not all, of New Mexico, but early Pennsylvanian erosion has obscured its original extent (Armstrong 1958 A, 1958 B, 1959).

Although the Andrecito and Alamogordo members of the Lake Valley formation were not studied in detail, faunal evidence indicates that these are a northward facies of member A, Keating formation, Escabrosa group. The Andrecito member varies in thickness and is a series of thin-bedded argillaceous limestone, which depending on the location of the outcrop, rests upon either the Cabellero formation (Chouteau) or on shales of late Devonian age. The argillaceous material in the Andrecito member frequently contains well-preserved fossils, such as articulated brachiopods; bedding planes are covered with fenestelloid bryozoans and frequently 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, massive, and consists in part of bioclastic debris, calcirudites, and primarily calcilutites. The Alamogordo member is stratigraphically a northwestward 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 member A.

The Caloso formation of west-central New Mexico is a northward continuation of this lower Osagian marine sedimentation. Its relationship to member A of the Keating formation is graphically shown in the Escabrosa group - Lake Valley formation correlation chart. It rests upon a Precambrian terrain 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 organisms. The rock types and lithologies of the Caloso formation were previously described in detail by Armstrong (1958, B).

The lower part of member B, Keating formation is correlated with the Nunn member of the Lake Valley formation. The correlation of the lower part of member A with the Nunn member is done in part 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 A is undergoing a two-fold lithologic change. One change is toward the gray, siliceous limestones with brown siliceous chert which is lithologically characteristic of the Rancheria formation to the east in the Franklin Mountains, Texas. The other change is the presence of a thin shale zone and argillaceous limestone which contain fossils that are typical of the Nunn member to the north in the Cooks Range. There is found in these shale zones Spirifer rowleyi Hall and Caninia cornucopiae Michelin. These fossils, particularly Caninia cornucopiae, are highly characteristic of the Nunn member. Lithologically the lower part of member A from Blue Mountain, Arizona, to the Big Hatchet Mountains of New Mexico is a dense fine-grained limestone, composed of fine, 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 energy and were thus below wave base.

To the northeast the Nunn member, Lake Valley formation, is primarily soft bluegray marl and nodular

crinoidal limestone. The brachiopods are generally articulated and well preserved, and crinoid calyxes are very common. These fossils, as was pointed out by Laudon (1957, p. 966), appear to represent periods when life was overwhelmed by sudden influxes of muds. The Nunn member represents waters with only mild agitation on the sea floor. It is believed that the time represented by the lower part of member B, Keating formation, and the Nunn member, Lake Valley formation, was a period of general lowering of the sea level in the southern part of the state. This resulted in sedimentation occuring at, or just below, wave base in the region. Paradoxically, the craton to the north was slightly elevated; and the marine water receded southward a short distance (50 to 70 miles). The craton with its fringing emergent plain of marine limestones underwent for a short period of time slightly more active subareal erosion. The stream, which flowed southward across the plain, carried mud and shales which were deposited in the relatively quiet waters of Nunn time. Stratigraphic support for this interpretation is present in west-central New Mexico in the Ladron Mountains. Here the Caloso formation of lowest Osage is separated from the crinoidal Kelly formation of Keokuk age by a hiatus which represents all of Burlington time and undoubtedly that part of Fern Glen time represented by the Nunn member to the south. (These relationships

are shown graphically in the Escabrosa group-Lake Valley Correlation diagram).

In the Escabrosa basin the crinoids were able in a stratigraphically 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 A, they do not dominate the fossils. Other organisms are abundantly represented by broken remains; they are brachiopods, bryozoans, corals and lesser amounts of gastropods and trilobites. One of the most spectacular aspects of member B is the presence of 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 to 200 feet) necessitates some paleoecological interpretation (the reader is referred to the lithology of the Keating formation for a detailed description of the chert and to the Nunn-Keating formation lithofacies map).

The chert in the upper part of member B, Keating formation, shows direct evidence of a replacement origin. The evidence is the 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

boundary. The silica, which formed the chert, 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, contained a higher concentration of dissolved silica. The origin of the silica in solution if a moot question. The complex problem of the origin of the bedded cherts in upper Paleozoic strata of the Cordilleran region is discussed in detail by Bissell (1959). A recent study by Pittman (1959) demonstrates that the primary method of precipitating silica from sea water is through the metabolism of organisms using silica as a skeleton. Sea water, which contained higher amounts of dissolved silica, would be conducive to abundant numbers of silica-using organisms, such as silica sponges and radiolaria. These in turn would yield more silica spicules and tests to the accumulating lime sand and lime muds on the sea floor. This syngenetic silica during diagenesis is then concentrated by metasomatic solutions into nodules and lenticular masses.

The upper part of member B is composed primarily of crinoid fragments and appreciable broken and abraded remains of the following organisms: brachiopods, rugose corals, bryozoans, trilobites, and gastropods. The limestone is dark gray in color, and petrographic

studies indicate the dark color is due to the high percentage of fecal pellets present between the fossil fragments. Insoluble residue studies reveal the almost complete absence of terrigenous material and the presence of appreciable organic (hydrocarbon) material. The organic matter is believed to be contained primarily in the brown fecal pellets. The highest bed of the Keating formation contains extensive zones of intraclasts (intraformational), conglomerates, and extensive distribution on the bedding planes of the worm burrows, Taonurus. The abundance of crinoid, brachiopod, and bryozoan remains indicate the sea waters were well-oxygenated. The dark color of the rocks, the abundant fecal pellets, abundant hydrocarbons and small, dissimented pyrite crystals suggest the muds beneath the water substratum interface were in a strongly reducing environment. At higher stratigraphic levels of member B an increase is shown in bioclastic materials. Near the top of this unit are found intraformational conglomerates and the fossil, Taonurus. These factors suggest marine water which became progressively more shallow and thus stronger wave and tidal currents were developed. 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.

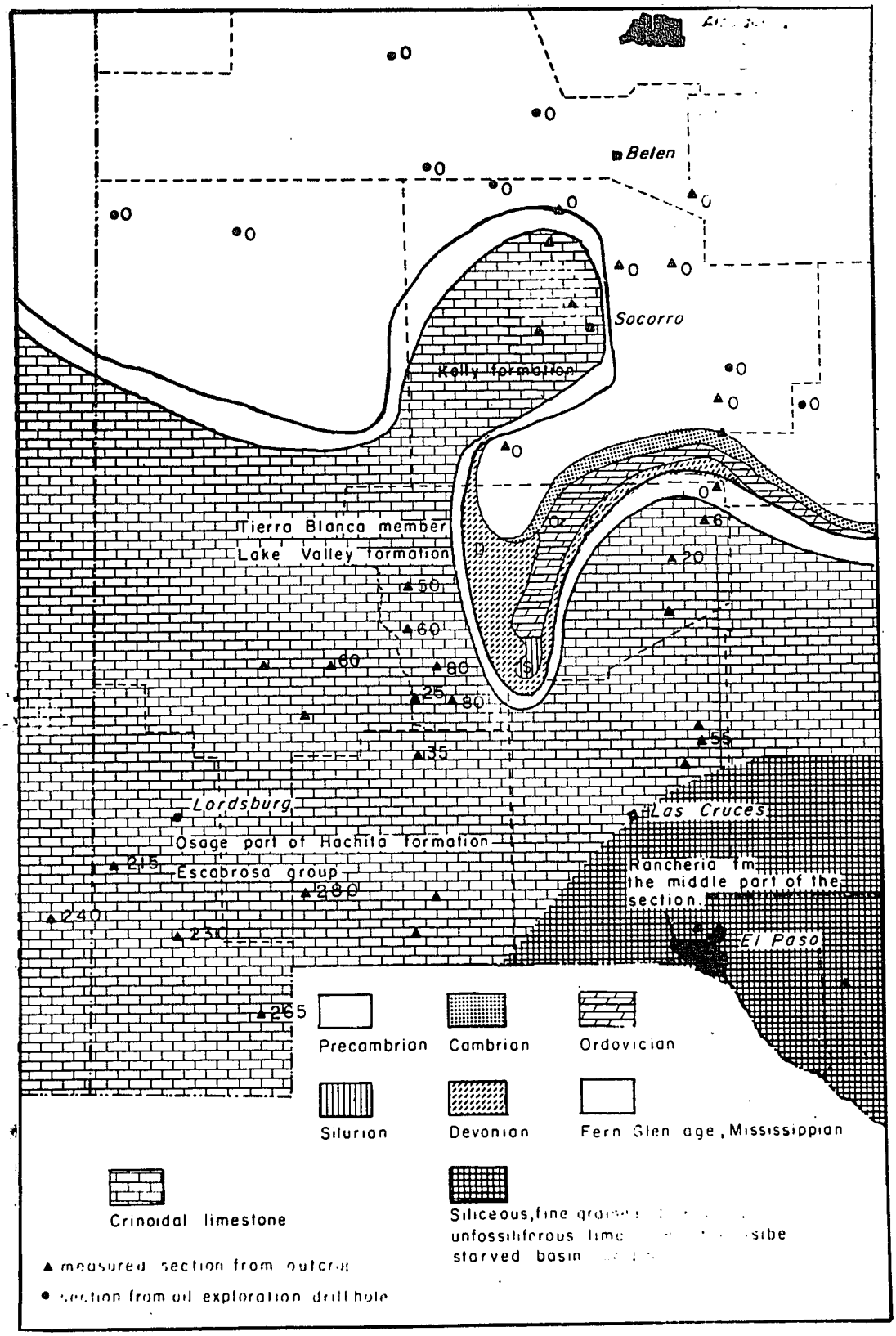

Figure 9. - Burlington-Keokuk, lithofacies map.

The Emergence of Crinoids to Dominance in Osage Time. - There is present, over all of southwestern and southcentral New Mexico, an extensive blanket of crinoidal limestone. In the southeastern part of the state this is replaced by the non-crinoidal Rancheria facies. This crinoidal limestone extends westward into southeastern Arizona. The encrinite represents most, if not all, of Burlington and Keokuk time. It covers a large area, as can be seen on the Burlington-Keokuk lithofacies map. Its thickness, ranging from 40 feet in the central part of the state to 300 feet along the Mexican border, is illustrated by the two regional correlation diagrams. The lithology of this series of encrinites is unique. It is characterized by limestones 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 microcrystalline lime calcite. Fecal pellets are almost completely absent in this encrinite, in contrast to most of the older crinoidal limestone of the Lake Valley formation and Escabrosa group which contain abundant brown pellets.

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

exclusion of other animals, appears to have begun a little earlier in southcentral 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 some 5 to 15 feet thick, and 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 crinoidal limestone 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 setting of Burlington to Keokuk time is considered to have been on a very flat shallow sea floor which extended over a extensive region a minimum of 45,000 square miles in the area of this study. This broad submarine plane sank very slowly. Its hinge-line with the craton in northern New Mexico appeared to be in the central part of the state, and 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

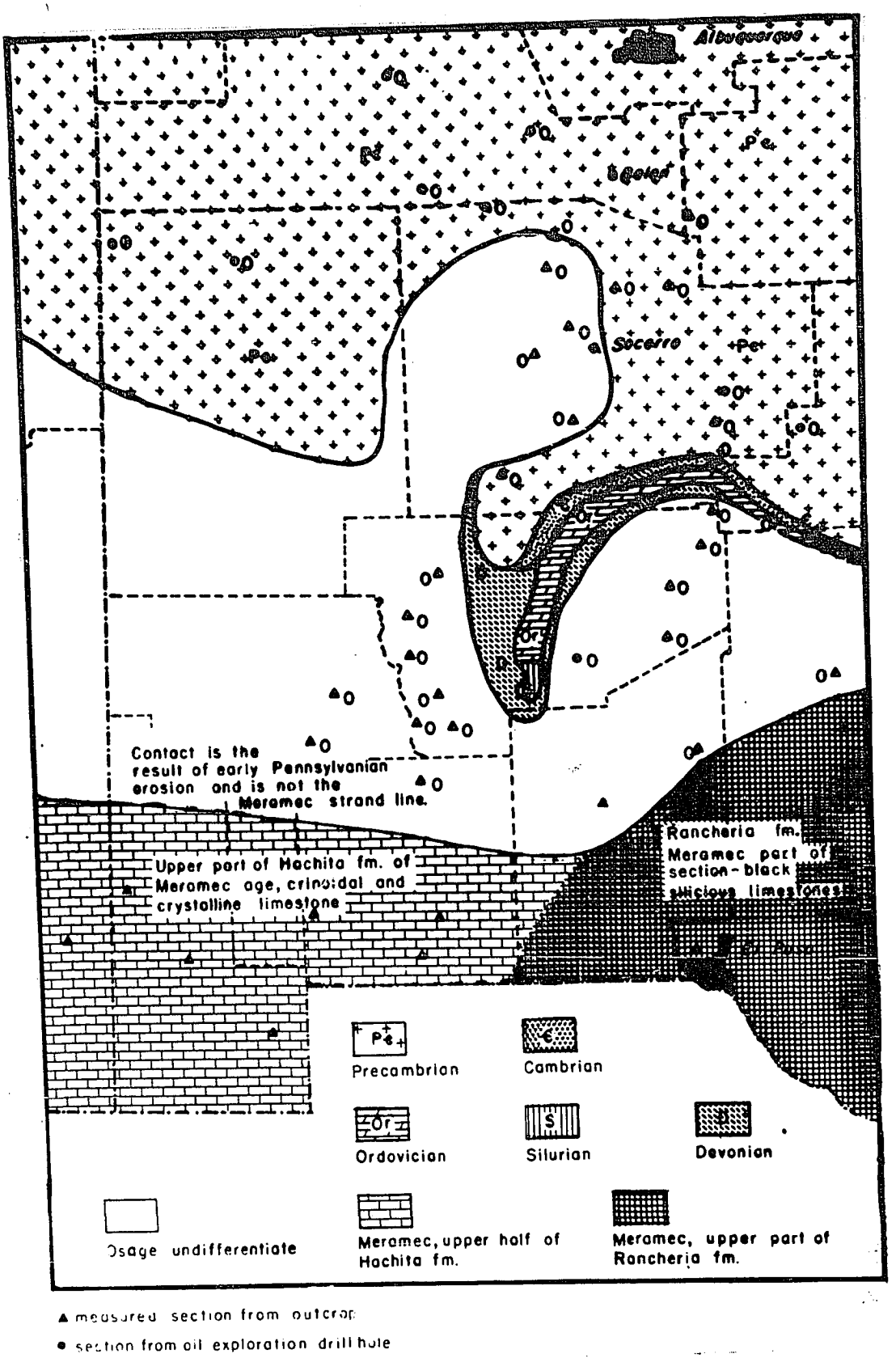

Figure 10. - Meramec lithofacies map.

of the region. Deposition on the sea floor was generally above wave base in a zone of high energy. The rocks indicate that some sedimentation did occur, also in rather quiet waters. The marine waters were warm, semi-tropical to tropical, clear, well-oxygenated, and must have contained abundant nutrients. The unconsolidated sediments below the water-substratum interface were in an oxydizing environment. The sea bottom during this time must have been primarily shifting bioclastic calcite sands intermixed with lime ooze, since depression below wave base would permit the accumulation of primarily lime mud with bioclastics. 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.

The ecological conditions which permitted the crinoids to flourish began in early Burlington time and continued, at least in the area of the Lake Valley formation, into Keokuk time. As the basin of deposition downwarped, the sea extended northward onto the craton. 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 Kelkuk age rests with a marked disconformity on the Caloso formation of Fern Glen age. The hiatus separating the two formations represents all of the 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 (1958, B) 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 due to the widespread removal of these sediments during early Pennsylvanian time. Scattered and isolated remains of Meramec limestone indicate that various Meramec submergences 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 submergence of the stable peneplained Precambrian craton of northern New Mexico (Armstrong, 1955, 1958 A, 1959). Meramecian rock are unknown in the central part of the state, but this is believed to be the result of Pennsylvanian erosion. They are now confined to the extreme southern parts of the state (see the Meramec lithofacies map).

Meramec time is represented in the Trans-Pecos region by the 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 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. The microlithology 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 the 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 sp. Some ecological factor (temperature, water depth, turbidity) must have been very detrimental to coral development. As can be seen on both the regional fence-diagram and the Escabrosa group-Lake Valley correlation diagram, the Meramec limestones are rapidly cut out by the early Pennsylvanian erosion surface in the northern part of the Escabrosa basin. The ancient northern limits of Meramecian marine sedimentation, and whether or not the younger parts may have been continuous with the Arroyo Penasco sea may never be known. It seems not unlikely that various phases of the

Meramec sea may have extended many tens or even hundreds of miles northward and originally have deposited over the Lake Valley formation from 100 to 200 feet of limestone.

Chester. - The Paleozoic systems of New Mexico, previous to Chester time, had been characterized by shallow platforms repeatedly covered by broad, epeiric seas. The thickest accumulations of sediments were always in the southern part of the state, and the craton to the north was generally emergent, very flat and stable. The pre-Chester Mississippian marine sedimentation closely resembled the older periods. Chester sedimentation and tectonics were markedly dissimilar to those of earlier Mississippian time. The beginning of the epoch heralded the beginning of structural and sedimentation patterns which were to dominate the Pennsylvanian period. At the end of Meramec time, marine waters withdrew from the northern craton and shelf areas and by Chester time were confined to the extreme southern part of the state (see Chester lithofacies map). Concurrent with the retreat of the marine waters, began the development of the Zuni, Sierra Grande and Pedernal highlands which were to become such conspicuous elements during Pennsylvanian time. The Osage and Meramec epochs were times of

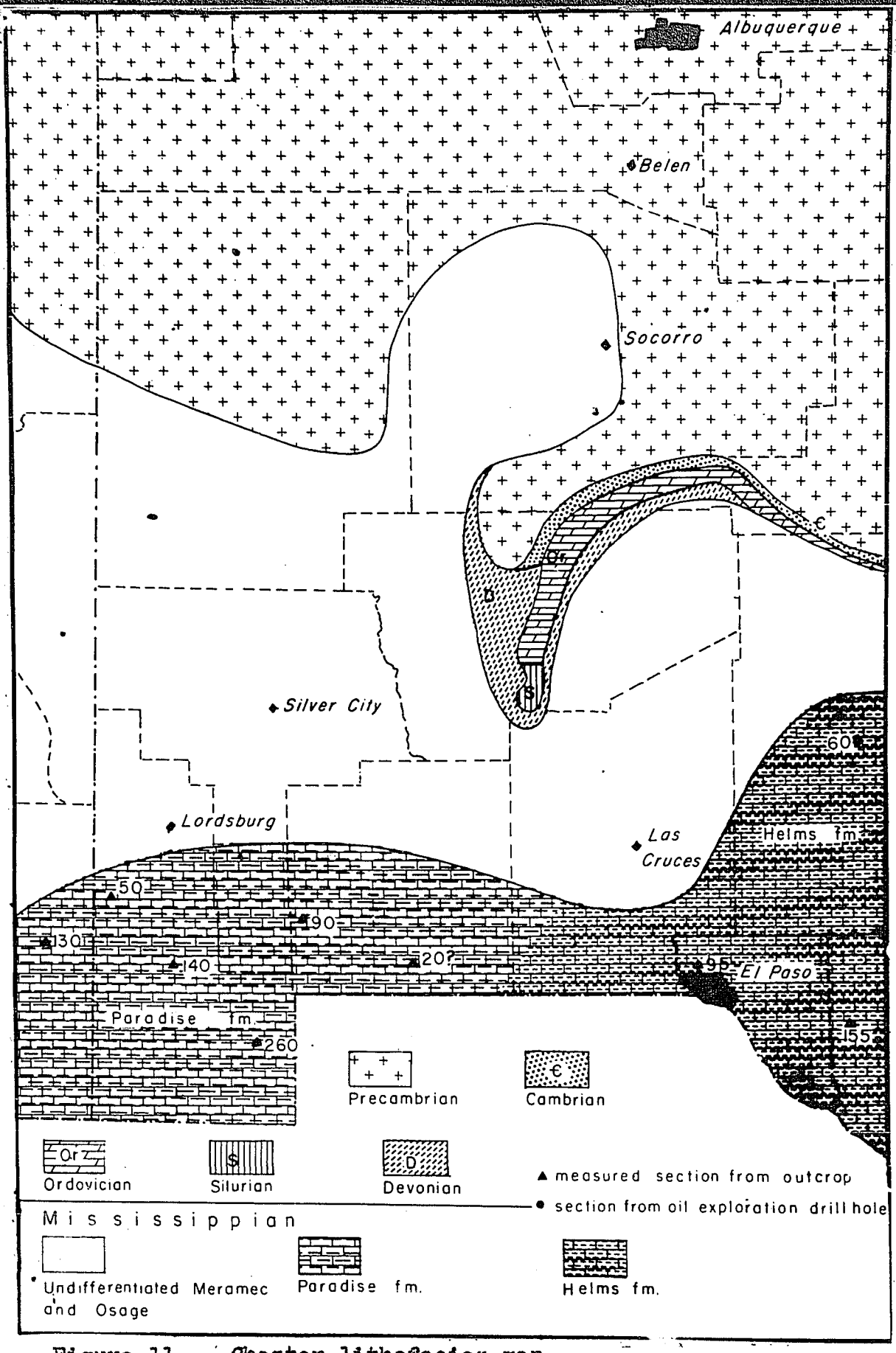

Figure 11. - Chester lithofacies map.

widespread, uniform environment and stability. The Chester sediments indicate, in contrast, a time of fluctuating sedimentation and crustal instability. In the Paradise formation the sediments are a series of cyclic, impure, microcrystalline to bioclastic limestones, fine-grained sandstones and shales. Some of the shales, particularly those in the higher part of the section, contain terrestrial plant remains that indicate interfingering of marine and terrestrial environment. The Paradise formation in the Big Hatchet Mountains is some 230 feet thick. The section shows a noticeable increase with time of clastic materials. The marine waters evidently fluctuated over a wide area repeatedly but generally were progressively pushed southward during Chester time. This was due to the increased influx of clastic material from the elevated highlands to the north and the gradual emergence of the whole region above sea level.

Although time was not available in this study to do a detailed, paleontologic study of the Paradise fauna; preliminary studies indicate that in the region of 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. Undoubtedly 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 ten to twenty-five feet of orthoquartzite which grades upwards into shales and massive limestones. Westward in the Animas and Chiricahua Mountains the basal Pennsylvanian is a marine, brown to gray, shale overlain by massive limestones.

Mississippian Bioherms. - The Escabrosa exposures were examined detailedly in an effort to determine biohermal buildups. It was expected that abundant evidence of bioherms would be encountered within the massive encrinites of the Hachita formation. However, inspection revealed that they are absent within this stratigraphic unit. The Hachita encrinites were deposited in a shallow sea in which there must have existed, wherever the bottom was stable, scattered gradens of crinoids. With the death of a crinoid, its remains were swept 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, Keating formation, on the

northeastern side of the Big Hatchet Mountains. Here there are present small crinoidal bioherms 60 feet high and about 150 feet wide. They are very conspicuous because chertification has altered them, rendering them dark brown in color in contrast to the enclosing light gray encrinites.

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. The first studies on these bioherms was done by Laudon and Bowsher (1941, 1949) in the Sacramento and San Andres Mountains. Pray's (1958) detailed study on these in the Sacramento Mountains showed their cores to be of fenestrate bryozoans. He also demonstrated 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 are smaller and 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

Family ENDOTHYRIDAE Rhumbler, 1895

Subfamily ENDOTHYRINAE Brady, 1884

Remarks. - The phylogenetic relationships of the endothyrids depicted by Zeller (1950, 1957) and Woodland (1958) are impressive but probably not totally correct. Before a reasonably accurate phylogenetic relationship within the endothrids can be obtained, certain fundamental questions must be answered. The first is the origin of the Mississippian endothyrids. Zeller (1950) indicated that the plainspiral upper Devonian Nanicella was the ancestor. He later (1957) considered the lower Mississippian assymmetrically coiled Granuliferella of the Cordilleran area to be the ancestor of the assymmetrical Paraendothyra and plainspiral Endothyra. In this lineage (Nanicella to Endothyra) it is necessary to go from symmetrical to assymmetrical to symmetrical forms.

The author suspects that neither the genus Endothyra or Paraendothyra had a single origin but now represent the artificial grouping of a polyphyletic series of species. Undoubtedly during lower and middle Mississippian time the asymmetrical and symmetrical endothyrids repeatedly were derived out of opposite forms.

The phylogenetic concepts of Zeller (1950, 1951) and Woodland (1957) which restrict the larger plainspiral

endothyrids (over 0.4 mm in diameter) to strata of Meramec age, has been proved incorrect by the study of Escabrosa foraminifera. Member A (lowest Osage), Keating formation, Escabrosa group contains in southwestern New Mexico and southeastern Arizona, a very large (1.2 mm in diameter) robust, Endothyra sp.

This lower Osagian endothyrid is an external, and in part internal, homeomorph of described species groups of Meramec Endothyra. Mississippian endothyrids at our present state of knowledge of their evolution can be used at best to correlate in North America at the series level. Correlation by endothyrids within shorter time spans than a series, even within a single basin of deposition, can be very hazardous. The writer has found that species or groups of species are prone to follow ecologic rather than time lines.

Woodland (1958) observed in his study of Mississippian endothyrids from central Utah that they "occurred in great abundance in a lithology of fossil hash of coarse enchinoderm fragments with a calcarenite or calcirudite groundmass". Within the Escabrosa group this type of lithology was found to be essentially devoid of endothyrids.

Oolitic limestones which occur within the Escabrosa group indicate the existence of waters which were super-saturated with calcium carbonate during their deposition.

The endothyrids are most abundant in these oolitic horizons. The exteriors of the endothyrid tests frequently show the addition of calcium carbonate and the tests are frequently the nuclei of oolites.

Most of the Escabrosa section consists of calcarenites devoid of oolites and composed of brachiopod, crinoid, coral and bryozoan remains. These horizons are essentially devoid of endothyrids.

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, v. 2, p. 277.

Endothyra, Brady, H. B., 1876, Palaeontolographical Society, v. 30, p. 90.

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

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

Endothyra, Zeller, E., 1950, University of Kansas Paleontological Contributions, Protozoan, art. 4, p. 3-4.

Endothyra, St. Jean, J., 1957, Indiana Geol. Survey 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, 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 aperature

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. 12, fig. 13.

Endothyra symmetrica Zeller, E. J., 1957, Jour. Paleont., v. 31, p. 701-702; pl. 75, figs. 14, 18, 19; pl. 78, figs. 8, 9; pl. 80, fig. 6.
Endothyra symmetrica, Woodland, R. B., 1958, Jour. Paleont., v. 32, p. 800; pl. 101, figs. 7, 9, 10.

Description. - The shell is discoidal, involute and the chambers are slightly swollen between the sutures. The coiling is planispiral. Moderately long septa show a slight anterior direction. Proloculus 30 to 40 microns in diameter. Secondary deposits are confined to the development of a prominent namulus in the final chamber. The specimens studied by the writer ranged in size from 0.4 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 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, more rapid rate of expansion, its less numerous septa and 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 that E. symmetrica was in the Cordilleran region characteristic of upper Meramecian; 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 has within the Escabrosa group a stratigraphic range from basal Warsaw to St. Louis, Meramec time.

Endothyra sp. indet.

Pl. 12, fig. 15

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

Remarks. - Endothyra, s. s. is apparently absent in pre-Meramec strata of the Midcontinent region (Zeller, 1950). In the 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, has yielded a very few large (maximum diameter of 1.2 mm) Endothyra. Their size and contour is 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 Meramecian homeomorphs by the possession of a final whirl which is expanded and by their very thin shell walls.

Genus Paraendothyra Chernysheva, 1940

Paraendothyra Chernysheva, N. E., 1940, Societe des Naturalistes de Moscou, Bulletin, v. 48, p. 129; pl. 134.
Plectogyra Zeller, E. J., 1950, University of Kansas Paleontological Contributions, 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 Bulletin, v. 48, p. 129-130, 135); lower Carboniferous Tournaisian stage, western slope of the southern Ural Mountains.

Range. - Mississippian to Pennsylvanian.

Diagnosis. - The shell is discoidal and probably umbilicate on one side. It is involute and the chambers swollen between sutures. The aperature 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 have 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 emended to Brady's definition so as to include both symmetrical and asymmetrical endothyrids. The strongest criticism of Zeller's genus Plectogyra has come 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 assymmetrical and symmetrical forms with Endothyra baileyi as a typical representative. St. Jean was also disturbed by the fact that if Zeller's Plectogyra was 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 assymmetrical forms, is not the ultimate criteria for defining the genus. Phillips' (in Brown) original description of the genus, which relates only to planispiral forms and is in reality the final definition. The arguments of St. Jean's 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 in populations studied, a ratio of Endothyra to Paraendothyra. This condition has not been observed in

the rather limited studies made. In the Escabrosa group and related formations the majority of Paraendothyra are strata of Osage age whereas Endothyra dominates 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 as asymmetrical forms. However, it has been found here that the great majority of endothyrids are easily identified as either Endothyra or Plectogyra. 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. It will become more frequent as more faunas are systematically described.

St. Jean (1957, p. 26) states correctly that Zeller's genus Endothyra is known entirely from thinsections; and, 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 points out that if these Foraminifera are used for stratigraphic work, as in the correlation of well samples, sectioning would probably not be feasible. Apparently St. Jean 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 their small size, 0.2 to 1 mm in diameter, they seldom, if ever, can be detected in rock samples except in randomly-made thinsections. Because of the nature of the enclosing rock and preservation, Mississippian endothyrid studies must rely almost entirely on thinsection studies. Internal features are viewed by the writer to be of much greater importance than external shell characters, which would possibly tend to be subject to more homeomorphism than the internal traits.

Paraendothyra sp. indet.

Pl. 12, fig. 15

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 is apparently absent 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 FUSULINIDAE 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, Geol. Survey Kansas, 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.

Diagnosis. - After Thompson (1951, p. 115). Shell minute, planispiral in all volutions, subellipsoidal to subdiscoidal in shape, with rounded to subangular periphery, straight axis of coiling, flush, slightly extended, to slightly umbilicate axial ends. The first one to one and one-half volutions of most forms are evolute, the following two to three volutions are completely involute, contain less than eight volutions and are slightly more or less than 1 mm in maximum diameter. In contrast to most fusulinids, the form ratios of most forms decrease slightly as maturity is approached. The proloculus is minute in size, and the chambers increase slowly and uniformly in height. The spirotheca is thin and is composed of a thin primary layer. In inner volutions, the primary

layer is covered above and below by thick tectoria. The septa are plane throughout all parts of the shell and are closely spaced. They are distinctly curved anteriorly as the poles are approached, but are about normal to the spirotheca above the tunnel. The tunnel is narrow, and its path is straight. The chomata are massive, high and distinctly asymetrical, with steep tunnel sides and broad but low poleward slopes.

Remarks. - Paramillerella can be distinguished from Millerella Thompson by its more tightly coiled shell, more massive chomata, and more nearly spherical shell. The last volution of Millerella is only slightly impressed over earlier volutions or is uncoiled. Paramillerella resembles somewhat closely the general shell shape of Staffella Ozawa but is smaller in size and has a distinctly different early shell shape, more deeply umbilicate axial areas in most forms, seemingly has a distinctly different spirothecal structure, large chomata, a relatively more loosely coiled shell, and has a smaller number of volutions in most forms.

Paramillerella tortula Zeller

Pl. 12, figs. 12, 13.

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 proluculus 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 and 0.35 mm wide and 0.08 and 0.10 mm long.

Horizon. - E. J. Zeller (1957, p. 694, and text fig. 1) stated that at Blue Mountain, Chiricahua Mountains, Arizona, "The fusulinid Paramillerella tortula is present in abundance throughout the Paradise formation". The writer made a number of thinsections at this locality 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 have been 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 plainspiral manner of coiling.

Paramillerella ? sp.

Pl. 12, fig. 12

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 plainispiral. The specimen has been partly obliterated by incipient recrystallization and the exact nature of the secondary deposits are 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.

Order RUGOSA Milne-Edwards and Haime, 1850

Suborder STREPTELASMATINE Wedekind, 1927

Superfamily CYATHAXONIICAE Milne-Edwards and Haime, 1850

Family HAPSIPHYLLIDAE Grabau, 1928

Genus Amplexizaphrentis Vaughan, 1906

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

Triplophyllites, Easton, W. H., 1944, Illinois Geol. Survey, Rept. of Invest., no. 97, p. 34.

Triplophyllites, Easton, W. H., 1951, Jour. Paleont., v. 25, no. 3, p. 391-392.

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

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

Type Species.(by subsequent designation: Lang, Smith and Thomas, 1940, p. 16) Zaphrentis bowerbanki Edward and Haime, Thomson, (1883, Proc. Phil. Soc. Glasgow, v. 14, p. 368).

Range. - Mississippian to lower Pennsylvanian.

Diagnosis.- The corallum is a small, solitary ceratoid or trochoid. The fossula is on the concave side of the corallum. The fossula is commonly oblique, and the septa is

wavy and arranged inequalaterally. Alar fossulae may be prominent. Minor septa are very short; the major septa are withdrawn from the axis, first in the counter quadrants. Septa become short in late ephebic stage. Cardinal septum is long in neamic stage, short in ephebic. Flat tabullae extend completely across the corallum, but in some species are bent down near the wall.

Remarks. - Amplexizaphrentis was proposed by Vaughn (1906, p. 62) as a subgenus of Zaphrentis Simpson. Easton (1944) argued that Amplexizaphrentis was inadequately known and errects in its place the genus Trilophyllites. Easton (1951, p. 391-393) elaborated his genus Trilophyllites into two subgenera based upon the position of the cardinal fossula on the corallum. His subgenus Trilophyllites (Trilophyllites) has the cardinal fossula on the convex side, whereas Trilophyllites (Homalophyllites) has the cardinal fossula on the concave 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. (Trilophyllites) 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 Homallophyllites 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 grovei n. sp.

Pl. 6, figs. 9-14.

Triplophyllum cliffordanum var hespere Grove, B.H., 1935, American Midland Nat., v. 16, p. 346-347; pl. 8, fig. 6; pl. 18, fig. 9-11.

Diagnosis. - Simple, trochoid, curved coral; ephebic stage, 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 silification was of such a nature as to destroy or obscure the original neamic characters.

The coralite is ceretoid and curved, 25 to 30 mm tall

and 12 to 15 mm in diameter. The exterior of the epitheca has pronounced rings formed by 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 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 tabullae to be incomplete, arched upwards in the region of the cardinal fossula, and slightly bent down near the epitheca. Tabullae occur about every 2 or 3 mm.

Remarks. - A. grovei from the Nunn member of the Lake Valley formation belongs to the Amplexizaphrentis enniskelleni (Edward and Haime) species group of Hill (1938, p. 141). A. grovei approaches A. enniskelleni var debienses (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. grovei in having a more pronounced cardinal fossula which extends 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. grovei and A. sonoraensis do occupy the same stratigraphic position, lower Osage, but existed in apparently two different types of ecology. It is conceivable that at the junctions of the Keating and Lake Valley facies these similar two species of amplexiphrentids were an interbreeding population, but at present the two forms in the ephebic stage can be readily and consistently distinguished.

Grove (1935, p. 346-347) described a specimen from the Lake Valley formation as a variety of Amplexizaphrentis cliffordanum (Milne-Edward and Haime) from the Fern Glen (lowest Osage) of the Mid-continent region. This form is characterized by 36 septa and a smaller corallite than the typical A. grovei. Grove's photographs (Pl. 11, fig. 8) of his variety A. cliffordanus hespere shows a smaller than average individual with a maximum of 24 septa.

Horizon. - Abundant in the calcareous shales of the Nunn member of the Lake Valley formation, throughout its area

of outcrop in southcentral New Mexico. The type specimens come from Apache Hill, northwest of Lake Valley, New Mexico.

Amplexizaphrentis northropi, n. sp.

Pl. 7, figs. 7, 14-17.

Diagnosis. - Corallite of medium to large size, trochoid, curved, 40-42 long major septa, 'U' shaped cardinal fossula, neamic and early ephebic septa thickened and fused by steroplasma. Short minor septa and dissepiments present, tabulae domed and incomplete.

Description. - Corallite is of medium to large size, trochoid, gently curved, and has longitudinal striations and faint annula. 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 together throughout their length. The septa of the cardinal quadrants are thickened and fused at their ends, but near the epithica 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 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 to 40 mm, 40 to 42 major septa are present which tend to withdraw from the axis. 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, cardinal fossula and dissepiments to Amplexizaphrentis centralis 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, (1944,a., 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 stratigraphically 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 were found to be particularly abundant in the Keating formation 50 feet below its contact with the Hachita formation in the Big Hatchet Mountains, and Klondike Hills of New Mexico and Blue Mountain, Chiricahua Mountains, Arizona.

Amplexizaphrentis sonaraensis n. sp.

Pl. 6, figs. 15-24.

Diganosis. - Medium-sized, trochoid coral of the A. enniskelleni type with 30 to 32 long major septa joined above a conspicuous linear cardinal fossula; minor septa absent; tabulae incomplete, domed.

Description. - The corallite is of medium-size, gently curved, trochoid. In the late neamic 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 (1.5-2.0 mm) due 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, Z. enniskilleni var derbiense

(Lewis, 1930, p. 279) with about 34 septa, but it differs markedly in that it has an ephebic stage which is amplexoid. A. sonoraensis is closely related to, and possibly cospecific with, A. grovei from the Lake Valley formation (see remarks under A. grovei). 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. grovei in number of septa and size, except that these species, according to their respective authors, lack tabullae. Both of these species need to be reexamined in the light of more modern techniques and possible Eurasian affinities.

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, Chiricuahua Mountains, Arizona.

Amplexizaphrentis clinatus (Greene)

Pl. 7, figs. 11-13.

Zaphrentis clinatus Greene, G. K., Contributions to Indiana Paleontology, pt. 19, p. 187, pl. 56, figs. 6-9.

Zaphrentis clinatus, Beede, J. W., 1906, Indiana Dept. Geol. Nat. Resc., 30th Ann. Rept., p. 1204, 1373, pl. 2, figs. 1a-1c. Triplophyllites (Triplophyllites) clinatus, Easton, W. H., 1951, Jour. Paleont., v. 25, p. 395-396, pl. 60, figs. 1-6.

Diagnosis. - In late ephebic state trochoid shape, at earlier stages wedge-shaped, keel centered on counter side of corallite; 34 long major septa, minor septa are ridges on epitheca, pronounced closed cardinal fossula.

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 amplexizaphentids. 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. On the exterior of the corallite annulations of growth are present.

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 spitheca. 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 corallite 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. Survey, Report of Investigation, no. 97, p. 42.

Triplophyllites (Homalophyllites), Easton, W. H., 1951, Jour. of Paleontology, vol. 25, no. 3, p. 398.
Homalophyllites, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F, Coelenterata, p. F267.

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

Horizon. - Mississippian and lower Pennsylvanian.

Diagnosis. - The corallum is ceratoid to calceoloid. Fossula is on the convex side of the corallum. The fossula expands axially, and the bounding septa are reinforced and thickened. The cardinal septum is pronounced in the neamic stage, and very reduced in ephebic stage. Very frequently the concave side of the corallum is flattened near the apex.

Remarks. - Easton (1944, 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. calceola Hall does not possess this contratingent nature of the septa. Easton (1951, p. 398) subsequently removed from the genus

Hapsiphyllites his subgenus Homalophyllites, and placed the latter under his genus Triplophyllites. Hill (1956, p. F267) raised Homophyllites to generic rank and placed Triplophyllites with the cardinal fossula on the concave side in synonomy with Amplexizaphrentis Vaughen 1906.

Homalophyllites circularis (Easton)

Pl. 7, figs. 8-10

Triplophyllites (Homalophyllites) circularis Easton, W. H., 1960, Smithsonian Misc. Collections, v. 119, no. 3; p. 22-24; pl. 1, fig. 4, 7-9.

Diagnosis. - Corallite small, slightly curved; ceratoid. Closed cardinal fossula on convex side of corallite. Fossula slightly expanded toward axis. Cardinal septa short, mature individuals with 31 to 32 major septa, minor septa very short, dissepiments very sparce. Corallite cylinderical throughout.

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

are very indistinct. Dissepiments were not observed.

Remarks. - H. circularis was errected by Easton (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 the Andercito member of the Lake Valley formation, which contains only H. calceolus, is an eastward facies of the above two, it is probable that the geographic distribution of H. calceolus and H. circularis, in respect to each other in earliest Osage time, was due to an ecological factor. It is conveivable that the two species were in reality one biospecies, which assumed in different environments two somewhat different forms. Because it is impossible to test this theory by interbreeding populations, it is more prudent paleontologically to consider them as two distinct species.

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

Homalophyllites calceolus (White and Whitfield)

Pl. 9, figs. 10-20.

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

Zaphrentis calceola, White, C. A., 1883, United States Geol. and Geog. Survey Terr., 12th Ann. Rept., pt. 1, Contr. Invertebrate Paleontology, n. 8, p. 156; pl. 39, fig. 62-6d.

Zaphrentis calceola, Keyes, R. R., 1894, Missouri Geol. Survey, v. 4, p. 110.

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

Homalophyllum calceolum, Hill, D., 1937, Royal Soc. Queensland, Proc., v. 48, p. 25, text fig. 5 on p. 24.

Hapsiphyllum (Homalophyllites) calceolus, Easton, W. H., 1944, Illinois Geol. Survey, Rept. of Invest. n. 97, p. 43-44, pl. 4, fig. 4-7; pl. 16, fig. 23-25.

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

Diagnosis. - Corallite small, slightly curved; ceratoid. Closed cardinal fossula on convex side of corallite. Fossula slightly expanded toward axis. Cardinal septa short, mature individual averages 30 septa; minor septa almost obsolete, dissepiments very sparce. Corallite flattened on cardinal side near apical end.

Description. - Corallite is slightly convex with posterior third of convex side of corallite progressively flattened toward the apical end. Cross section of corallite at its anterior 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 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 marked by the interrupted pinnate septal arrangement. Cardinal fossula are weakly developed. 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 very poorly developed. Dissepiments are very 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. The individuals from a given horizon upon close examination showed the cardinal fossula remained constant in its position but the forms displayed a relatively wide range in the number of septa. The finding of a continuous series of mature Homalophyllites, which have a septa 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. Many species of this genus in the literature have been errected 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 per cent 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 loaned to him by Dr. A. Stoyanow. This specimen was from the Escabrosa group of Arizona, and

from the illustration and description is a 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, large and higher count species of Homalophyllites, H. subcrassus with 40 to 44 major septa and H. paucicinctus with 46 major septa. Neither of these species have been encountered in the Escabrosa group.

Easton, 1958, describes a new species of Homalophyllites circularis from the Represo limestone of northwestern Sonora, Mexico. According to Easton (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 states 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 primarily in their distribution by ecology.

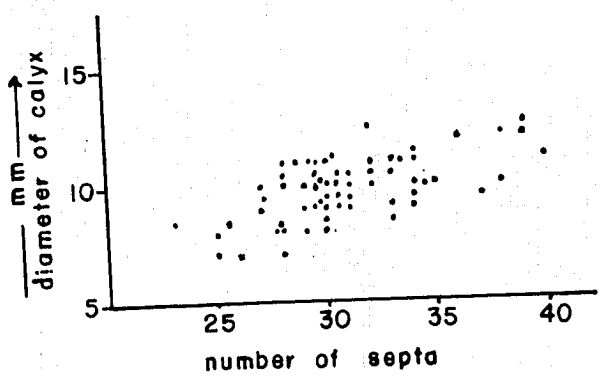

Figure 12- Scatter diagram of the diameter of the calyx of Homalophyllites calceolus plotted against the number of major septa. The specimens were etched from one limestone boulder, taken in place, from the coral zone, member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.

Genus Hapsiphyllum, Simpson, 1900

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

Enalophyllum Greene, G. K., 1901, Contributions to Indiana Paleontology, v. 1, pt. 7, p. 54.

Hapsiphyllum, Easton, W. H., 1951, Jour. Paleont., v. 25, p. 389.

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

Non Hapsiphyllum, Easton, W. H., 1944, Illinois Geol. Survey, Rept. Investigation, n. 97, p. 42.

Non Hapsiphyllum, Moore, R. C. and Jeffords, R. M., 1945, Univ. Texas Bull. 4401, p. 123, 124.

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

Range. - Mississippian.

Diagnosis. - (after Hill, 1956, p. F267) Fossula is expanded axially; septa are arranged pinnately in cardinal quadrant, and radially in counter quadrant. The minor septa are long and contratingent. The cardinal septum are short in adult stages. Tabulae are incomplete, conical with the highest point at inner edge of fossula. No dissepiments are present.

Remarks. - I know of only three species of Hapsiphyllum described from the Mississippian of North America. They are the type species H. calcariformis (Hall) from the St. Louis group, H. ulrichi (Worthen) from the Warsaw limestone of Kentucky and H. grabaui (Greene) from the Salem linestone of Indiana. All of these species are described from their late ephebic 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 contratigent minor septa, no dissepiments and with an inner wall developed around the cardinal fossula.

The genus Amplexizaphrentis Vaughan would embrace Moore and Jeffords' description of Hapsiphyllum from the lower Pennsylvanian of Texas.

Hapsiphyllum nunnensis n. sp.

Pl. 7, figs. 18-22.

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 neamic. Tabulae incomplete.

Description. - The corallum is ceratoid and slightly curved, has the fossula on the concave side and is 30 to 35 mm tall and 20 to 22 mm in diameter. The epitheca shows slight, longitudinal ribbing and strong annulation. In a late neamic stage at 8 mm in diameter 21 septa are present which met and fused at the axis. Alar fossulae 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 together above the cardinal septum. The cardinal fossula is closed, 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, 38 major septa are present, 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 bulbous. The cardinal septum is short. Longitudinal sections show incomplete tabulae, which are bent upwards in the region of the fossulae.

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. calcariformis (Hall) from the St. Louis group of Indiana, H. ulrichi (Worthen) from the Warsaw limestone of Kentucky and H. grabaui (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. calcariformis and H. ulrichi show in their late ephebic stage that all of their minor septum are contratingent with the major septa (Simpson, 1900, p. 23 and Easton, 1951, pl. 61, fig. 11). H. nunnensis in the opinion of the writer would fit much illogically into the genus Amplexizaphrentis where there does not exist any known species with persistent contratingent minor septa.

Family CYATHOPSIDAE Dybowski, 1873

Genus Caninia Michelin, 1840

Caninia Michelin, H., 1840, in Gervais, P., Article "Astree, Astraea" in 'Dictionnaire des Sciences naturelles, Supplement, v. 1, p. 485, (fide Hill, 1948, p. 105).

Cyathopsis D'Orbigny, A., 1850, Prodrome de Paleontologie, Paris, v. 1, p. 105.

Pseudozaphrentoides Stuckenberg, A., 1904, Com. geol., St. Petersburg, Mem., v. 5, n. 4., p. 91; (fide Hill, D., 1956, p. F292).

Caninia, Carruthers, R. G., 1908, Geol. Mag., (dec. 5), v. 5, p. 108.

Caninia, Bather, F. A., 1908, Geol. Mag., (dec. 5), 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, Palaeontographical Soc., p. 105, 106.

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

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

Caninia, Easton, W. H., 1944, Illinois Geol. Survey, Rept. Invest., n. 97, p. 49.

Pseudozaphrentis Moore, R. C. and Jefford, R. M., 1945, Texas Univ., Pub. 4401, p. 145.

Caninia, Moore, R. C. and Jefford, R. M., 1945, Texas Univ. Pub. 4401, p. 145.

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

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

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

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

Type Species. - (Original designation) Caninia cornucopiae Michelin, H., in Gervais, P., 1840, Article "Astree, Astraea in Dictionnaire des Sciences naturelles, Supplement, v. 1,

p. 485. Lower Carboniferous of Tournai.

Range. - Mississippian to Permian.

Remarks. - Siphonophyllum Scouler is similar to Caninia except it has a wide lonsdaleoid disseptimentarium. Caninophyllum Lewis is also distinguished by its dissepimentarium which has wide, angular dissepiments. Bothrophyllum Trautsold and Kakuiphyllum 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. 8, figs. 12-16.

Caninia cornucopiae Michelin, H., 1840, in Gervais, P., Article "Astree, Astraea" in Dictionnaire des Sciences naturelles, supplement, v. 1, p. 485.

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

Caninia cornucopiae, Carruthers, R. G., 1908, Geol. Magazine, v. 5, p. 159; pl. 6, figs. 1-4.

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

Caninia cornucopiae, Hill, D., 1938, Palaeontographical Society, v. 92, p. 106-107.

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

Caninia cornucopiae, Sloss, L. L., 1945, Jour. Paleont., v. 19, p. 310-311; pl. 48, figs. 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 fossulae 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 which are 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, down-bent 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 states that it differs from C. cornucopiae in its large size, shorter septa in the earlier part of the corallite, 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 discussed that Carruthers (1908, p. 164) has shown that the British and Belgian C. cornucopiae commonly pass through an amplexoid neamic stage (Carruthers' "hystiana 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 neamic 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 non-persistent dissepiments. Sloss' (1945, p. 310-311) example C. cornucopiae from the Yakinikak 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)

reports C. cornucopiae from the Yakinikak limestone of Montana to be of possible St. Louis age.

Genus Kakwiphyllum Sutherland, 1954

Pl. 8, figs. 1-5.

Kakwiphyllum Sutherland, P. K., 1954, Geological Magazine, v. 91, p. 366.
Kakwiphyllum, Hill, D., 1956, in Treatise on Invertebrate Paleontology, pt. F, (Coelenterata), p. F294.
Kakwiphyllum, Sutherland, P. K., 1958, Geological Survey of Canada, Mem. 295, p. 69.

Diagnosis. - Taken from Sutherland, 1954, p. 365. Large, solitary, cylindrical corals with long major septa which extend to axial region, but do not join; major septa have overall radial symmetry which may be modified by regular or irregular grouping of septa into bunches caused by shortening of septa in some areas; cardinal and counter septa and the cardinal fossula may tend to be obscured in ephebic stages by radial arrangement of septa; minor septa short or absent; peripheral zone of dissepiments consisting of an outer series of lonsdaleoid dissepiments through which the septa are not continuous and an inner zone in which dissepiments are small and have a herring-bone or concentric arrangement between septa; dissepiments often

gradational with the tabulae which are numerous, incomplete and inclined downward axially where they form a concave floor.

Type Species. - (Original designation) Kakwiphyllum dux, Sutherland, P. K., 1954, Geological Magazine, v. 91, p. 366, Rundle formation (Meramec), Alberta.

Kakwiphyllum sutherlandi n. sp.

Pl. 8, figs. 1-11.

Diagnosis. - Solitary cylindrical corals with long, major septa, 38-44, which extend 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.

Description. - The corallite 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 neamic portion of the corallite 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, those in the cardinal

quadrants which 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 tabulae which are concave. The corallite 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 Kakwiphyllum dux, the type species, also describes and figures Kakwiphyllum cf. K. dux and Kakwiphyllum sp. A. The three taxa differ in number of septa with 66 in K. dux, 72 to 78 in K. cf. K. dux, and 84 in K. sp. A.

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

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

Genus Caninophyllum Lewis, 1929

Caninophyllum Lewis, H. P., 1929, Ann. Mag. Nat. Hist. (ser. 10), v. 3, p. 456-468, pls. 11, 12.
Vesiculophyllum Easton, W. H., 1944, Illinois Geol. Survey, Rept. Invest. n. 97, p. 52.
Caninophyllum, Hill, D., 1956, Treatise Invertebrate Paleontology, pt. F, (Coelenterata), p. F292.
? Vesiculophyllum, Hill, D., 1956, Treatise Invertebrate, Paleontology, pt. F, (Coelenterata), p. F292.
Caninophyllum, Campbell, K. S. W., 1957, Jour. Paleont., v. 31, p. 91, 92.

Diagnosis. - After Hill, 1957, p. F292. Large solitary caninid corals; wide dissepimentarium with angulate dissepiments; fossula open, major septa long, not confluent at the axis; in youth major septa dilated in tabularium.

Remarks. - The validity of Vesiculophyllum Easton (1949 p. 52) was questioned by Hill (1956, p. F292). Easton

(1958, p. 29) considered his genus Vesiculophyllum to be a subgenus of Caninophyllum Lewis. For a comparison of Caninophyllum with Bothrophyllum the reader is referred to remarks under the latter genus.

Type Species. - (Original designation) Cyathophyllum archiaci Edward and Haime, 1852, A Monograph of British Fossil Corals, Palaeontographical Soc., p. 183, pl. 34, fig. 7. Lower Carboniferous limestone, Llanymynech, North Wales.

Range. - Lower Carboniferous, Europe, Asia and North America; Middle and Upper Carboniferous U.S.S.R.

Caninophyllum cf. increassatum Easton and Gutschick

Caninophyllum increasatum Easton, W. H. and Gutschick, R. C., 1953, Southern California Acad. Sci., Bull., p. 17-18, pl. 3, fig. 104.
Caninophyllum sonorense Easton, W. H., 1958, Smithsonian Misc. Coll., v. 119, n. 3.

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 ephebic 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 septa is long, dilated and extends into the axis. In the ephebic 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 well developed with concentric to lonsdaleoid dissepiments.

In the early ephebic stage, 15 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 within the Escabrosa group 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 C. sonorense differs from C. increassatum 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 C. sonorensis (1958, pl. 2, figs. 1-3)

and C. increasatum (1953, pl. 3, figs. 1-4) and the type specimen of C. increasatum believes there does not exist specific differences between Easton's two "species". The two have corallites of the same general size, similar septal counts and very similar dissepiments. Placing specific value on the length of the minor septa is of doubtful value. Because in the rugose corals the minor septa will vary in length within individuals in population and even more within the ontogeny of a single individual.

C. 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 the poor preservation.

Caninophyllum sp.

Pl. 8, fig. 17

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 corallites in transverse section are from 20 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. - It 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. - Caninophyllum sp. indet. from the Hachita formation is clearly distinct from Caninophyllum increassatum Easton and Gutschick from the Osagian Redwall limestone of Arizona and lower Osagian Represo limestone of Sonora, Mexico, which has strongly dilated major septa in the tabularium and rudimentary minor septa. Caninophyllum sedialense (White) is separated from Caninophyllum sp. indet. by its sinuous, dilated major septa, and weakly developed minor septa.

Genus Bothrophylum Trautschold 1879

Cyathophyllum (Bothrophyllum) Trautschold, H., 1879, Soc. Imp. Nat. Moscow, Mem. v. 14, p. 30, (fide Lang, Smith and Thomas, 1940, p. 28).

Brothrophyllum, Dobrolyubova, T. A., 1937, Inst. Paleozool. Acad. Sci. U.S.S.R., Trans, v. 6, p. 26.

Brothrophyllum, Hill, D., 1956, Treatise Invertebrate Paleontology, Pt. F, (Coelenterata), p. F292.

Type Species. - (Original designation) Bothrophyllum conicum (Fischer von Waldheim) Trautschold, 1879, (Mem. Soc. Imp. Nat. Moscow, v. 14, p. 30, pl. 5, figs. 1a-1f). Middle Carboniferous of Central Russia.

Range. - Mississippian, Europe, North America, Australia, middle and upper Carboniferous, U.S.S.R., China.

Diagnosis. - After Hill, 1956, p. F292. Large solitary corals, with wide dissepimentarium with angular dissepiments; fossula open; axial ends of major septa commonly joined to an elongate counter septum forming a weak, impersistent axial structure; major septa dilated in tabularium, those of counter quadrants less than those in cardinal quadrants.

Remarks. - As was shown by Campbell (1957, p. 91). The relationship between Bothrophyllum Trautschold and Caniniophyllum Lewis (1929, p. 456) is obscure. Lewis when describing his genus compared it with Caninia and

made no reference to Bothrophyllum. Campbell after a study of the literature could see little or no difference between Bothrophyllum and Caninophyllum. Hill (1956, F292) believes the difference between the two genera is the presence in Bothrophyllum of an elongate counter septum which joins with the ends of the major septa to form the axial structure. Doborolyubora (1937, p. 26) in her restudy of the type species B. conicum described the axial structure as "major septa which sometimes reach the center and form fairly sparse irregular mesh which is cut across by a slender counter septum."

Campbell believes the possibility exists that the differences between Caniniphyllum and Bothrophyllum are of specific rather than generic rank and the two genera may be found to merge.

Campbell (1957, p. 92) was incorrect when he stated "Neither Bothrophyllum nor Caninophyllum is known to occur in North America." To the writer's knowledge the following species have been described from North America:

Caninophyllum sedaliense (White), Chouteau limestone, Missouri.

Caninophyllum incrassatum Easton and Gutschick, lower Osage Redwall limestone, Arizona, and lower Osage Represo limestone of northwest Sonora, Mexico.

Caninophyllum ? readi (Merrian), Chester, Coffee Creek limestone, Oregon.

Bothrophyllum ? Kansasense (Miller and Gurley), Kansas City group, Pennsylvanian, Kansas City, Missouri.

Bothrophyllum sp.

Pl. 8, fig. 18.

Description. - Large, solitary, caninid type coraallite, which is in an ephebic individual 25 to 30 mm in diameter. In transverse section the corallite 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 long, slightly sinuous and dilated in the tabularium. Dissepimentarium wide with concentric dissepiments. Minor septa apparently absent.

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

Remarks. - The specimens studied are considered to belong to the genus Bothrophyllum because they have a caninid corallum and an elongated counter septum which is joined by the distal ends of the major septa. The specimens are found as broken, abraded and frequently crushed corallites. The crushing was apparently the result of compaction within the encrinites during diagenesis.

Family AULOPHYLLIDAE Dybowski, 1837

Subfamily AULOPHYLLINAE 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; (fide Hill, D., 1938, p. 65).

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

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

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

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

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 tabullae, 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 radium

of the corallum; the dissepiments are frequently inosculating. Tabulae are incomplete and bracket-shaped; the tabellae 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.

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, figs. 2, 3. Lower Carboniferous limestone, Scotland. fide Hill, 1938, p. 65.

Range. - Upper Visean and lower Namurian, British Isles, Belgium, France, Russia and the western Sahara. Bell (1929, p. 95) found the genus to be present in Nova Scotia. Newell reported D. valeriae from the Missourian of Kansas which may prove to belong to the genus Koninekophyllum Thomas and Nicholsom. The only other known occurance of the genus in North America is D. bipartitum koninckí from the Chester of West Texas.

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

Dibunophyllum bipartitum koninckí (Edward and Haime)

Pl. 9, figs. 21, 22; Pl. 10, figs. 1-7.

Clisiophyllum Koninckí Edwards, M. M. and Haime, J., 1851, Mon. Polypiors Fossiles des Terrains Palaeozoiques, p. 410-411.

Dibunophyllum bipartitum koninckí, Hill, D., 1938, Palaeontographical Society, p. 75-78; pl. 1, fig. 20, pl. 2, figs. 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, tabullae arranged into series, those of the outer series being fewer and less steeply inclined than those at the inner series.

Description. - The corallite is robust, curved in the early stage, cylindrical in the ephebic stages. The epitheca is wrinkled transversely. Mature corallites 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 move 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 tabellae are flat near the dissepimentarium, becoming progressively more uparched towards and particularly near the column. An outer series of tabellae may develop between those at the axial structure and the dissepiments. These are convex upward and outward.

Horizon. - This genus was known in North America only from Nova Scotia, (Bell, 1929). In the western hemisphere this European species is known to occur only at the top of the Helms formation (Chester), Franklin Mountain, SW¼, 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 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) reports 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 ephebic individual, two much weaker developed dissepimentarium and a smaller mature corallite. Newell (1935, p. 33-346, pl. 33, figs. 1-3) D. valeriae Newell from the upper part of the Missourian series (Pennsylvania). It differs markedly from D. bipartitum konincki in having only 33 septae in mature specimens and a weakly developed dissepimentarium. The illustrations of D. valeriae show certain characteristics which indicate the species may belong to the genus Koninckophyllum Thomas and Nicholsom. Newell's illustrations show D. valeriae to have relatively long minor septa and major septa which are withdrawn from the axis.

D. bipartitum konincki from the Franklin Mountains of west Texas differs from the majority of British material described by Hill (1838) in generally having septa which extend further into the axial region and a corresponding smaller axial column.

The west Texas specimens, however, can be matched almost exactly to some of Hills (1938, pl. 2, figs. 9, 13) illustrations of D. bipartitum koninckí.

Merrian (1942, p. 373) described from Chester strata of central Oregon Dibunophyllum oregonensis. This species differs from D. bipartitum koninckí 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.

Genus Koninckophyllum Thomson and Nicholson, 1876

Koninckophyllum Thomson, J. and Nicholsom, 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), (dec. 5), v. 10, p. 49.

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

Koninckophyllum, Hill, D., 1938, Palaeontographical Soc., p. 85-89.

Koninckophyllum, Hill, D., 1956, Treatise Invertebrate Paleontology, Pt. F (Coelenterata), p. F286.

Type Species. - (subsequent designation; Thomas, J., Royal Phil. Soc. Glasgow, Proc., v. 14, p. 419), Koninckophyllum magnificum Thomas and Nicholsom, (1876, Ann. Mag. Nat. Hist. London, pl. 12, figs. 2, 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 occurrances of this genus in the New World outside of Nova Scotia.

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 which has a well-developed axial structure, and degenerates to absent minor septa.

Koninckophyllum elpasoensis, n. sp.

Pl. 9, figs. 1-9.

Diagnosis. - Trochoid Koninckophyllum with a dibunophylloid axial structure in neamic 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. - Corallite is curved in the neamic stages and cylindrical in the ephebic stages; corallite gently increasing in diameter, with growth constrictions probably due to rejuvenescence. The diameter of a mature corallite is between 15 and 22 mm.

In the ephebic stage there are 30 to 33 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.

Earlier in the ontogeny of the coral 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 tabullae in the axial zone are slightly dome-shaped. The tabullae at the periaxial zone are short, tightly packed and more strongly domed. The fossula is very weakly developed, the cardinal septum is perceptably shortened in comparison to adjacent major septa. The major septa are neither curved about the cardinal septum nor away from it. In the neamic 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 and the columella is left in an axial void. In the late ephebic stage the axis 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 the Chester of Nova Scotia. This and Koninckophyllum talonatum Easton from the upper Chester Pitkin formation of Arkansas are the only known previous recorded occurances of this genus in North America. K. elpasoensis is now known only from the Helms formation (Chester) of the Franklin Mountains, SW¼, sec. 67, Blk. 82, El Paso County, Texas.

Remarks. - K. elpasoensis shows closest kinship to K. interruptum Thompson and Nicholson from the upper Visean of Scotland and England. The relationship between the two species is not close. K. interruptum has a much larger corallite (120 mm in diameter in an ephebic specimen) and at all growth stages contains a higher septal count. This is dramatically illustrated by Lewis' (1931, p. 240) chart which shows K. interruptum at various ontogenetic 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 the formers much wider dissepimentarium, a thicker and more persistent median plate and longer major septa in the ephebic stage.

Family AULOPHYLLIDAE Dybowski, 1837

Subfamily AMYGDALOPHYLLINAE Grabau in Chi, 1935

Genus Ekvasophyllum Parks, 1951

Ekvasophyllum Parks, J. M., 1951, Jour. Paleontology, v. 25, p. 175.

Ekvasophyllum, Sutherland, P. K., 1958, Geol. Survey Canada, Mem. 295, p. 74-77.

Type Species. - (Original designation) Ekvasophyllum inclinatum, Parks, J. M., (1951, Jour. Paleont., v. 25, p. 175), Brazer limestone (Mississippian) Utah.

Range. - Lower Osage to Meramec, presently known only from North America.

Diagnosis. - After Parks (1951) and Sutherland (1958). Medium size corallite, solitary, slightly curved, trochoid. Numerous septa tending toward a radial symmetry except near the prominent cardinal fossula where they are pinnately arranged. Axial column highly variable in size and shape, generally it is laterally compressed solid, rod-like. Tabulae incomplete and arch upward axially to join column. Dissepiments generally present.

Remarks. - Hill (1956, pl. F290) in the Coelenterata section of the Treatise of Invertebrate Paleontology

placed Ekvasophyllum Parks as a junior synonym of Amygdalophyllum Dun and Benson. The type species of the genus A. etheridgei from the lower Carboniferous of New South Wales is characterized according to Dun and Benson (1920) by having a trochoid corallite, numerous long and radially arranged major septa which extend to the axis and touch a thick solid columella. The minor septa are long and extend three-fourths the length of the corallite. In the ephebic stage a well-developed dissepimentarium exists in which the septa die out and fail to reach the epethica. A cardinal fossula is not discernable in the type species.

Sutherland (1958, p. 76-77) was first to emphasize and state correctly that Ekvasophyllum, with its pronounced cardinal fossula, reduced dissepiments, and minor septa, was a distinct genus from Amygdalophyllum. Parks' (1951) original description of the genus Ekvasophyllum was from material collected from the Meramec Brazwer formation of Utah. Sutherland (1958) described four species of Ekvasophyllum from the Meramec Rundles and Banff formations of British Columbia. The genus is represented in the lower Osagian, member A, of the Keating formation, Escabrosa group by the single species Ekvasophyllum primum n. sp.

Ekvasophyllum primum n. sp.

Pl. 6, figs. 1-8.

Diagnosis. - Small to medium size corallite, with 36 to 40 major septa, the majority of which reach the columella. Minor septa short, frequently fused with major septa. Dissepiments rare, present only in ephebic stage. Tabulae incomplete, inclined upwards toward columella, which they join at an acute angle.

Description. - The corallite is curved, trochoid. The dimensions of four individuals are:

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

All of the specimens available for study had their surface ornamentation obliterated. An ephebic individual will have 36 to 40 major septa. The major septa are long and have a radial symmetry, which is slightly pinnate near the cardinal fossula. The septa are strongly dilated at the early ephebic stage, and 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 are frequently fused with the major septa. The dissepimentarium is weakly developed and in some individuals nonexistent. A prominent, open cardinal fossula is present, which extends to the columella. The cardinal fossula is on the convex side of the corallite, but its position may vary among individuals from the same horizon. The cardinal septum at the neamic and early ephebic stages is long, reaching to, and joining, the columella; in the late ephebic stage it is withdrawn and almost obsolete.

The columella is formed primarily of counter and major septa which are fused together. In the neamic 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 endings are interwoven in a manner reminiscent of a spider web. The tabulae are incomplete and inclined upward. Their inclination is the strongest when they join the columnella. In all of the material available for study the finer details of the structure of the septa, dissepiments and tabulae have been destroyed by silification.

Horizon. - E. primum is abundant in the coral zone, member A, Keating formation, Escabrosa group in southeastern Arizona and southwestern New Mexico. The species

is very common in the Big Hatchet Mountains and the Klondike Hills.

Remarks. - The majority of the specimens of E. primum showed a tendency in the ephebic stage for the minor septum to be fused with the major septum. The genus Hapsiphyllum Simpson in the family Hapsiphyllidae has this character highly developed, but lacks any central axis. This trait of E. primum to have its minor septa fused with the major septa could possibly justify the errection of a new genus, but the more conservative attitude is preferred until more is known about the phylogeny of the genus Ekvasophyllum.

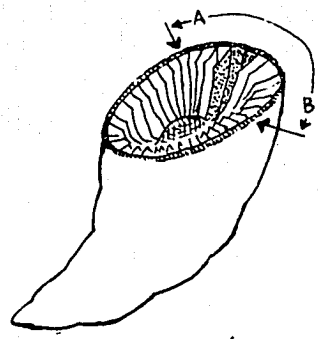

Figure 13- Diagrammatic illustration of variable position of the cardinal fossula on the convex side of the corallite of Ekvasophyllum primum.

Family LITHOSTROTIONIDAE d'Orbigny, 1851

Genus Lithostrotion Fleming, 1828

Lithostrotion Fleming, J., 1828, A History of British Animals, Edinburgh, p. 504.

Stylaxis McCoy, F., 1849, Ann. Mag. Nat. History, v. 3, p. 119-120.

Siphonodendron McCoy, F., 1849, Ann. Mag. Nat. History, v. 3, p. 127-128.

Petalaxis Edward, N. H. and Haime, J., 1852, Paleontographical Soc., v. 6, pt. 3, p. 204.

Lithostrotion, Yabe, H. and Hayasaka, I., 1915, Jour. Geol. Soc. Tokoyo, v. 22, p. 93.

Cystidendron Schindewolf, O. H., 1927, Palaeontologische Zeitschrift, v. 10, p. 149.

Cystistrotion Schindewolf, O. H., 1927, Palaeontologische Zeitschrift, v. 10, p. 149.

Lithostrotion, Hill, D., 1934, Proc. Royal Soc. Queensland, v. 45, n. 12, p. 81-84.

Stylostrotion Chi, X. S., 1935, Palaeontologia Sinica, Ser. B, v. 7, pt. 6, p. 20-22.

Lithostrotion, Hill, D. 1940, Palaeontographical Soc., v. 94, pt. 3, p. 165-168.

Lithostrotion, Kelly, W. A., 1942, Jour. Paleont., v. 16, p. 359.

Lithostrotion, Merrian, C. W., 1942, Jour. Paleont., v. 16, p. 376-377.

Lithostrotion, McLaren, D. J., and Sutherland, P. K., 1949, Jour. Paleont., v. 23, p. 628.

Lithostrotion, Hill, D., 1956, Treatise on Invertebrate Paleontology, pt. F, (Coelenterata), p. F282.

Lithostrotion, Sutherland, P. K., 1958, Geol. Survey Canada, Mem. 295, p. 92.

Non Lithostrotion Londsdale, W., 1848, in R. I. Murchinson, E. de Verneuil and A. von Keyserling, The Geology of Russia and the Ural Mountains, p. 602-603.

Type Species. - (Opinion 117, International Commission of Zoological Nomenclature) Lithostrotion striatum Fleming, J., (1828, p. 504, A History of British Animals, Edinburgh, type locality unknown; fide D. Hill, 1940, p. 166).

Range. - Mississippian in North America.

Diagnosis. - Phaceloid and cerioid corals, which have typically a columella, long major septa, and large conical tabula, usually supplemented by smaller outer and nearly horizontal tabula. Dissepiments are well developed in the large species, but absent in the very small forms. Increase is non-parricidal (after Hill, 1940, 1956).

Remarks. - Lithostrotionella Yabe and Hayasaka, 1915, has the same characteristics as Lithostrotion except that in the former the septa are separated from the epitheca by a zone of dissepiments. Vaughn (1905, p. 277) defined Lithostrotion as those forms in which all of the major and minor septa penetrate the ring or rings of dissepiments and fuse with the epitheca. In his study of North American Lithostrotionella Hayasaka (1936, p. 49) followed Vaughn's concept of Lithostrotion and generally placed in Lithostrotionella those forms in which a few or all of the septa did not reach the epitheca. Hill's (1938; pl. 9, fig. 17, 19, 20; pl. 10, figs. 2, 3, 7) interpretation of Lithostrotion is broader, for she shows numerous transverse sections of corallites illustrating occasional minor and major septa which do not fuse with the epitheca. Merrian (1942, p. 377) in the description and illustration of his species Lithostrotion packardi showed septa which are occasionally discontinuous, and some corallites have developed a strong vesicular peripheral zone.

McLaren and Sutherland (1949) and Sutherland (1958) have described a Lithostrotion type colonial coral from the Meramec Prophet formation of British Columbia which has represented in one colonial corallum three different genera, Lithostrotion, Lithostrotionella and Thysanophyllum, all of which they consider to be genomorphs. According to them, "a genomorph does not constitute a true genus but is

an expression of a trend which some external or internal stimulus has provoked to rapid development in a colony or in certain individuals in a colony". They suggest that the individual genomorph is the forerunner of an evolution which may take place in closely or distantly related stocks and may give rise to new generic forms. McLaren and Sutherland (1949, p. 627) follow nomenclatural procedures set forth by Smith and Lang (1930, p. 179) and Smith (1945, p. 22) that recommend the genomorphic name be enclosed in square brackets after the genus in the position of the subgeneric name. The Keating formation Lithostrotion, written as a genomorph, would be Lithostrotion, [Lithostrotionella] lochmani. McLaren and Sutherland (1949) advocate "that employing a genomorphic name the usage is analogous to that of a subgeneric and suggest that this practice be adopted in dealing with a taxonomic problem which has no parallel in neontology, and can thus have no counterpart in normal zoological nomenclature". Although the genomorphic concept has merit, its implementation is not covered by the International rules of zoological nomenclature, and for that reason is not used in this study. At the present it is premature for special nomenclatural rules for the Lithostrotion and related corals which admittedly fit very poorly in the existing rules of systematics. At this time we have no concept of the existence of homomorphy which may be extensive within the group.

Hill (1939, p. 81) had found that the boundaries of both genera and their species are extremely difficult to define, since the individuals of all species vary a great deal. Most subsequent workers have also encountered and commented on this problem, when they try to define various species of the two genera.

Hill (1940) noted that the two genera, Lithostrotion and Lithostrotionella had not been found in Eurasia and and Australia in horizons older than Viséan. It was generally believed until recently that these two genera were absent in North America below the Meramec-Osage boundary, the one exception being Lithostrotion microstylum White from the upper Chouteau limestone (present day Sedalia limestone) of Missouri. Recent study of the thick Mississippian sediments in the Cordillerian region has resulted in the description of four species of Lithostrotionella and two species of Lithostrotion which occur in pre-Meramec strata. The species recognized by the writer are:

Lithostrotionella circinatus Easton and Gutschick, Redwall limestone, northern Arizona; lower Osage.

Lithostrotionella micra Kelly, upper member Banff formation, Canada; Osage.

Lithostrotionella jasperensis Kelly, middle member Banff formation, Canada; upper Kinderhook-lower Osage. Joana limestone, Nevada, lower Osage?.

Lithostrotionella confluens Easton, Represo formation,

northwest Sonora, Mexico. Member A, Keating formation, southwestern New Mexico and southeastern Arizona. Andercito and Alamogordo members, Lake Valley formation, southwestern New Mexico; all lower Osage.

Lithostrotion mutabile (Kelly), upper member, Banff formation, Canada; Osage.

Lithostrotion lockmani n. sp., member A, Keating formation, southwestern New Mexico, southeastern Arizona; Andercito and Alamogordo members, Lake Valley formation, southwestern New Mexico. All lower Osage.

Lithostrotion lochmani n. sp.

Pl. 4, figs. 1, 2, 4, 6, 7.

Diagnosis. - Cerioid corallum with 4 to 6 slightly curved sides, a conical axial structure, 13 to 15 septa of each order and one primary series of dissepiments.

Description. - Corallum is a compressed cone, up to a half a meter in diameter. The mature corallites are of somewhat equal size ranging in diameter from 5 to 8 mm. In a transverse section there are some 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 septa may fuse with an adjoining major septa. 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. - As can be seen in pl. 4, figs. 1, 2, the holotype is not a perfect example of the genus Lithostrotion. There is developed in some corallites a zone of dissepiments in which the septa do not penetrate. The extreme of this type of corallite is illustrated in pl. 4, fig. 4, which is a Lithostrotionella type corallite. The opposite type is illustrated on pl. 4, fig. 6, in which all of the major and minor septa fuse with the epitheca. In the corallum the majority of the major septa fuse with the epitheca.

Lithostrotion lochmani shows closest affinities to Lithostrotion macouni Lambe from the southern Canadian Rockies. The exact stratigraphic position of this species is unknown (Nelson, 1960, p. 122). L. macouni differs in several important respects. The minor septa are very weakly developed and 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 11 being present.

The nature and number of septa, columella and the tabularium of both L. lochmani and Lithostrotionella micra

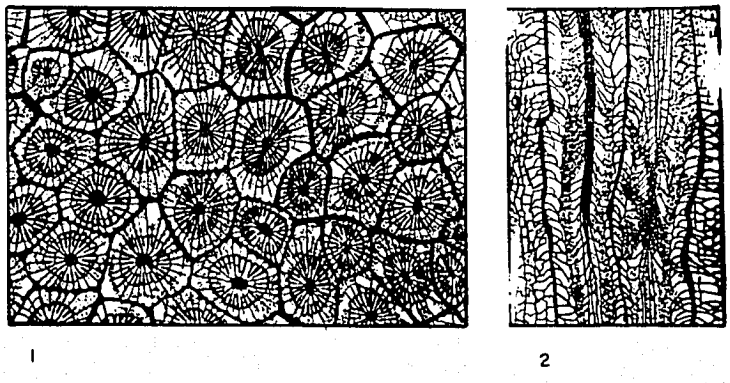

Figure 4 Inked drawing X; 1, transverse section; 2, longitudinal section; Lithostrotion lockmani; n. sp. from member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.

Kelly are very similar. It is in the dissepimentarium that a difference of family rank is present. The dissepimentarium of L. micra is devoid of septa and consists of septa which have few intercepts.

Lithostrotion microstylum from the upper Chouteau (present Sedalia limestone) of Sedalia, Missouri, differs markedly from L. lochmani in possessing a cerioid astreoid corallum, a poorly defined zone of dissepiments, septa which are noticeably thickened in both the tabularium and dissepimentarium, and a thick circular columella.

L. lochmani and L. 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 corallums of L. confluens are smaller, are more conical in shape, and the individual corallites are more erect and 2 to 3 times larger than those in corallums of L. lochmani. A transverse section in the corallum of L. confluens will reveal corallites of varying size. A transverse section in L. lochmani will show the corallites to be of much more uniform size. The number of septa in an ephebic corallite of L. confluens will have between 17 to 24 major septa as compared to 10 to 12 in L. lochmani.

Horizon. - The species of 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 Andercito and Alamogordo members of the Lake Valley formation in the Santa Rita Mining district, Cooks Range and northwest of Silver City in the Lone Mountains. It is particularly abundant in the exposures in the Klondike Hills and westward to Blue Mountain, Chiricahua Mountains, Arizona.

Lithostrotion microstylum White

Pl. 5, figs. 4-6.

Lithostrotion microstylum, White, C. A., 1880, United States Geol. and Geog. Surveys Terr., 12th Ann. Rept., pt. 1, Contr. Invertebrate Paleontology, n. 8, p. 159; pl. 40, fig. 7a.
Lithostrotion microstylum, Easton, W. H., 1944, Illinois Geol. Survey, Rept. Investigation n. 97, p. 53; pl. 13, figs. 1-3; pl. 17, fig. 1.

Diagnosis. - Asteroid corallum, corallites 8 to 11 mm in diameter, 15 to 18 major septa which fuse with the circular columella, minor septa present. Tabulae may be absent.

Description. - L. microstylum has a flattened corallum of some 11 cm. in diameter and 3 cm. thick. The corallum is astreoid and the corallites are from 8 to 11 mm in diameter.

The septa of adjoining corallites are frequently separated by a zone of londaleoid dissepiments. There are 15 to 18 major septa in each corallite, the majority of which join the thick circular columella. Also present are 15 to 18 minor septa which extend only a short distance into the tabularium.

In a longitudinal section the columella is a solid rod; the dissepiments are irregular in size and shape. The area between corallites is a confused zone of dissepiments; no separating epitheca is present. Tabulae were not observed.

Remarks. - L. microstylum was illustrated by White (1880) by a small scale drawing of the holotype corallum. Easton (1944) in a redescription of the species used for his illustration only an ink drawing of the sawed sections. The writer considers the use of inked drawings exclusively in the illustration of coral sections unsatisfactory, because of the unavoidable personal bias introduced by the draftsman. Inked drawings of sections can be used very successfully in supplementing photographs, particularly in the case of poorly preserved material. Because of the stratigraphic and phylogenetic importance of L. microstylum, it was thinsectioned, redescribed and photographed.

Nelson (1960) believed that Lithostrotionella jasperensis is closely related to L. microstylum. The writer disagrees

with this theory, if one accepts Hill's (1934, p. 81-83) phylogenetic concepts of trends within the lithostrotionids. Hill considers the following as progressions within the group: the astreoid trend, the disappearance of walls between corallites; the disioid trend, the complete tabulae being replaced by tabulae while the axis remains; cionoid trend in which the columella becomes very large. All of these trends are well developed in Lithostrotion microstylum and are rudimentary or absent in Lithostrotionella jasperensis.

Family LONSDALEIIDAE Chapman, 1893

Subfamily LONSDALEIINAE Chapman, 1893

Genus Lithostrotionella Yabe and Hayasaka, 1915

Lithostrotionella Yabe, H. and Hayasaka, I., 1915, Geol. Soc. Tokoyo, 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, Merrian, C. W., 1942, Jour. of 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. of Paleont., v. 23, p. 629.

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

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

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

Range. - Mississippian to Permian.

Diagnosis. - After Hill (1956, p. F306-F307) and Sutherland (1958, p. 92). Phaceloid and cerioid rugosa corals. Corallites with a persistent axial structure or columella. The columella is generally continuous with counter and cardinal septum. Dissepimentarium with wide lonsdaloid dissepiments. The tabulae are complete cones or flat-topped domes. Dissepiments are well developed in larger species, but absent in the very small forms.

Remarks. - For a discussion of the genus Lithostrotionella the reader is referred to remarks under the genus Lithostrotion.

Lithostrotionella confluens Easton

Pl. 4, figs. 3, 5, 8.

Lithostrotionella confluens Easton, W. H., 1958, Smithsonian Misc. Collections, v. 119, no. 3, p. 31-33; pl. 1, fig. 12; pl. 2, figs. 8, 9.

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. - The colonial corallum is up to one-fourth of a meter in diameter, and is a compressed cone. The corallites are nearly of equal size, ranging in maximum diameter from 10 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. The tabulae in the tabularium form concentric rings. In longitudinal section a pronounced zone of dissepiments is present, and in the tabularium the tabulae are at first down-bent sharply and then up-arched to join with the columnella.

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) shows that this latter species also occurs in Canada at about the same stratigraphic position as L. confluens. The writer noted the following

differences between the two, which at the present time tentatively justifies 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 lonsdaloid dissepiments with fewer intercepts. Stensaas and Langenheim (1960) describe and illustrate with ink drawings a L. jasperensis from the Joana limestone. They believe their specimen came from horizons of Meramec age, but their proof was not at all conclusive. They state the average corallite is 10 mm in diameter and some as large as 15 mm. There are present 20 to 24 (rarely 24) major septa. Their drawing text figures, 9a and 10b, do contain 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) places 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 lonsdaloid 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 Andercito member of the Lake Valley formation in the southern part of the Black Range, New Mexico.

Lithostrotionella shimeri (Crickmay)

Pl. 4, figs. 1, 2, 3.

Lithostrotion pennsylvanicum Shimer, H. W., 1926, (partim.) Geol. Survey, Canada, Bull. 42, p. 27.
Lithostrotionella pennsylvanica, Kelly, W. A., 1942, Jour. Paleont., v. 16, p. 352; pl. 50, figs. 1, 2, 5, 6, 8.
Lonsdaleia pennsylvanica, Crickmay, C. H., 1955, The Minnewanka section, published by the Author, p. 13, pl. 1; figs. 11, 12, fide Nelson, 1960.
Lonsdaleia shimeri Crickmay, C. H., 1955, The Minnewanka section, published by the Author, p. 13, pl. 1, figs. 9, 10, fide Nelson, 1960.

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

Diagnosis. - Cerioid corallum, large corallites, 20 to 23 major septa, minor septa absent or present, weakly-developed columella, dissepimentarium with large sparce dissepiments, tabulae down-arched, flattened.

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

In transverse section the larger corallites are 13 mm in width. There are 20 to 23 major septa, which extend almost to, or reach, the weakly-developed axial structure. Minor septa may, or may not, be present. If present they are very short and weakly developed. In the axial structure, the columella is generally formed by extension of the counter septum. In the dissepimentarium the major septa may, or may not, penetrate and are rarely fused with the epitheca. The dissepiments are widely spaced and have few intercepts. In a longitudinal section the dissepimentarium consists of one row of dissepiments. 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 be gently down-arched ne r the dissepimentarium and horizontal near the columella.

Remarks. - The L. shimeri from the Black Prince limestone agrees very closely with Nelson's (1960, p. 115) 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 Meramec age strata. It is interesting to note that lithostrotionid have not been found in any of the Meramec strata of 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 lithostrotion coral found in New Mexico was a fasciculate Lithostrotion aff. whitneyi from the Arroyo Penasco formation, near Taos, New Mexico. It has been the observation of the writer that in New Mexico and Arizona, lithostrotionid coral are "fairly abundant" in lowest Osage rocks but very rare in Meramec strata.

Horizon. - Shale at base of Black Prince limestone, Gunnison Hills, Arizona, NE $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 4, T. 16S., R. 23E., United States Geological Survey Collection no. 13844.

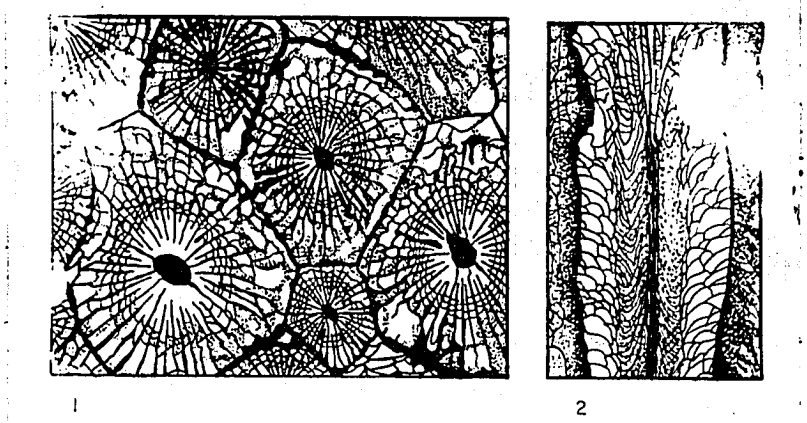

Figure. 15 Inked drawing, X ; 1, transverse section; longitudinal section of Lithostrotionella confluens Easton, from the coral zone, member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico.

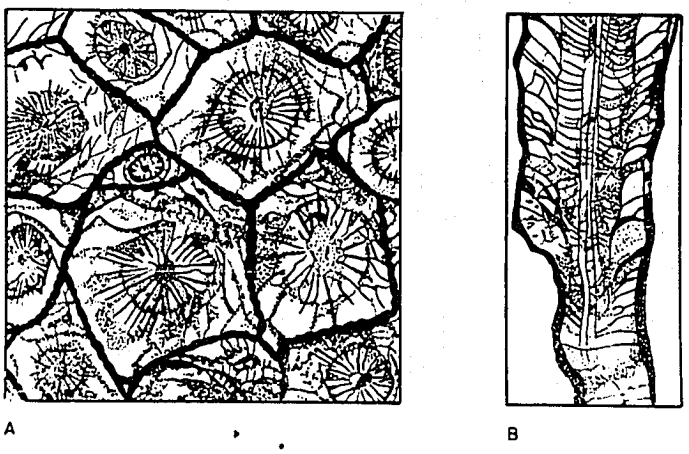

Figure. - Inked drawing X ; A, transverse section; B, longitudinal section of Lithostrotionella shimeri (Crickmay) from the Black Prince limestone, Escabrosa group, Gunnison Hills, Arizona.

Order TABULATA Milne-Edwards and Haime, 1850

Family AULOPORIDAE Milne-Edwards and Haime, 1851

Subfamily SYRINGOPORINAE Nicholson, 1879

Genus Syringopora Goldfuss, 1826

Syringopora Goldfuss, G. A., 1826, Petrefact. Germaniae, v. 1, p. 75; (fide Lang, Smith and Thomas, 1940, p. 132).

Syringopora, Edward, H. S., and Haime, J., 1851, Palaeontographical 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. Queensland Proc., v. 45, n. 12, p. 99.

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

Syringopora, Hill, D., 1956, Treatise on Invertebrate Paleont., 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; Edward and Haime, 1850, British Fossil Corals, Palaeontographical Soc., p. LXII) Syringopora ramulosa Goldfuss, G. A., (1826, Petre facta Germaniae, v. 1, p. 76; pl. 25, fig. 7). Carboniferous; aus dem Uebergangskalk von Olne im Limburgischen, Germany.

Range. - Silurian throughout Pennsylvanian.

Diagnosis. - (After Hill, 1956, 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. - A large proportion of the species of Syringopora have been erected on the size, shape and distribution of the septal spines and the tabulae within the corallite. Unfortunately, a number of Mississippian species have been created primarily on the size of and the distance between corallites. Studies on living scleractinid corals have shown the corallum to be highly susceptible to modification because of various ecological factors. Undoubtedly this was true also of Paleozoic tabulates. Many of the existing fossil species of Syringopora probably represent in reality a smaller number of biospecies. At present virtually nothing is known of the phylogenetic trends within the genus and, consequently, Syringothyris is of very limited value in stratigraphic correlation. If the phylogenetic trends were known, the genus probably would be valuable in correlation.

Syringopora aculeata Girty, 1899

Pl. 11, figs. 6, 7.

Syringopora aculeata Girty, G. H., 1899, United States Geol. Survey, Mon. 32, pt. 2, p. 484, 509; pl. 67, fig. 5a, 5b.

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

Diagnosis. - Syringoporid with corallites 1.5 mm in diameter, separated from adjacent corallites by 2 to 3 mm. Septal spines and concentric tabulae present.

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

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

Syringopora surcularia Girty

Pl. 11, figs. 2, 3.

Syringopora surcularia Girty, G. H., 1899, United States Geol. Survey, Mon. 32, pt. 2, p. 510; pl. 67, figs. 4a-4b. Syringopora surcularis, Easton, W. H., and Gutschick, R. C., 1953, Southern California Acad. Science Bull., 4. 52, p. 22-23.

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

Description. - Corallites 2.5 mm in diameter are separated from adjacent corallites by about 4 mm. In cross section, septal spines numbering about 20 are very short. Tabulae intersections are arranged in about 6 to 8 concentric ellipses which are closely packed and are excentrically 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 septa. In some oblique and longitudinal sections the spines are readily visable as vertical rows.

Remarks. - S. surcularia is distinguished from S. aculeata and S. harveyi by its larger corallites and much less dense packing of the corallites in the corallum. S. robusta with corallites 4 mm in diameter is conspicuously bigger and readily distinguished from S. surcularia.

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 Andercito and Alamogordo

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

Syringopora robusta n. sp.

Pl. 11, figs. 1, 4, 5.

Diagnosis. - Syringoporid with large, 4 mm in diameter corallites and wide spacing between corallites; septal spines absent.

Description. - Corallites are 4 mm in diameter and separated from adjacent corallites by about 6 to 7 mm. In cross sections septal spines are not apparent. Tabulae intersections are arranged in about 4 to 6 concentric ellipses, which are closely packed and are excentrically located in the corallites. In a 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 septa. Spines were not visible in either oblique or longitudinal sections.

Remarks. - S. robusta occurs in the middle of the massive crinoidal limestones of the Hachita formation. These limestones are characterized by extensive diagenetic recrystalization, which has tended to destroy the finer

details of the corallites. Very short, narrow spines may have once been present on this species but were subsequently destroyed by recrystallization. S. robusta is readily distinguished in the field from S. aculeata and S. surculania by its much larger corallites and wider spacing between corallites.

Range. - S. robusta 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 colony in thinsection came from the northeast side of the Big Hatchet Mountains, New Mexico.

Family FAVOSITIDAE Dana, 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. 21; (fide Edward and Haime, 1850, p. LX).

Michelinia, Nicholson, H. A., 1879, Tabulate Corals of Palaeozoic Period, p. 139-142.

Michelinia, Hill, D., 1934, Royal Soc. Queensland Proc., p. 97.

Pleurodictyum Goldfuss, Easton, W. H., 1943, Jour. Paleont., v. 17, n. 2, p. 138.

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

Pleurodictym Goldfuss, Easton, W. H. and Gutschick, R. C., 1953, Southern California Acad. Sci. Bull., v. 52, p. 23-24.

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

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

Type Species. - (Subsequent designation, Edward and Haime, 1850, p. LX) Michelinia tenuisepte de Koninck, L. G., (Descriptions des Animals fossiles qui se trouvent dans le Terrain carbonifere de Belgique, p. 31, pl. C, figs. 3a-3b.)

Range. - Upper Devonian through the Permian.

Diagnosis. - Discoid or hemispherical corallum; corallites large, thickened 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 Michelina being a junior synonym of Pleurodictyum. Fenton and Fenton (1936, p. 23) and Lang, Smith and Thomas (1940, p. 84, 102) considered 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 was made. In the United States Easton (1943, 1944, 1953, and 1958) followed Lang, Smith and Thomas and placed Michelinia as a junior synonym of Pleurodictyum. The issue was not totally settled for Moore and Jefford (1945, 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 apparently studying type material considers Pleuredictyum 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.

Pl. 11, figs. 8-9.

Diagnosis. - Michelinia with a depressed hemispherical corallum; corallites are hexagonal to circular in section, 6 to 10 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 measured some 40 by 50 mm in diameter. The corallites are hexagonal to circular in outline, from 6 to 10 mm in diameter. Septal spines obsolete. Mural pores very scarce. Tabulae abundant, generally convex, 5 to 8 occuring in the space of 10 mm, some tabulae may be complete. The walls are thin and have a very thin investment of stereome.

Horizon. - M. leptosphragma has been found at the top of the Hachita formation (St. Louis), 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 Kinderhookian and Osagian Michelinia expanse White except 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 the walls are much thicker. Michelinia williamsi Greene and Michelinia indianensis Beede from the lower Meramec of Indiana have small corallites of 2 to 3 mm in diameter. Michelinia eugenei White primarily a Morrow (lower Pennsylvanian) fossil which does occur in Chester age strata (Easton, 1943, p. 136) is separated from M. leptosphragma by its much smaller corallites.

Phylum BRACHIOPODA Dumeril, 1806

Class ARTICULATA Huxley, 1869

Suborder STROPHOMENOIDEA Maillieux, 1932; emend. Opik, 1934; emend. Williams, 1953

Superfamily ORTHOTETACEA Williams, 1953

Genus Werriea Campbell, 1957

Orthotetes Fischer de Waldheim, Weller S., 1914, Illinois Geol. Survey, Mon. 1, p. 74-78.

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

Diagnosis. - The following is taken from Campbell (1957, p. 44).

This genus includes orthotetids in which the greatest width is at or near the hinge. The profile of the pedicle valve is flat or resupinate and the brachial valve strongly convex. The cardinal area of the pedicle valve is moderately high and bears the usual surface ornament of the family, and the brachial area is narrow. Both valves are costate, the costae increasing by intercalation. Thick, but short, dental lamellae unite with an independent median septum to isolate a small triangular spondylium. The cardinal process is a short thick structure which bears a variable median ridge on its anteroventral surface and is quadrilobed on its posterior surface. The crural plates are short, simple and subparallel to the hinge.

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

Range. - Mississippian of Australia and North America.

Remarks. - According to Campbell (1957, p. 43-44, fig. 2) Werriea arose from Schuchertella and represents in Mississippian time the ancestorial stock from which in Meramec time two distinct lineages Orthotetes and Derbyia evolved. Werriea has short dental lamellae which are buttressed against an independent median septum to form a spondylium. Orthotetes has the median septum and dental lamellae as independent structures and a small spondylium. Derbyia has at the apex of the beak weakly developed dental lamellae joined with the median septum.

Werriea keokuk (Hall and Whitney)

Pl. 13, figs. 1-6.

Orthis Keokuk Hall, J. and Whitney, J. D., 1858, Iowa Geol. Survey, v. 1, pt. 2, p. 640; pl. 19, figs. 5a-5b.
Streptorhynchus keokuk, Hall, J., 1883, Rept. New York State Geol., pl. 41, figs. 1-3.
Orthis keokuk, Gordon, C. H., 1890, American Geol., v. 5, n. 5, p. 261, pl. 1, fig. 7.
Derbya Keokuk, Hall, J. and Clarke, J. M., 1892, Nat. Hist. New York, Paleont., v. 8, pt. 1, pl. 11, figs. 1-3.

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

Derbya keokuk, Girty, G. H., 1899, United States Geol. Survey, Mon. 32, p. 524.

Orthotetes keokuk, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 75-77; pl. 7, figs. 1-4.

Description. - Shell is large, subelliptical in outline, greatest width slightly posterior to or at the hinge line, cardinal extremities obtusely angular. The dimension of three large pedicle valves in mm width; 70, 72, 81; 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, 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 spendylium. The median septum is well

developed and extends anteriorly from the beak 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 the 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 more posterior than in W. keokuk.

Suborder CHONETOIDEA Muir-Wood, 1955

Superfamily CHONETACEA Schrock and Twenhofel, 1953

Family CHONETIDAE Hall and Clarke, 1895

Genus Chonetes de Koninck, 1842

Type Species. - (Subsequent designation, de Verneuil, 1845, p. 238): Terebratulites sarcinulatus Schlotheim, 1820, (Die Petrefactenkunde, pl. 29, figs. 3a, 3b). Lower and middle Devonian, Harz Mountains, Germany (fide Campbell, 1957).

Range. - Chonetes auct. Silurian - Permian.

After an extensive literature study (Campbell, 1957, p. 63) gave the following description of C. sarcinulatus: "a chonetid of medium size, semicircular to subrectangular in outline, and with a long hinge shell. The surface is ornamented with approximately fifty striae which may dichotomise or remain simple. Internally the pedicle valve has a low median septum which extends beyond the middle of the valve, and the brachial valve has a very weak median septum and two slightly oblique septa which are higher and longer, extending to within 1 to 2 mm of the anterior margin of the valve."

As was indicated obliquely by Dunbar and Contra, (1932, p. 133) and more directly by Stehli (1954, p. 309) and Campbell (1957, p. 63) a number of Chonitid genera have been proposed but the relationship between these genera and

the phylogeny of the group is poorly known. The writer knows of some 23 genera most of which have been proposed for Devonian, Pennsylvanian and Permian species. The Mississippian forms have not as yet been subdivided and are grouped under the genus Chonetes s. l.

If Campbell's (1957, p. 63) description of the type species of Chonetes, C. sarcinulatus from the lower and middle Devonian is correct then as he indicated common Mississippian species which possess the following traits will need a new genus errected for them. These traits are a multistriated valve and a brachial valve with a long median septum flanked by two very short septa which divide the diductor scar. The following forms have these characteristics: the American species such as Chonetes illinoisensis Worthen, C. multicosta Winchell, C. Klondikia n. sp., European forms such as C. dalmaniana Koninck, C. carboniferous Keyserling, and the Australian species C. careyi Campbell. It is interesting to note that Sokolskaya (1950, p. 46, 53) placed in her definition of the genus Chonetes Fischer s. s. both C. dalmaniana and C. carboniferous.

The writer agrees with Campbell (1957, p. 63) that since the holotype of Chonetes Fischer is lost, topotype material must be collected and studied and documented before the Mississippian chonitids can be split into genera. Because of this Chonetes auct. is used in this study.

Chonetes klondikia, n. sp.

Pl. 14, figs. 1-7.

Diagnosis. - Greatest width along hinge line, in outline anterolateral anterior margins form a semicircle. Pedicle valve with faint median sinus. Shell surface marked by 110-130 fine radiating costae. Pedicle valve has large teeth, medium 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 is along the hinge line. The outline of the anterior and anterolateral margins is a half circle. The anterior margin of the shell meets the hinge line of an angle of 90 degrees. The beak is very small and slightly incurved. A faint and ill defined medium sinus is present from the umbo to the anterior margin, where it is broad and shallow. Along the cardinal margin on both sides of the umbo 3 to 4 spines are present. The surface of the shell is marked by 110 to 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 alongate triangle. Delthyrium 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, and the cardinal extremities are flattened. The cardinal area is

very narrow.

The pedicle valve has large teeth and a low narrow medium septum which extends about one-third the length of the valve. The most anterior portions of the pedicle valve blend imperceptably into the contour of the shell. The adductor scars are lobate smooth areas on either side of the posterior half of the medium septum. The shape is rather poorly defined. The adductor scars were imperceptable on the material preserved. The anterior and lateral surface is papillose.

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 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 hardensis Phillips from the lower Carboniferous of England in the number of costae and the shell outline. C. hardensis as described by Davidson (1861, 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 higher number of costae (175 to 225). Snider's (1915, p. 76; pl. 3, fig. 12-15) Chonetes

oklahomensis from the Fayetteville and Pitkins formations of Oklahoma differs from C. klondikia in that its pedicle valves are more convex and in its absence of a sinus. The species, which shows the greatest similarity to C. klondikia, is Campbell's (1957, p. 63; pl. 12, figs. 21-26) Chonetes careyi from the upper Tournaiaian of New South Wales. C. careyi has a slightly wider shell, and a better developed and longer medium septum in the brachial valve than does C. klondikia.

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

Chonetes glenparkensis Weller

Chonetes glenparkensis Weller, S., 1906, St. Louis Acad. Sci., Trans., v. 16, p. 441-442.
Chonetes glenparkensis, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 87-89; pl. 8, fig. 30, 47-49.
Chonetes glenparkensis, Branson, E. B., Univ. Studies, Missouri, v. 8, p. 29-30; pl. 1, figs. 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 very small. Sinus very weak, indicated by flattening from umbo to anterior margin.

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

Remarks. - The preservation of a poorly preserved, single valve makes specific and even generic identification somewhat hazardous. The size and shape, strong curvature of the umbo and related regions, 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.

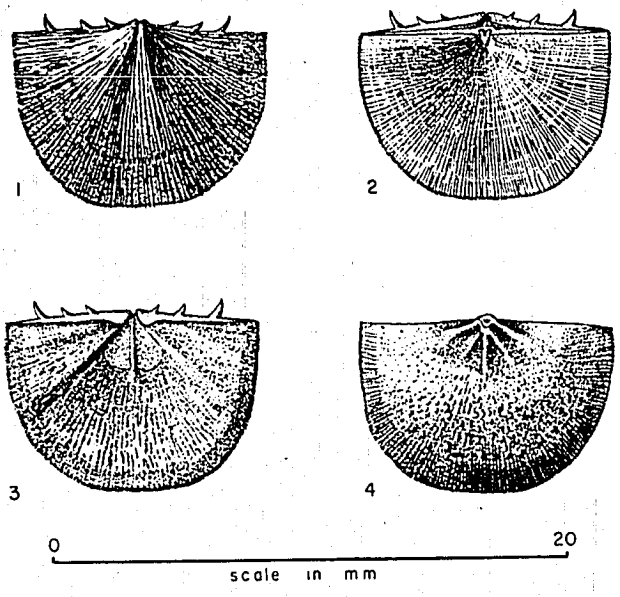

Figure.17 Inked drawing of Chonetes klondika; (1) pedicle exterior; (2) brachial exterior; (3) pedicle interior; (4) brachial interior.

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 Britian, London, v. 2, p. 41, (fide Holland, 1958).

Spirifer, King, W., 1850, (pars) Palaeontographical Society, Permian fossils of England, p. 125.

Spirifer, Davidson, T., 1851, (pars) Palaeontographical Society, British fossil brachiopods, v. 1, p. 79-80.

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

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

Spirifer, Chao, Y. T., 1929, (pars) Palaeontologica Sinica, ser. B, v. 11, 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. Survey; Bull. 5, p. 317.

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

Spirifer, Dunbar, C. O., 1955, Meddelelser om Gronland, Bd. 110, Nr. 3, p. 131.

Spirifer, Dresser, H., 1954, (pars) Bull. American Paleont., 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 then long. Plications numerous on fold and sinus, and the lateral slopes. Plications generally simple but 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 striatus Martin, W., 1793, "Figures and Descriptions of Petrifactors Collected in Debyshire, pl. 23, figs. 1, 2, and Martin, W., 1809, "Petrificata Derbiensia", pl. 23, figs. 1, 2; fide A. M. Cvancara, 1957, p. 873. Lower Mississippian.

Range. - Mississippian - Lower Pennsylvanian.

Remarks. - The majority of the confusion about the generic characteristics of Spirifer s. s. has arisen out of one fact Martin's type specimen is lost. Campbell (1957, p. 67) has shown that 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 original type and collected from the same locality. The neotype of Spirifer will have to be similar to the one figured by Martin, which has 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 synonym to include forms both with a hinge line shorter 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. rowleyi Weller, S. grimes, Hall, S. logani Hall, S. gregeri Weller, S. keokuk Hall, and S. bifucatus Hall.

Holland (1958, p. 214) observed that it is difficult if not impossible to distinguish, on external characters, due to the close similarity and gradation of forms, the

genera Cyntospirifer Nalivkin and Spirifer s. s. Holland further believes "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 spiriferids".

Holland (1958, p. 216) states 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 delthrial 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. Sanders on the presence of these plates assigned S. latori, a Chouteau age spiriferoid to the genus Crytospirifer.

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, is frequently

mucronate. In the sinus the plications are relatively few in number. Brachythyris McCoy is very distinctive with its very short hinge line, plications which are broad and flat on the lateral slopes and are weakly developed or absent on the fold and sinus.

Spirifer gregeri Weller

Pl. 16, figs. 5, 6.

Spirifer gregeri Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 359; pl. 55, figs. 1-8.
Spirifer gregeri, Branson, E. B., Univ. Missouri Studies, v. 8, p. 59; pl. 7, figs. 1-3, 15, 16.
Spirifer esplanadensis Brown, R. A. C., 1952, Geol. Survey Canada, Mem. 264; p. 97; pl. 5, figs. 1a-1e.

Diagnosis. - Shell wider than long, pedicle valve sub-hemispherical 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 curving 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 some 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, nature and size of the plications are characteristic of S. gregeri. Brown (1952, p. 97-98; pl. 5, figs. 1a-1e) described a new species, Spirifer esplanadensis, from the Baniff 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. 16, figs. 7-10.

Spirifer bifurcata Hall, J., 1856, Albany Inst., Trans., v. 4, p. 8, (fide Weller, 1914, p. 320).

Spirifer Leidyi var. Merimacensis, Swallow, G. C., 1866, St. Louis Acad., Trans., p. 47; pl. 6, figs. 13-15.

Spirifer bifurcata, Whitfield, R. P., 1882, American Mus. Nat. Hist., Bull. 1, p. 47; pl. 6, figs. 13-14.

Spirifer bifurcata, Hall, J., 1883, Indiana Geol. Survey, 12th Rept., p. 326; pl. 29, figs. 13-16.

Spirifer bifurcata, Beebe, J. W., 1906, Indiana Geol. Survey, 30th Rept. p. 1314; pl. 22, figs. 13-15.

Spirifer bifurcatus, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 346-347; pl. 47, figs. 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 behind the cardinal area. Cardinal extremities slightly rounded. The dimensions of one incomplete individual area, 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 may show 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 on 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. - Due to 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, plate 3, figure 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, and number and nature of the plications on the lateral slopes. The Hachita specimens differ in having a weakly-developed median plication in the sinus, a weakly-developed furrow on the fold and a brachial valve which appears to be less convex. The exact extent of these differences cannot be accurately ascertained due to their poor state of preservation.

In general, the material studied from the Hachita formation is in the opinion of the writer clearly cospecific 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 greater number of which are simple but some of which divide. In the sinus the costae are relatively few in number, 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 are 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 striato-convoluta, Benson, W. N., and Dun, W. S., 1920, Proc. Linn. Soc. New South Wales, v. 45, n. 179, p. 350, pl. 20, figs. 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 Kinderhookian and Osagian of North America. The writer considers Spirifer lateralis Hall, from the Warsaw and Salem (lower Meramec) is also

a member of the genus Unispirifer.

Remarks. - Campbell (1957, p. 67-68) distinguishes Unispirifer from Cyrtospirifer Nalivikin and Sinospirifer Tien on the nature of the sinal plications. In the Cyrtospirifer-Sinospirifer species group the sinal costae are always numerous, seven or more in the adult and in most species two 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.

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

Spirifer s. s. is distinguished from Unispirifer Campbell by a hinge line which is shorter than the greatest width of the valve, a multiplicated sinus and fold and a triangular area. Brachythyris McCoy in marked contrast to Unispirifer has a very short hinge line, tend to be as wide as long or frequently longer than wide and have 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., U. vernonensis (Swallow) and U. forbesi (Norwood and Pratton). The lower Meramec strata contain U. lateralis (Hall).

Unispirifer balki n. sp.

Pl. 17, figs. 1-8

Diagnosis. - Mucronated 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 below medium size, broadly subtriangular in outline; greatest width along the hinge line, well-preserved specimens show a mucronated condition. The dimensions of three disassociated valves are in mm:

		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 curving abruptly to the cardinal margin. Surface of the shell is progressively flattened toward the cardinal extremities. Beak is large,

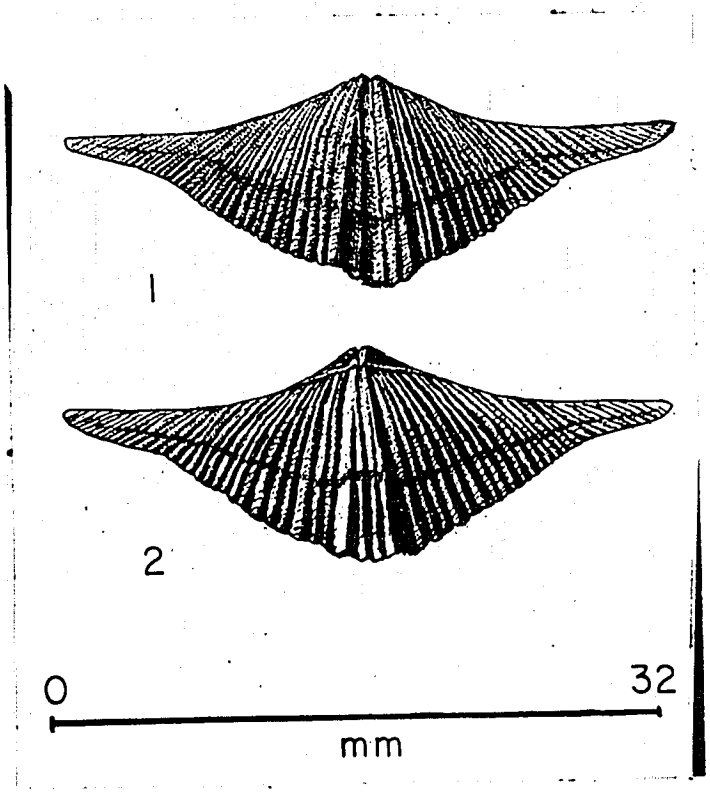

Figure. - Inked drawing of restored and typical example of Unispirifer balki n. sp. from the coral zone, member A, Keating formation, Escabrosa group.

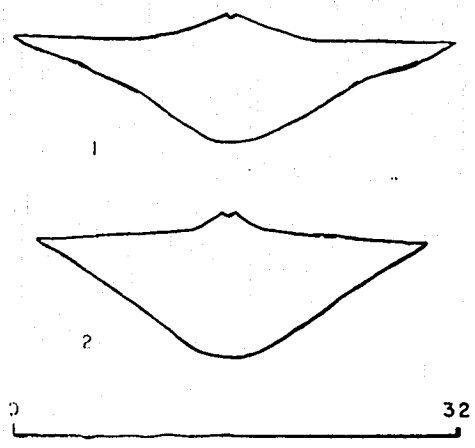

Figure 19. - Outline drawing (1) of U. balki n. sp. compared with outline drawing (2) of the holotype drawing of U. platynotus Weller.

and incurved. Cardinal area is concave and of moderate height, delthyrium opening an equilateral triangle. Sinus present at beak, shallow, becomes wider anteriorly but ill defined. Median plication present at apex of beak, and does 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 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 slope. 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 Andercito member of the Lake Valley formation in the Cooks Range area.

Remarks. - Unispirifer balki is closely related to Unispirifer platynotus (Weller). It differs from the latter in possessing an umbo and beak which is much larger and more pronounced. U. balki at all stages of growth has pronounced, mucronated 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 veronensis (Swallow)

Pl. 16, figs. 1-4.

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

Spirifer Vernonensis, Winchell, A., 1865, Philadelphia Acad. Nat. Sci., Proc., v. 17, p. 119.

Spirifer vernonensis, Weller, S., 1909, Geol. Soc. America, Bull., v. 20, p. 310; pl. 37, fig. 3-8.

Spirifer vernonensis, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 310; pl. 37, figs. 8-17.

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

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 are present a series of growth lamellae on the anterior margin of the shell, which become more numerous and pronounced toward the line of commissure. The outline of the anterior and lateral margins of the shell is a semi-circle, 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 starts out 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.

The brachial valve is almost as convex as the pedicle 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 some 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 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 anteriorly are free and anklose, and are present for approximately one-fourth the length of the valve.

The brachial valve has long dental sockets which reach into the umbo. The inner edge of each socket is thickened and anteriorly developes into a crus which is

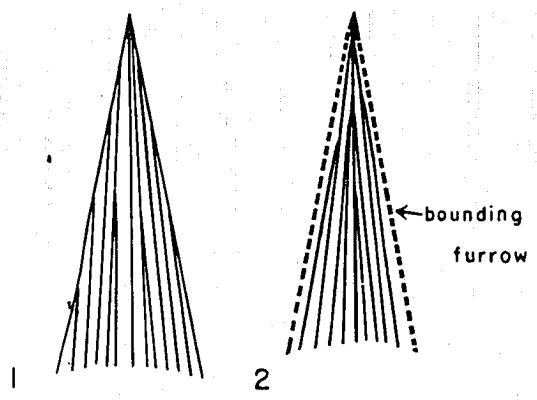

Figure. 20 The arrangement of the plications (1) on the sinus, and (2) on the fold of Unispirifer vernenensis (Swallow) from the lower part of member B, Keating formation, Escabrosa group, Blue Mountain, Arizona.

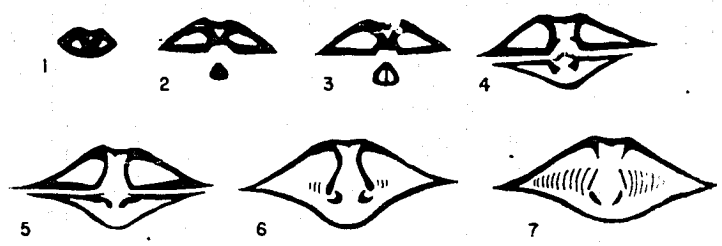

Figure. 21 Diagrammatic serial sections through the umbo of Spirifer vernenensis (Swallow) from the lower part of the cherty member, Escabrosa formation, Blue Mountain, Arizona.

attached to the descending lamellae of a spire. Each spire appears to have 12 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 cospecific 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 as broad and have a wider and more rounded sinus. They agree closely with the forms from Missouri in general overall contour, 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. l. reported in literature from the Escabrosa group may belong to this species. Spirifer centronatus Winchell s. s. differs from Unispirifer vernonensis in having fewer lateral

and coarser plications, fewer plications on the sinus and fold, a larger linear cardinal area, a shallower fold and a less-pronounced linguloid extension.

Unispirifer forbesi (Norwood and Pratten)

Pl. 17, figs. 14-17.

Spirifer Forbesii Norwood, F. G. and Pratten, H., 1855, Acad. Nat. Sci., Philadelphia, Jour., v. 2, p. 73; pl. 9, figs. 3a-c.

Spirifer forbesi, Hall, J. and Whitfield, R. P., 1858, Iowa Geol. Survey, v. 1, pt. 2, p. 600; pl. 13, fig. 1.

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

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

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

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 arises in the sinus at the apex of the beak, 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.

Brachial valve is equal 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. Some 22 to 28 plications are present on each lateral slope.

Horizon. - U. forbesi is found in the upper half of the member B, Keating formation. At this horizon this species

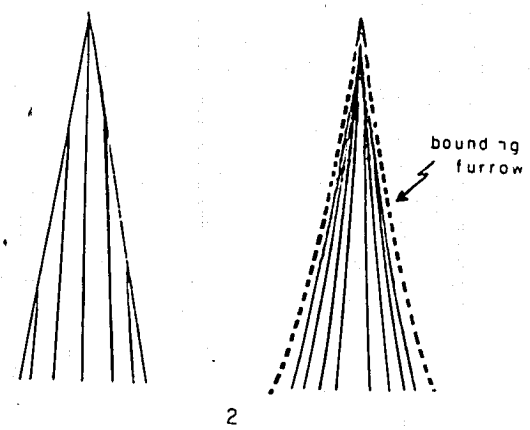

Figure 21. - The arrangement of the plications on the sinus and fold of Unispirifer forbesi.

is by far the most abundant brachiopod, occuring at times in large numbers as broken and disassociated valves. It is common in the Klondike Hills, Big Hatchets, Animas, and Pelencillo Mountains of New Mexico and the Chiricahua and Dragoon Mountains of Arizona.

Remarks. - The Escabrosa forms compare very well with the described midcontinent examples except that in the southwestern population 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). U. forbesi in the Cordillerian region may prove to be an excellent index fossil to strata of Burlington age.

Unispirifer lateralis (Hall and Whitfield)

Pl. 17, figs. 9-13.

Spirifer lateralis Hall, J. and Whitfield, R. P., 1858, Geol. Iowa, v. 1, pt. 2, p. 661; pl. 23, figs. 7a-7c.
Spirifer lateralis, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 330-331; pl. 43, figs. 11-15.
Spirifer lateralis, Cooper, G. A., 1943, in Shimer, H. W. and Shrock, R. R., Index fossils of North America, p. 325; pl. 124, figs. 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 14 to 18 plications, which arise by successive bifurcation from the medium 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. - S. 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 Tylorthyris

Tylorthyris, North, F. J., 1920, Quant. Jour. Geol. Soc. London, v. 76, p. 197.

Tylorthyris, Cavncara, A. M., 1958, Jour. Paleont., v. 32, p. 876.

Type Species. - (Original designation) Cyrtia laminosa 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.

Diagnosis. - (Abstracted from North, 1920, p. 195-196) Shell is spiriferoid, about twice as wide as long with greatest width along the hinge line. The sulcus is wide and subangular, mesial fold very distinct, subangular plications on each lateral slope. Growth lamellae pronounced and regularly spaced on surface of shell. Shell is fibrous and impunctate. Dental lamellae and well developed median septum within one pedicle valve. Brachial valve has a well developed median ridge.

Tylorthyris novamexicana (Miller)

Spirifer novamexicana Miller, S. A., 1881, Cincinnati Soc. Nat. Hist., Jour., v. 4, p. 314, pl. 7, figs. 10-10B.
Spirifer magnicostatus, Weller, S., 1909, Geol. Soc. America, Bull., v. 20, p. 307; pl. 13, figs. 12-15.
Delthyris novamexicana, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 304, 305; pl. 36, figs. 15-24.
Delthyris novamexican, Croneis, C., 1930, Arkansas Geol. Survey, Bull. 3, pl. 11, figs. 21-23.
Delthyris novamexicana, Branson, E. B., 1938, Univ. Missouri Studies, v. 13, p. 58-59; pl. 6, figs. 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 D. 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. 128.

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

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

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

Brachythyris, Chao, Y. T., 1929, Palaeontologia Sinica, ser. B, v. 11, fas. 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, Univ. Queensland, Papers, v. 4, n. 5, p. 26-27.

Type Species. - (Original designation) Spirifera 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 to late Chester.

Diagnosis. - The shell is small to large and spiriferoid. Hingeline 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 (Schumard)

Pl. 13, fig. 9

Spirifer? pecularis Schumard, B. F., Missouri Geol. Survey, First and Second Ann. Repts., p. 202; pl. C, figs. 7a-7c.

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

Brachythyris pecularis, Weller, S., Illinois Geol. Survey, Mon. 1, p. 381, 382; pl. 57, figs. 12; pl. 58, figs. 9-20; pl. 83, figs. 3-5.

Brachythyris peculiaris, Branson, E. B., 1938, Univ. Missouri Studies, v. 8, n. 3, p. 66, pl. 6, figs. 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 and Whitney)

Pl. 14, figs. 19, 24-26.

Spirifer suborbicularis Hall, J. and Whitney, J. D., 1858, Iowa Geol. Survey, Rept. v. 1, pt. 2, Paleont. p. 644.

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

Brachythyris suborbicularis, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 374-376; pl. 61, figs. 1-8; pl. 62, figs. 1-12.

Brachythyris suborbicularis, Armstrong, A. K., 1958, New Mexico Bur. Mines and Mineral Resources, Mem. 5, p. 24-25; pl. 3, figs. 10-11.

Description. - The pedicle valve is suborbicular to subrhomboidal in outline. The cardinal extremities are rounded or obtusely angular. The dimension of an incomplete pedicle valve is: 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 medium plication. Each lateral slope is marked by 10-13 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 sparcely fossiliferous lower 150 feet of the Hachita formation of the Escabrosa group.

Remarks. - The B. suborbicularis from the Hachita formation is smaller in size 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, figs. 10-11) from the Kelly formation of Keokuk age in west-central New Mexico.

Brachythyris subcarbiiformis (Hall and Whitney)

Pl. 13, fig. 8.

Spirifer subcarbiiformis Hall, J. and Whitney, J. D., Iowa Geol. Survey Rept., v. 1, pt. 2, p. 660; pl. 23, figs. 6a-6b.

Spirifer subcarbiiformis, White, C. A., 1880, United States Geol. Survey 12th Ann. Rept., Cont. to Inv. Paleont., n. 8,

p. 165; pl. 41, figs. 2a-2c.

Spirifer subcarbiiformis, Beede, J. W., 1906, Geol. Survey of Indiana 30th Ann. Rept., p. 1313; pl. 21, figs. 2-2b.

Brachythyris subcarbiiformis, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 376-377; pl. 60, figs. 1-15.

Description. - Pedicle valve is subrhomboid in outline. It 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 four 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 characters 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. 14, figs. 20-24.

Brachythyris ozarkensis Snider, L. C., 1915, Oklahoma Geol. Survey, Bull. 24, p. 90-91; pl. 5, figs. 3-6.
Brachythyris chesterensis Butts, C., 1926, Geol. Survey of Alabama, Spec. Report 14, pl. 61, figs. 9-12.
Brachythyris chesterensis, Hernon, 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 due to the nature of preservation, but faint, concentric lines of growth were observed.

Remarks. - The illustrations of the type specimens of B. ozarkensis by Snider (1915, pl. 5, figs. 3-6) are very

poor, and using them as a comparison with the Paradise forms is hazardous. The writer received on loan 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, figs. 9-12) description of his species Brachythyris chesterensis consists of four photographs and no written description. Butts' species compare favorably with Snider's B. ozarkensis except the former apparently has stronger developed plications.

Family SPIRIFERINIDAE Davidson, 1884

Subfamily SYRINGOTHYINAE Schuchert and LeVene, 1929

Syringothyris Winchell, 1863

Syringothyris Winchell, A., 1863, Philadelphia, Acad. Nat. Sci., Proc., v. 3, second series, p. 6-8.

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

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

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

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

Syringothyris, North, F. J., 1920, Quart. Journ. 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. 110.

Syringothyris, Holland, F. D., Jr., 1958, Thesis, Doctor of Philosophy, Univ. of Cincinnati (in press, Paleont., Res. Inst., 1959), p. 275-294.

Syringothyris, Sass, D. B., 1959, Thesis, Doctor of Philosophy, University of Cincinnati, p. 169-194. (in press, Paleont. Res. Inst., 1960).

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

Range. - Mississippian. Glenister (1955, p. 47) discounts Maxwell (1954, p. 41-42) reports of Syringothyris in beds of Permian age in India, Spitzbergen and Australia. Sass (1959, p. 190) and Holland (1958, p. 77-78) believe 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. Maxwell's report of Syringothyris s. s. in beds younger than Mississippian is strongly doubted.

Diagnosis. - The shell is spiriferoid in shape. The brachial valve is convex with a small, straight beak. The pedicle valve acutely pyramidal due to 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 marked by simple plications. The rounded fold and sinus is 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 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 water (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 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. 1) 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, medium 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.

Remarks. - Holland (1958) and Sass (1959) demonstrated that when Winchell (1863) errected 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 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, 1959).

Sass (1959, p. 182) 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. The fold and sulcus may display faint plicae, particularly along their lateral margins. This distinction is apparently more common in the sulcus.
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 and Whitney)

Pl. 16, figs. 11-15.

Spirifer subcuspidatus Hall, J., and Whitney, J. D., Iowa Geol. Survey, v. 1, pt. 2, p. 646; pl. 20, figs. 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, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 26, figs. 8, 11; pl. 27, fig. 18.
Syringothyris subcuspidatus, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 401-403; pl. 71, figs. 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 some 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 imperceptable.

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, 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.

The pedicle valve interior 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 calcified and embedded in shell material at its posterior end, extends past the mid-point of the valve. The syrinx 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 syrinx 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.

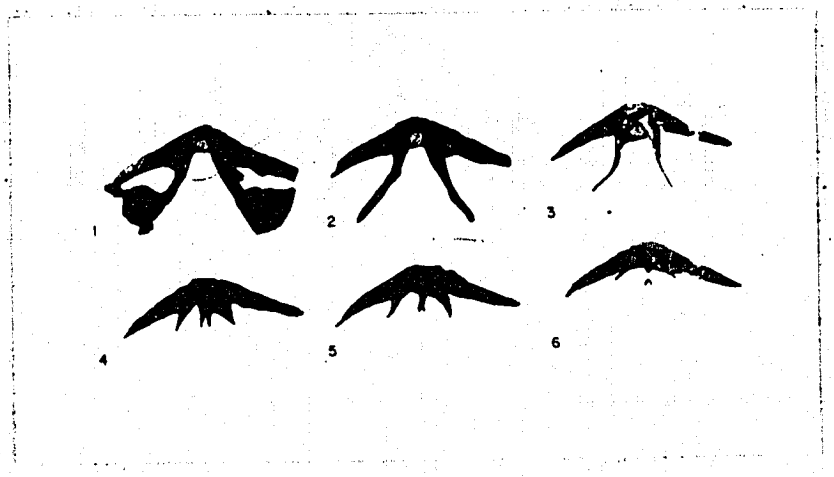

Figure. 23 Diagrammatic serial sections through the umbo of the pedicle valve of Syringothyris subcuspidatus (Hall) from the top of the Hachita formation, Big Hatchet Mountains, New Mexico

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

Genus Cleiothyridina Buckman, 1906

Cleiothyris King, W., 1850, Palaeontographical Soc. (Permian Fossils of England) p. 137, pl. 10, figs. 1-10.

Cleiothyris, Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, 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. Survey, Mon. 1, p. 472-473.

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

Cleiothyridina, Cooper, A. A., 1943, in Shimer, H. W. and Shrock, R. R., Index fossils of North America, p. 333.

Cleiothyridina, Dresser, H., 1954, Bull. American Paleontology, v. 35, p. 38-39.

Cleiothyridina, Dunbar, C. O., 1955, Meddelelser om Gronland, Bd. 110, Nr. 3, p. 123-124.

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

Type Species. - (Original designation) Athyris roysii Davidson, 1857, Palaeontographical Society, p. 84, pl. 18, figs. 1-11. The lower Carboniferous limestones of England.

Range. - Mississippian - Pennsylvanian.

Diagnosis. - After King (1850, p. 137-138) and Dunbar and Condora (1933, p. 359) and Dunbar (1955, p. 123-124). Shell subcircular to transversely subelleptical in outline. Fold and dinus well developed to obsolete. Surface at valve has lamellar extension 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 which give 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.

Remarks. - The writer concurs after a study of the literature with Dresser (1954, p. 38-39) and Dunbar (1955, p. 123-124) that when Buckman (1906, p. 323-324) proposed the genus Cleiothyridina he did not give a description or a figured specimen but evidently intended King's (1850, p. 137) misinterpretation of Cleiothyris Phillips (1841, p. 55) stand as a generic description. Buckman (p. 324) further emphasized that Phillips interpretation of Cleiothyris was incorrect by placing a non in front of Phillips (1841). Fortunately Hall and Clarke (1884, p. 90-91) had introduced the genus Cleiothyris

into the American literature in the meaning of Buckman's (1909) Cleiothyridina by using King's (1850) diagnosis.

Hall and Clarke (1884, p. 90-91) in contrasting "Cleiothyris" to Athyris McCoy, and Weller (1914, p. 472), Dunbar and Condra (1932, p. 359), Cooper (in Shimer and Shrock) and Dresser (1954, p. 38) in contrasting Cleiothyridina to Athyris noted the only distinguishing feature between the two genera was on the external concentric lamellae of the shell. On Cleiothyridina the lamellar extensions of the shell are divided into flat spines and on Athyris the lamellae extensions are undivided.

Holland (1958, p. 324) in accordance with King (1850, p. 137) believes there exist internal differences between the two genera. Holland (1958, p. 324) noted that in "Cleiothyridina" the hinge plate is essentially triangular and the primary lamellae are attached to the crura at their apices but also for a short distance along their inner faces and do not form the "nooses" as in Athyris.

Cleiothyridina everharti n. sp.

Pl. 14, figs. 10-13, 16-18.

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 nine individuals in mm are:

Both valves present:

Specimen	Length	Width	Thickness
1.	13.0	12.5	6.5
2.	12.0	12.0	6.0
3.	13.0	13.0	7.0
4.	9.0	8.0	4.0

Pedicle valve only:

5.	19.0	20.5
6.	14.0	14.0
7.	10.5	11.0
8.	13.5	14.0
9.	12.0	12.0

Specimens 1 to 7 are from beds of lower Meramec age, Hachita formation, Blue Mountain, Arizona. Specimens 8 and 9 are from the top of the member B, Keating formation, Big Hatchet Mountains.

Pedicle valve moderately convex, greatest convexity posterior to the middle and on the umbo. Surface curving 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 cardinal area, much less to the lateral and anterior margins. The beak 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 to 4 of which are present in 1 mm.

Interior. - A few silicified pedicle valves were etched by hydrochloric acid which 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 flabelate, well defined. A well defined medium septum is present for over half the length of the valve. Interior of a brachial valve was not available for study.

Remarks. - Cleiothyridina everharti is closely related to Cleiothyridina sublamellosa (Hall), but differs from that species in several important respects. C. sublamellosa tends to be longer than wide, to have rounded (semicircular)

anterolateral and anterior margins, to have the greatest width of the shell posterior to the middle, and gently convex posterolateral margins.

C. everharti is characterized by a shell slightly wider than long, a faintly to strongly truncated anterior margin, the greatest width of the shell noticeably anterior to the middle and posterolateral margins which are linear.

Horizon. - Cleiothyridina everharti is common as silicified shells in the upper half of member A of the Keating formation. It is absent in the great bulk of the Hachita member, but appears abundantly in the lower Meramec portion of the Hachita member of the Escabrosa formation. It is a very numerous fossil in the lower parts of the Paradise formation. This species spans and is a conspicuous fossil in beds of Burlington to lower Chester age. The upper horizons of member A may also contain this species. Insoluable residue studies have yielded possible silicified fragments of this fossil or closely related forms.

Cleiothyridina hirsuta (Hall)

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

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

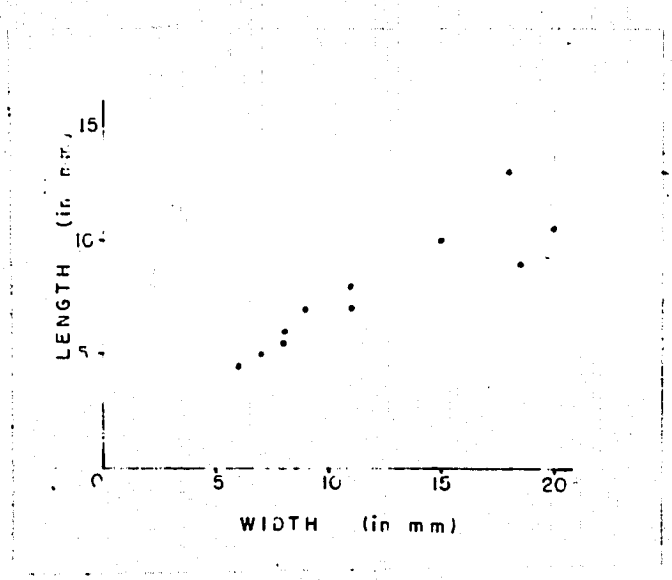

Figure. 24.-Scatter plot of the ratio of length/width of the pedicle valve of Cleiothyridina everharti, from the Escabrosa group.

Athyris hirsuta, Walcott, C., 1884, United States Geol. Survey, Mon. 8, p. 222; pl. 18, fig. 5.

Cliothyris Roysii, Hall, J. and Clarke, J. M., 1894, Introduction to the Study of Brachiopods, pt. 2, pl. 46, fig. 23 (non fig. 24).

Cliothyridina hirsuta, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 479-480; pl. 80, figs. 13-24.

Cleiothyridina hirsuta, Cooper, G. A., 1943, in Shimer, H. W. and Shrock, R. R., Index Fossils of North America, p. 333; pl. 128, figs. 1-2.

Cleiothyridina hirsuta, Armstrong, A. K., 1958, New Mexico Bur. of Mines and Mineral Rescourses, Mem. 5, p. 26; pl. 3, figs. 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. 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 on most specimens near the anterior margin.

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 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 lower 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 Cleiothyridina everharti n. sp., which occur in the same horizon and are a closely related species to Cleiothyridina hirsuta (Hall), have the same general contour as C. hirsuta. These two species

occur as separate populations in one horizon, which indicates that they are a distinct, biologic species. 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, p. 480). C. hirsuta is characteristic in New Mexico and Arizona of 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 incrassata (Hall)

Athyris incrassata Hall, J. and Whitfield, R. P., 1858, Iowa Geol. Survey, v. 1, pt. 2, p. 600; pl. 12, fig. 6.
Athyris incrassata, Hall, J. and Clarke, J. M., 1894, (pars), Nat. Hist. New York, Paleontology, v. 8, pt. 2; pl. 46, fig. 21.
Athyris incrassata (?), Girty, G. H., 1899, U. S. Geol. Survey, 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. 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 (1895) 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 impricating lamellae divided into spines. Thus, there exists a possibility that the specimen identified as C. incrassata is an Athyris and a different species. The specimens exhibit 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.

Suborder TEREBRATULOIDAE Muir-Wood, 1955

Superfamily TEREBRATULACE 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, Nat. Hist. New York, Paleont., v. 8, pt. 2, p. 300.

Dielasma, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 256-257.

Dielasma, Dunbar, C. O. and Condra, G. E., 1932, Geol. Survey Nebraska, 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. Paleontology, v. 30, n. 2, p. 302.

Type Species.- (Original Designation) Beecheria davidsoni Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, p. 2, p. 300, figs. 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 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 in the brachial interior have 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. 15, figs. 17-19.

Terebratula formosa Hall, J., 1856, Albany Inst., Trans., v. 4, p. 6.

Terebratula formosa, White, C. A., Indiana Geol. Survey, 11th Ann. Rept., p. 361; pl. 39, figs. 6-7.

Terebratula formosa, Whitfield, R. P., 1882, American Mus. Nat. Hist., Bull. 1, p. 55; pl. 6, figs. 59-64.

Terebratula formosa, Hall, J., 1883, Indiana Geol. Survey, 12th Ann. Rept., p. 337, pl. 29, figs. 59-64.

Dielasma formosa, Hall, J. and Clarke, J. M., 1894, (pars) Introduction to the Study of Brachiopods, pt. 2, pl. 53, figs. 15-17, (non fig. 18-19).

Dielasma formosa, Hall, J. and Clarke, J. M., 1894, (pars) Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 81, figs. 18-23, 25-26, (non 12-17, 24).

Dielasma obovata, Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 81, figs. 38-40.

Dielasma obovata, Hall, J. and Clarke, J. M., 1897, New York State Geol., 14th Ann. Rept., p. 372; pl. 14, figs. 12-14.

Dielasma formosa, Weller, S., 1911, Jour. Geol., v. 19, p. 440; figs. 1a-1n.

Dielasma formosum, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 265-267; pl. 33, figs. 12-17.

Dielasma formosum, Cooper, G. A., 1943, in Shimer, H. W., and Shrock, R. R., Index Fossils of North America, p. 364.

Diagnosis. - Terebretuliform 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. No trace of a sinus. 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.

A brachial valve was sectioned 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. - Scarce 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

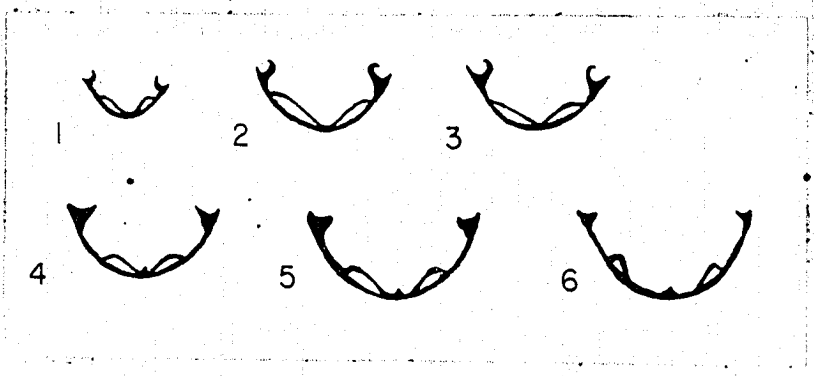

Figure. 26 Serial sections through the umbo of the brachial valve of Beecheria formosa (Hall) from the Syringothyris subcuspidatus zone of the Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona.

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 chouteauensis (Weller)

Pl. 15, fig. 20.

Dielasma formosa Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 81, fig. 24 (non figs. 12-23 or 25-26).

Dielasma chouteauensis Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 257-259; pl. 32, figs. 1-17.

Dielasma chouteauensis, Branson, E. B., 1938, Univ. Missouri Studies, v. 8, p. 55-56; pl. 5, figs. 28-30.

Dielasma chouteauensis, Armstrong, A. K., 1958, New Mexico Bur. Mines and Mineral Resources, Mem. 5, p. 26-27; pl. 2, figs. 1-7, 11-14, 17-28, 31.

Description. - The species is represented by broken and disassociated valves. One badly 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. Medium septum is 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 Gilbert (1958) in the Banffian 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. of Geology, v. 19, p. 443-444.

Dielasmoides, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 251-254.

Dielasma, Dunbar, C. O., 1955, Meddelelser om Grønland, Bd. 110, Nr. 3, p. 117.

Dielasma, Stehli, F. G., 1956, Jour. of Paleont., v. 30, n. 2, p. 299-302.

Non *Epithyris* Phillips, King, W., 1850, Palaeontographical Society, v. 3, Permian fossils of England (*Epithyris* Phillips, 1841, Geol. Soc. Great Britian, Mem., p. 178; a Jurassic terebratula).

Non *Dielasma*, Hall, J. and Clarke, J. M., 1894, Introduction to the Study of the Brachiopods, pt. 2, p. 295.

Non *Dielasma*, Weller S., 1914, Illinois Geol. Survey, Mon. 1, p. 256-257.

Non *Dielasma*, Dunbar, C. O. and Condra, G. E., 1932, Nebraska Geol. Survey, Bull. 5, p. 303-304.

Non *Dielasma*, Cooper, G. A., 1943, *in* Shimer, H. W. and Schrock, 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 Hinsich: Akad. der Wissenschaft. zu Munchen, Denkschriften, Mathema tischephysikalische Klasse, v. 6, p. 27, figs. 7a-7c). Permian Hohlen Kalks ein, Thuringia (Species type destroyed during W. W. 2, lectotype, chosen by Stehli, 1956, p. 299).

Range. - Middle 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 Terabratula elongatus Schlothein, 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.

Dielasma bisinuata (Weller)

Pl. 15, figs. 1-15.

Dielasmoides bisinuata Weller, S., 1911, Jour. Geol. v. 19, p. 443, figs. 3a-3g.

Dielasmoides bisinuata, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 254-255; pl. 31, figs. 19-24.

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.

Description. - Shell medium size, ovate to subtriangular in outline; the greatest width near the anterior third of the shell. The dimensions of a suite of complete but somewhat crushed specimens are:

Specimen Number	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 surface is strongly curved to meet opposite valve. Near middle of the shell begin two broadly rounded sinuses which strengthen anteriorly.

Brachial valve equal 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 has the socket plates lying at the plane of valve with its inner margins joined by the cardinal plates which join at the floor of the valve. Cardinal process or diductor muscle attachment and crura absent.

Remarks. - The Dialasma bisinuata from the Paradise formation differ from those shown by Weller (1914, pl. 31, figs. 19-24) in that they possess 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 typotype material of D. bisinuata which he had examined more often shows a uniplicate rather than a sulciplicate anterior commissure. The majority of mature specimens from the Paradise formation possessed the sulciplicate condition.

The brachial interior of D. bisinuata from the Paradise formation and Weller's type differs from the type of the genus, Dielasma elongatum (Schlotheim) in not possessing crura on the socket plates. This condition is considered by the writer to be a specific trait. The absence of a cardinal process in D. bisinuata is considered by Sanders (in Easton, 1958, p. 50) to be a valid trait

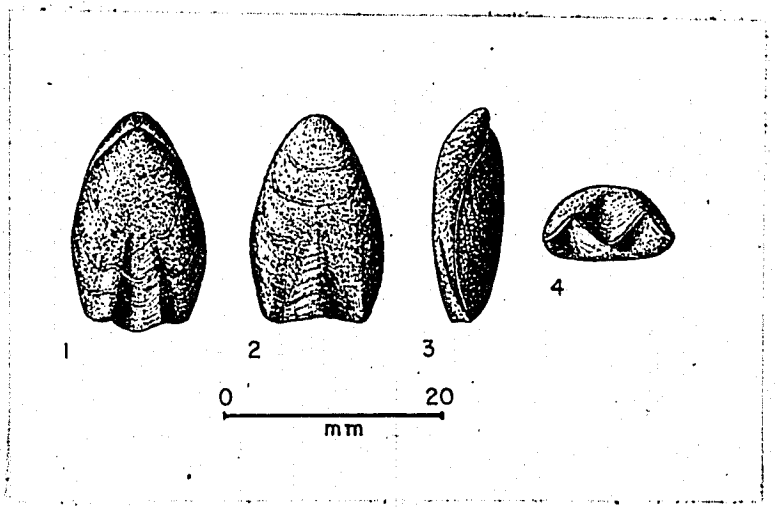

Figure. 2-7 Inked drawing of a restored and typical example of Dielasma bisinuata (Weller) from the Paradise formation.

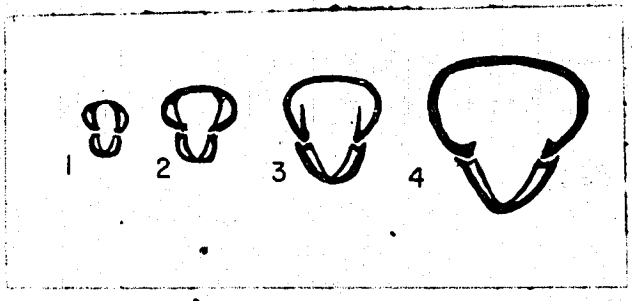

Figure. 28 Diagramatic serial sections through Dielasma bisinuata (Weller) from the lower half of the Paradise formation, Blue Mountain, Arizona.

for recognizing the genus Dielasmoides Weller.

Horizon. - Highest horizon 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.

Superfamily PUNCTOSPIRACEA Cooper, 1944

Family RHYNTHOSPIRINIDAE Schuchert and LeVene, 1929

Subfamily RHYNTHOSPIRINAE Schuchert, 1894

Genus Eumetria Hall, 1863

Eumetria Hall, J., 1863, New York State Cabinet Nat. Hist., 16th Ann. Rept., p. 54-55.

Eumetria, Whitfield, R. P., 1882, Amer. Museum Nat. Hist., Bull., v. 1, p. 50.

Eumetria, Hall, J., 1883, State Geol., Indiana, 12th Ann. Rept., p. 335.

Eumetria, Weller, S., 1914, Illinois Geol. Survey, 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. Survey, v. 1, pt. 2, p. 704, pl. 27, fig. 3a): Kaskaskia limestone, Chester, Illinois.

Diagnosis. - Shell is small to medium sized, subequally biconvex with a very short hingeline. Shell has radiating

costae or costellate ornamentation. The shell is punctate. Pedicle valve has a prominent, incurved umbo, perforated at its apex by a large circular foramen. The delthyrium meet the foramen only at the apex. The cardinal area is restricted to a small flattened extension on either side of the delthyrium. The pedicle valve is devoid of dental lamellae. The hinge plate at the brachial valve bears two curved projections of variable length, which extend into the umbo of the pedicle valve and lie close to the deltidium. The hinge plate is short and is supported by two long slender plates which converge at the beak and anteriorly become almost vertical. These plates extend almost half the length of the valve. They are united by a spondyloid process which is an anterior extension from the hinge plate. They increase in height anteriorly, and from their anteroventral edges the descending lamellae of the brachia are derived. The spires have up to nine volutions and are directed laterally.

Remarks. - The distinguishing interior characteristics of the genus were clearly defined by Hall(1863, p. 54-55) and Weller (1914, p. 437). These characteristics are the absence of dental lamellae in the pedicle valve and the presence in the ventral valve of two long slender plates joined by a connecting spoon-shaped process.

In North America three species of Eumetria are recognized from the Meramec and Chester, which are

differentiated by their number of costae. These are E. verneuilana (Hall) which has 48 to 55 costae, E. vera (Hall) with 42 to 48 costae, and E. costata (Hall) with 30 to 42 costae. E. verneuiliana occurs in the Meramec part of the Escabrosa formation and the lower 90 feet of the Paradise formation. E. vera occurs throughout the Paradise formation, including the lower zones with E. verneuiliana. The highest 60 feet of the Paradise formation in the Big Hatchet Mountains contains E. costata with occasional E. vera.

There exists in the progressively higher beds of the Paradise formation a tendency for each succeeding population of Eumetria to display individuals having fewer costae. At the base of the Paradise formation the population is dominated by E. verneuiliana with individuals of 55 costae at one extreme; at the other extreme is E. vera with about 46 costae. In the Big Hatchet Mountains, where the Paradise formation is some 220 feet thick, the highest zones contain a fauna of Eumetria dominated by E. costata with lesser amounts of E. vera.

Almost all horizons of the Paradise formation will yield a population of Eumetria made up of two or three "species" which grade imperceptably into each other. It would seem that Hall's species of Eumetria are in reality not true biospecies. This condition was recognized by Girty (1903, 1904, 1915) and was his justification for

putting E. vernuiliana, E. vera, E. costata into synonymy with E. mercyi Swallow. The latter species he thought was valid and had priority over E. verneuiliana. Hall's "species" have repeatedly proved to be very useful in the stratigraphic study of the Paradise formation and elsewhere (Weller, 1914, p. 442-446; Elias 1957, p. 522-527.).

Eumetria verneuiliana (Hall)

Pl. 15, figs. 28-30.

Retzia verneuiliana Hall, J., 1856, Albany Inst., Trans., v. 4, p. 9.

Retzia verneuiliana, Hall, J. and Whitney, R. P., Iowa Geol. Survey, v. 1, pt. 2, p. 657; pl. 23, figs. 1a-1d.

Eumetria verneuiliana, Whitfield, R. P., 1882, American Mus at. History, Bull., v. 1, p. 50; pl. 6, figs 28-30.

Eumetria verneuiliana, Hall, J., 1883, Indiana Geol. Survey, 12th Rept., p. 335; pl. 29, figs. 28-30.

Retzia verneuiliana, Walcott, C. D., 1884, United States Geol. Survey, Mon. 8, pl. 7, figs. 5-5a.

Eumetria verneuiliana, Hall, J. and Clarke, J. M., 1894, Introduction to the Study of Brachiopods, pt. 2, pl. 37, figs. 1-4, 6, 10.

Eumetria verneuiliana Hall, J. and Clarke, J. M., 1895, Nat. Hist. New York, Paleont., v. 8, pt. 2, pl. 51, figs. 13-26, 34, 35; pl. 83, figs. 26-27.

Eumetria verneuiliana, Girty, G. H., 1899, United States Geol. Survey, Mon. 32, p. 560; pl. 68, figs. 12a-12b.

Eumetria marcyi? Schumard, Girty, G. H., 1904, (pars) United States Geol. Survey, Prof. Paper, 21, p. 49; pl. 10, fig. 15, (Non. figs. 16, 17).

Eumetria marcyi Schumard, Beede, J. W., 1906, Indiana Geol. Survey, 30th Ann. Rept., p. 1319; pl. 22, figs. 28-30.

Eumetria verneuiliana, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 442-444; pl. 86, figs. 18-24.

Eumetria marcyi Schumard, Girty, G. H., 1915 (pars) United States Geol. Survey, Bull. 593, p. 75-77; pl. 4, fig. 18, (non figs. 19a, 19b).

Eumetria verneuiliana, Snider, L. C., 1915, Oklahoma Geol. Survey, Bull. 24, p. 94.

Eumetria verneuiliana, Weller, J. M., 1931, Kentucky Geol. Survey, Symposium, pl. 38, figs. 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, figs. 1-2.

Diagnosis. - Eumetria with 48 to 55 costae, small to medium-size ovate shell.

Description. - Three specimens, two of which are crushed and exfoliated, and one complete ephebic individual were

available for study. Their dimensions are in mm:

Length	Width
19	16
18.5	16

Shell outline is ovate, with the anterolateral margins forming a semi-circle 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 perceptable 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 projects 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 broke off or were badly crushed. In most specimens the crushing was restricted primarily to the pedicle valve. Grinding of selected specimens resulted in

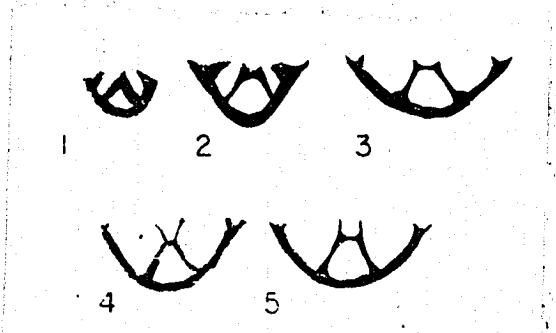

Figure. 28 Diagrammatic serial sections through the brachial valve of Eumetria verneuiliana (Hall) from the Paradise formation, Big Hatchet Mountains, New Mexico.

finding intact the interior structures of the brachial valve. These had the characteristic convergent plates in the beak. These plates anteriorly became discrete but are joined by a concave transverse spondyloid platform. These vertical plates are present one-third of the distance to the anterior margin.

Horizon. - The Meramec part of the Hachita formation in the Big Hatchet and Animas Mountains of New Mexico and Blue Mountain, Arizona. 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 and Whitney)

Pl. 15, figs. 24-27.

Retzia vera Hall, J., and Whitney, R. P., 1859, Iowa Geol. Survey, v. 1, pt. 2, p. 704, p. 27, fig. 3a.

Eumetria vera, Hall, J. and Clarke, J. M., 1894, Introduction to the Study of Brachiopods, pt. 2, pl. 37, figs. 8, 12.

Eumetria vera, Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleont., v. 8, pl. 51, figs. 36, 37.

Eumetria vera, Bassler, R. S., 1909, Virginia Geol. Surv., Bull. 2A, pl. 29, figs. 4, 5.

Eumetria vera, Snider, L. C., 1915, Oklahoma Geol. Survey, Bull. 24, p. 94.

Eumetria marcyi, Girty, G. H., 1915, (pars), United States Geol. Survey, Bull. 593, p. 75-77; pl. 4, figs. 19-19b. (non fig. 18).

Eumetria vera, Weller, J. M., 1931, Kentucky Geol. Survey Symposium, p. 265, pl. 38, figs. 7a-7b.

Eumetria vera, Hernon, R. M., 1935, Jour. of 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, figs. 38-41.

Eumetria vera, Elias, M. K., 1957, Jour. of Paleont., v. 31, p. 523-524; pl. 58, figs. 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,

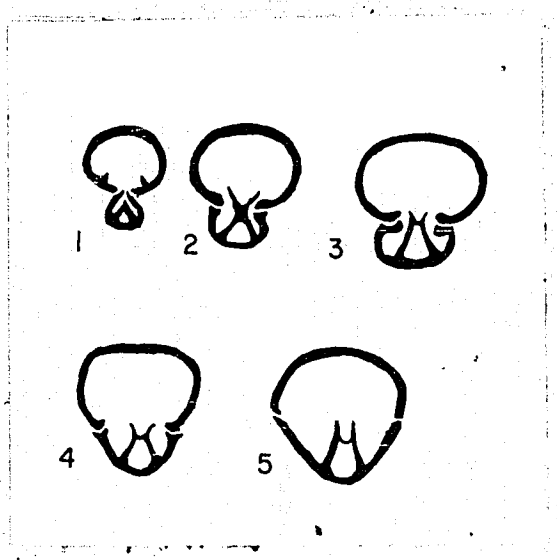

Figure 29 Diagrammatic sections through the umbo of Eumetria vera Hall from the Paradise formation, Blue Mountain, Arizona. The sections have been cut at intervals of 0.3 to 0.4 mm.

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 flattening, which 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. In the beak these plates converge, 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.

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 and Whitney)

Pl. 15, figs. 21-23.

Retzia vera var. costata Hall, J. and Whitney, R. P., 1858, Iowa Geol. Survey Rept., v. 1, pt. 2, Paleont., p. 704, pl. 27, figs. 3a-3b.

Retzia vera var. costata, Hall, J. and Clarke, J. M., 1894, Introduction to the study of Brachiopods, pt. 2, pl. 37, figs. 5-11.

Eumetria vera var. costata, Hall, J. and Clarke, J. M., 1894, Nat. Hist. New York, Paleontology, v. 8, pt. 2, pl. 51, figs. 27-33.

Eumetria costata, Weller, S., 1914, Illinois Geol. Survey, Mon. 1, p. 444-445; pl. 76, figs. 25-29.

Eumetria costata, Snider, L. C., 1915, Oklahoma Geol. Survey, 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. - The dimensions of one pedicle valve is 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 only complete pedicle valves have been found, their contour and number of plications leave little doubt as to their generic and specific identification.

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, Catalogue of the Blastoidea in the Geological Dept. of the British Museum, p. 229-232.

Cryptoblastus, Cline, L. M., 1937, Jour. of 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, Acad. Nat. Sci. Philadelphia, Jour., v. 2, pt. 1, p. 65; pl. 7, figs. 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 subglobos 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, two 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. 12, figs. 1-10.

Pentremites melo Owen, D. D. and Shumard, B. F., 1850, Acad. Nat. Sci. Philadelphia, Jour., v. 2, pt. 1, p. 65; pl. 7, figs. 14a-14c.

Cryptoblastus melo, Hambach, G., 1903, Acad. Sci. St. Louis, Trans., v. 13, p. 40.

Cryptoblastus melo, Etheridge, R. and Carpenter, P. H., 1886, Cat. Blastoidea in the British Museum, p. 232-234; pl. 7, figs. 14-15.

Cryptoblastus melo, Keyes, R. R., 1894, Missouri Geol. Survey, p. 139; pl. 18, figs. 7a-7b.

Cryptoblastus melo, Cline, L. M., 1937, Jour. of Paleont., v. 11, n. 8, p. 636-637.

Cryptoblastus melo, Cline, L. M., 1943, in Shimer, H. W. Shrock, R. R., Index Fossils of North America, p. 137; pl. 51, figs. 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, a large

oval anal opening with a star-shaped mouth. Four hydrospire folds are under each ambulacra.

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. It is infrequently encountered again in the massive encrinites in the lower half of the Hachita formation (Middle Osage) at Blue Mountain, Chiricahua Mountains, Arizona.

Description. - The calyx is 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 2.0-2.5 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 deltoid suture then contract gently aborally. Ambulacra reach almost the full length of the calyx. Average specimen has ambulacrum which are 8.5 mm long and near the mouth are 1.6 mm wide. Silicification had destroyed the finer details of the ambulacra and surface ornamentation on the specimens studied. Eight spiracles are present which pierce deltoids near their apex. The mouth is lzrge 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. Hydrospire folds are stalked and are sac-like in section; four are present in each ambulacra.

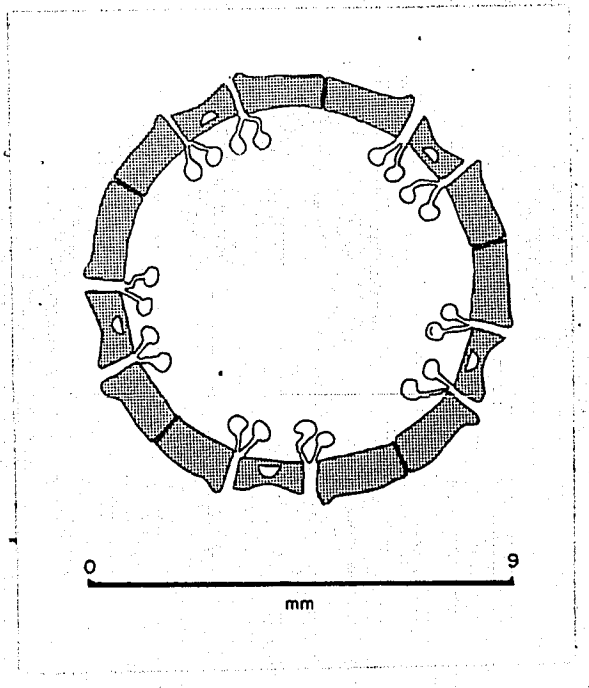

Figure 30 Transverse section of Cryptoblastus melo from the lower part of member A, Keating formation. A section from a C. melo from the stratigraphically higher Hachita formation was similar.

APPENDIX

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 our geologic jargon to both professional geologists and laymen.

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

Argillaceous. - Rock contains appreciable (but less than 50 per cent) clay.

Arkosic. - Rock contains 10-25 per cent clastic feldspar grains.

Bands. - (banded) 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 1/16 inch
platy - 1/16 to 1/2 inch
very thin-bedded - 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 build mainly by sedentary organisms and enclosed in normal rock of different lithologic character.

Biostrome. - Laterally extensive-bedded structures consisting of, and mainly built by, sedentary organisms.

Calcarenite. - Limestones made up of clastic 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.

Calcilutite. - Even-laminated to cross-laminated 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, stringer, 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.

Cross-bedded. - Beds characterized by included minor beds that are oblique and inclined to the main stratification.

Dense. - Tightly cemented clastic 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 per cent) 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 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-forming 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 considered to be probably invertebrate fecal pellets.

Sandy. - Rock contains appreciable (but less than 50 per cent) sand-sized grains of minerals, usually a mixture of quartz, calcite and others; contrasted with arenaceous, which is applied when clastic fragments are chiefly quartz.

Shaly. - Rock contains appreciable (but less than 50 per cent) clay and very fine silt, with fissile bedding.

Siliceous. - Rock with cement of, or intimate replacement by, silica.

Sparry calcite. - Usually as simple pore-filling cement, precipitated in place within the sediments. It usually forms grains or crystals 10 microns or more in diameter and is distinguished from microcrystalline calcite by its clarity and coarser crystal size.

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PLATE 1

All photomicrographs are X 40

1. Encrinite, abraded and broken crinoid plates in a in a sparry calcite cement. Believed to be deposited in a high-energy environment. The calcite muds are believed to have been winnowed out by the strong currents. Basal limestone, of member A, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.

2. Calcilutite, originally calcite mud and ooze, formed in a low energy environment, of weak currents. 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, calcite ooze cement also indicates poor sorting and a relatively low energy environment. Top of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico.

4. Oolitic limestone; oolites with a sparry calcite cement. Undoubtedly the oolites developed and were deposited in a high energy environment. 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. Believed to have been deposited in an environment of gentle currents. 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. Environment of deposition was believed to have been rather quiet water. Upper part of member B, Keating formation, Escabrosa group, Klondike Hills, New Mexico.

PL 1


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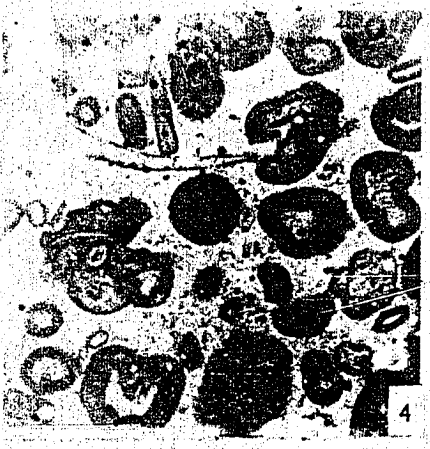
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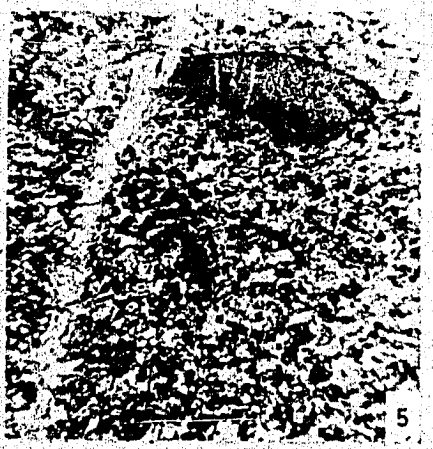
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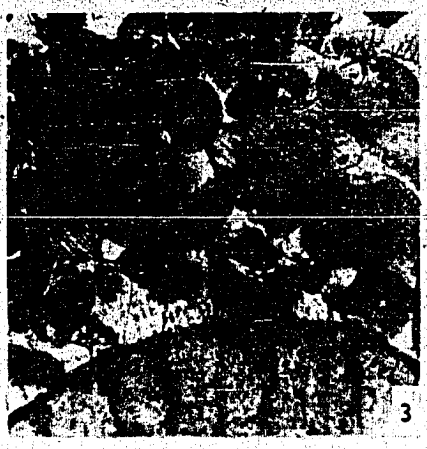
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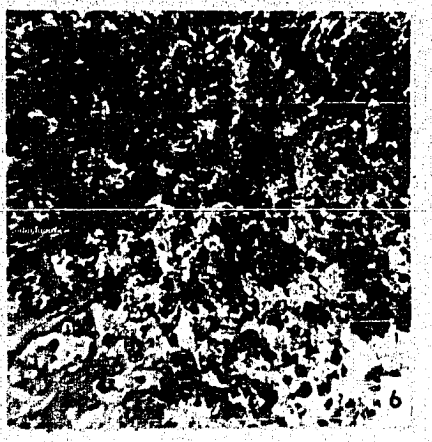
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PLATE 2

All photomicrographs are X 40

1. Encrinite, composed of broken and abraded crinoid remains with lesser amounts of bryozoan fragments, cemented by sparry calcite. Deposition believed to have occurred in a high energy zone. Transition beds between Keating and Hachita formations, Big Hatchet Mountains, New Mexico.

2. Coquina, composed of oolites which have as their nuclei endothyra, fossil fragments, fecal pellets, cemented by sparry calcite and microcrystalline calcite. The environments had strong currents which swept the larger particles into a zone of quieter water where deposition occurred. Meramec part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.

3. Encrinite (calcarenite to calcirudite), large, broken and abraded crinoid fragments, cemented by microcrystalline calcite and lesser amounts of sparry calcite. Sorting, as shown by size, range and calcite mud, was poor; waters were probably quiet with weak currents. Osage part of Hachita formation, Escabrosa group, Big Hatchet Mountains, New Mexico.

4. Coquina, broken and abraded fragments of crinoids, bryozoans and brachiopods. Sorting and sparry calcite indicate a high energy environment of deposition. Meramec part of Hachita formation, Escabrosa group, Blue Mountains, Chiricahua Mountains, Arizona.

5. Limestone, majority of rock is microcrystalline calcite containing abundant fine abraded particles and occasional large pieces of crinoids. This rock type collected in protected quiet waters adjacent to meadows of growing crinoids. Osage part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.

6. Bryozoan coquina, rock is composed of tightly packed fragments of bryozoan zoarium, sparry calcite cement. Bryozoans probably lived and died and were deposited in an environment of strong currents. Meramec part of Hachita formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona.

PL 2


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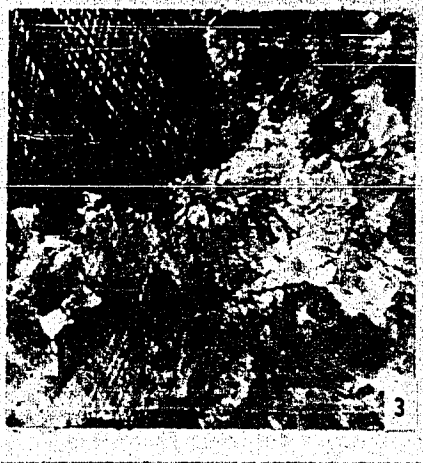
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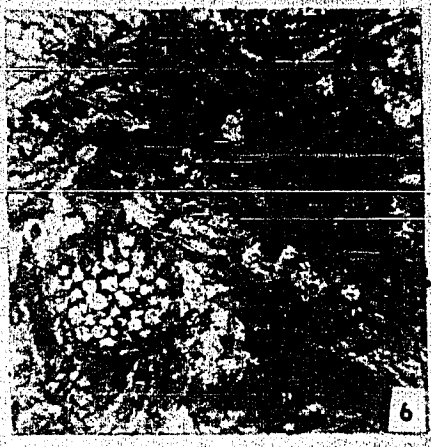
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PLATE 3

All photomicrographs are X 40

1. Bryozoan coquinite from same horizon as fig. 6, pl. 2 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. Deposited in a quiet water environment. Highest horizons of Hachita formation (Meramec), Blue Mountain, Chiricahua Mountains, Arizona.

3. Limestone, a bioclastic limestone which was originally fossil fragments and microcrystalline calcite and has undergone partial recrystallization to a sparry calcite. Primarily the large fossil fragments are being 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 bryozoan brachiopods and mollusca fragments. Cement is microcrystalline calcite and sparry calcite. Believed to have been deposited in quiet waters. Lower part of Paradise formation (Chester), Big Hatchet Mountains, New Mexico.

5. Limestone, composed of fecal pellets, bryozoan, brachiopod 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. Believed to have been deposited in quiet water. Basal limestone of Paradise formation, Blue Mountain, Chiricahua Mountains, Arizona.

PL 3


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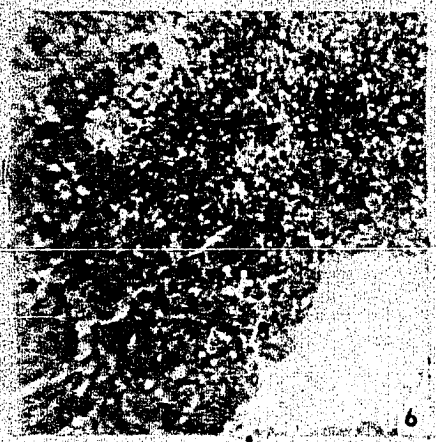
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PLATE 4

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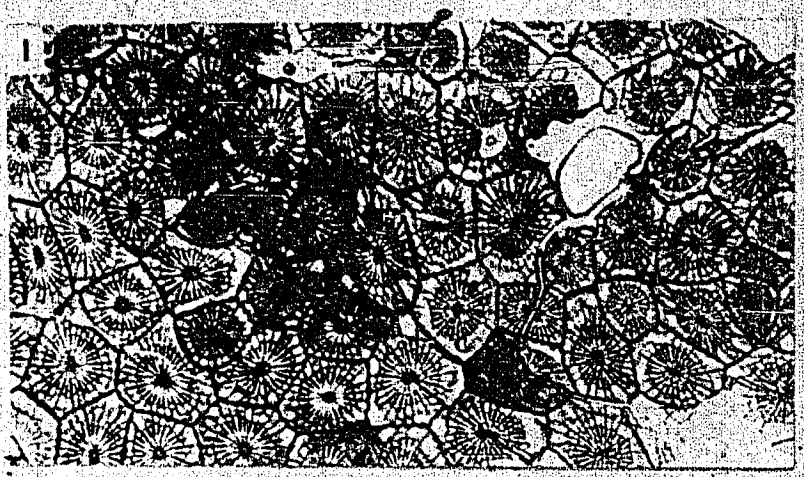
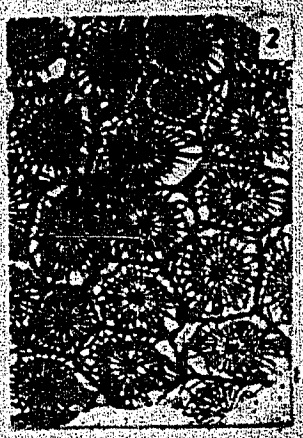
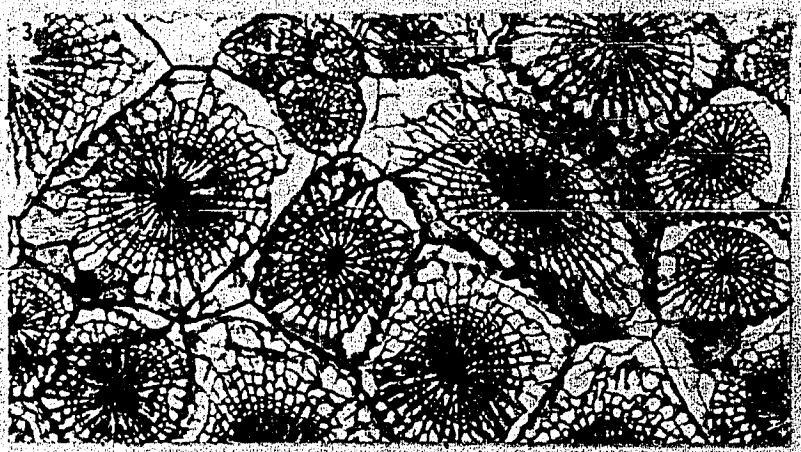
1-5. Lithostrotion lochmani n. sp.; one colony, 1,2, section of corallum illustrating the nature of the major and minor septa. 3. section at X 5, an incomplete peripheral zone of dissepiments and major septa which do not join the epitheca; this trait is characteristic of the genus, Lithostrotionella; 4. corallite X 5 which has all of its major septa fused to the epitheca. 5. longitudinal section X 3 showing the central axis, up-arched tabulae and the dissepiments 159

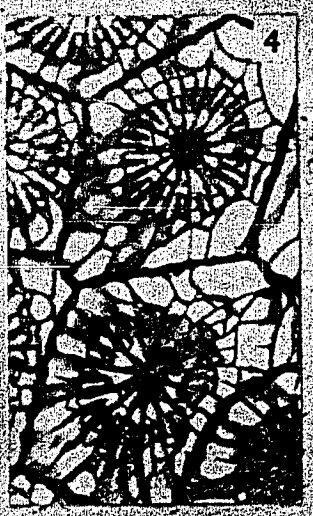
6-8. Lithostrotionella confluens Easton; all X 3. 6, 7. cross-section of corallum. 8, longitudinal section illustrating the central axis, strongly up-arched tabulae and the well-developed dissepimentarium 167

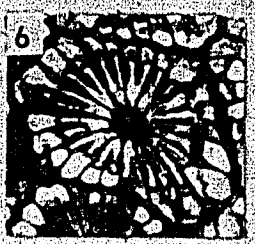
PL 4

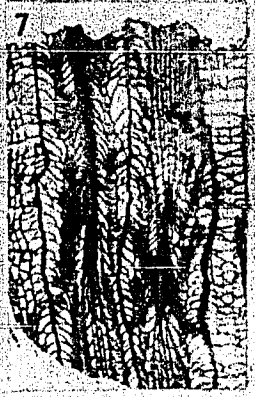












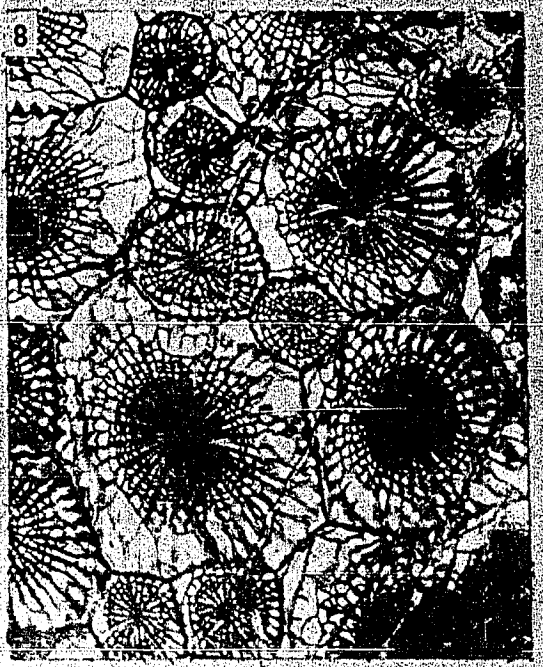


PLATE 5

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1-3. *Lithostrotionella shimeri* (Crickmay); X 2.5, 1, longitudinal section of a corallite, illustrating the weakly-developed columella and the dissepimentarium; 2, transverse section of the corallum, specimen has been fractured; 3, transverse section of ephebic corallites. Black Prince limestone, Gunnison Hills, Arizona. United States Geological Survey Collection No. 13844 . . . 170

4-6. *Lithostrotion microstylum* White; X3, 4. transverse section of corallum, illustrating the relationship between corallites. X5, 5. transverse section of a corallite showing the thick central columella, minor and major septa. X3, 6. longitudinal section of corallum. University of Missouri, Geology Collection No. 1357 163

PL 5

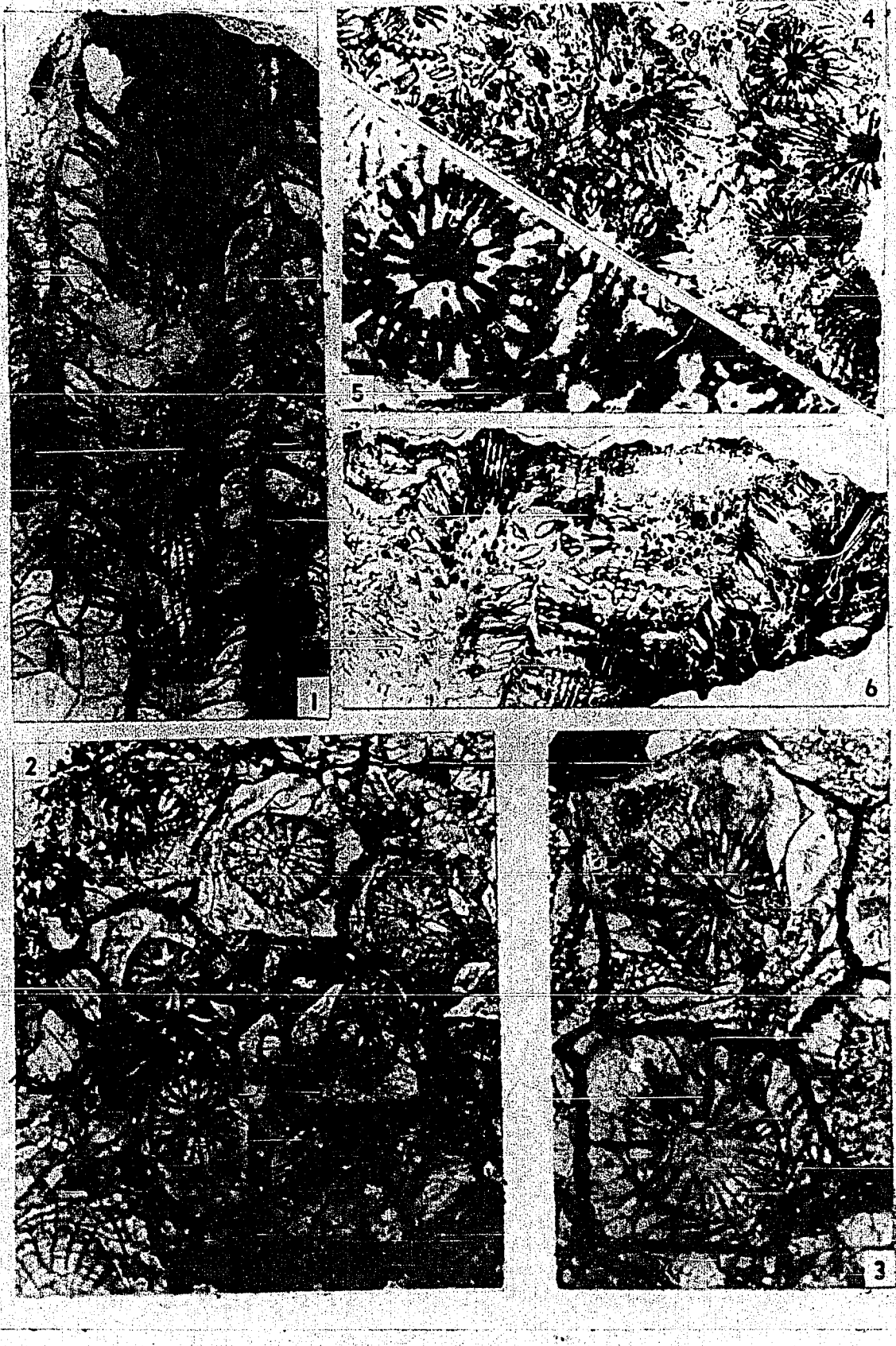

PLATE 6

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1-8. Ekvasophyllum primum, n. sp. X 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 corallite; 5. transverse section at the ephebic stage with thickened septa in the dissepimentarium; 6. transverse section at the early ephebic stage; 7, 8. transverse sections at the late ephebic stage, note thickening of septa and fusing of minor septa to major 150

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PL 6

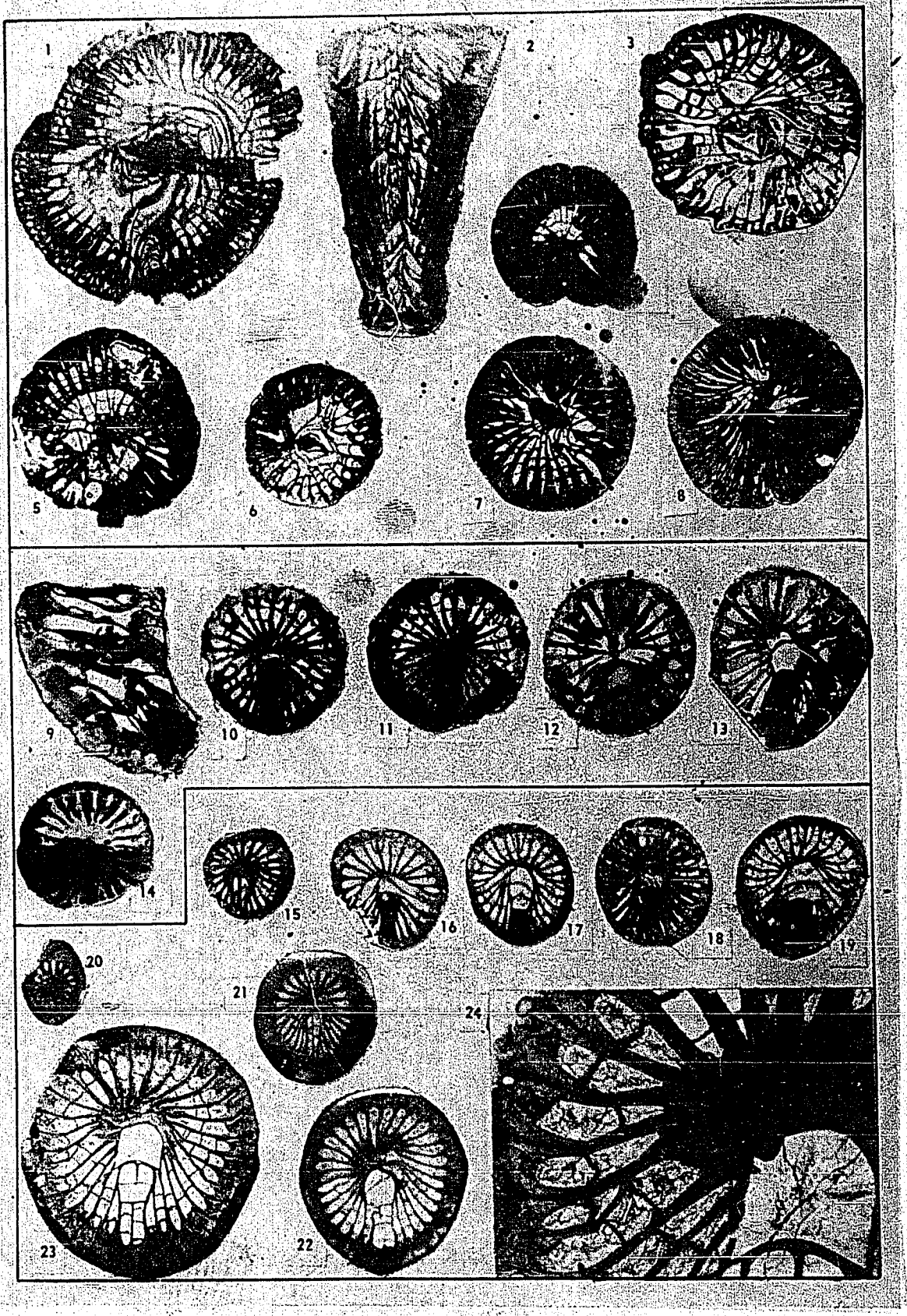

PLATE 7

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1-4. Ekvasophyllum primum, n. sp. X 2, 1, 2. view of calyx of two mature etched specimens; X 1, 3, 4. side view of corallites. Member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico 150

5-6. Amygdalophyllum sp. X 1, view of calyx; X 1.5, view of calyx, showing columella and absence of cardinal fossula.

8-10. Homalophyllites circularis Easton. X 1, 8, 9. side views of corallite; X 2, 10. view of calyx. Member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona 111

11-13. Amplexizaphrentis clinatus (Greene). X 1, 11. counter cardinal side view; 13. side view of corallite; X 2, 12. view of calyx. Lower part of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico . . . 107

7, 14-17. Amplexizaphrentis northropi, n. sp. X 2, transverse section at early ephebic state; 14. longitudinal section; 15-17. series of transverse sections from very early to late ephebic stage. Top of member B, Keating formation, Escabrosa group, Big Hatchet Mountains, New Mexico 103

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PL 7

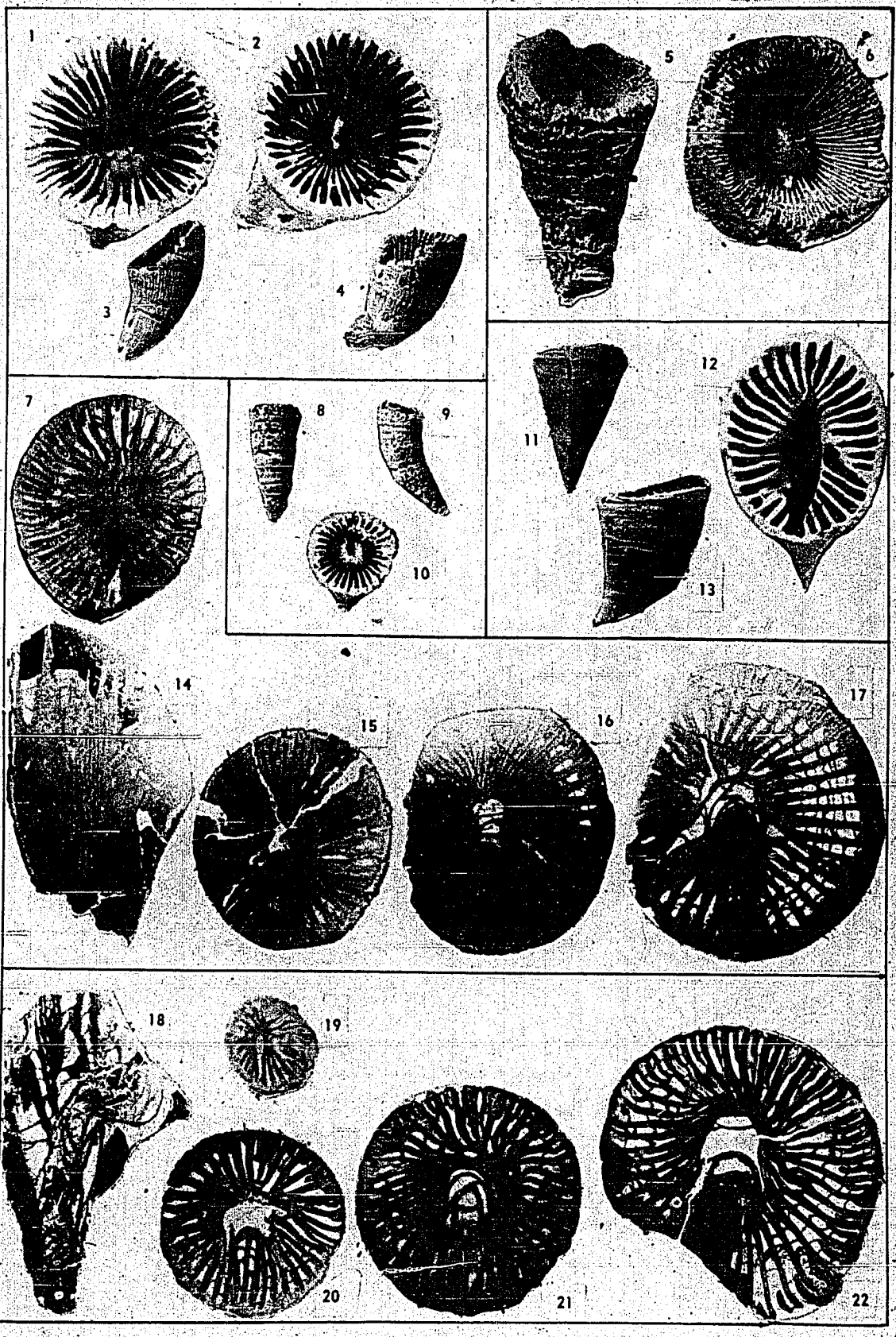

PLATE 8

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1-4. Kakwapiphyllum sutherlandi, n. sp. X 2, 1. section in the calyx illustrating the nature of the dissepimentarium; 2. section at base of calyx; 3,4. sections in the late ephebic stage; 5-9. sections of an inmature individual illustrating the nature of the septa and the gradual disappearance of the dissepimentarium in earlier growth stages; 10. longitudinal section of the calyx in the late ephebic stage; 11. longitudinal section in the early ephebic stage. From member A of the Keating formation, Blue Mountain, Chiricahua Mountains, Arizona 128

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17. Caninophyllum sp. X 2, transverse section; Hachita formation, Big Hatchet Mountains, New Mexico 133

PL 8

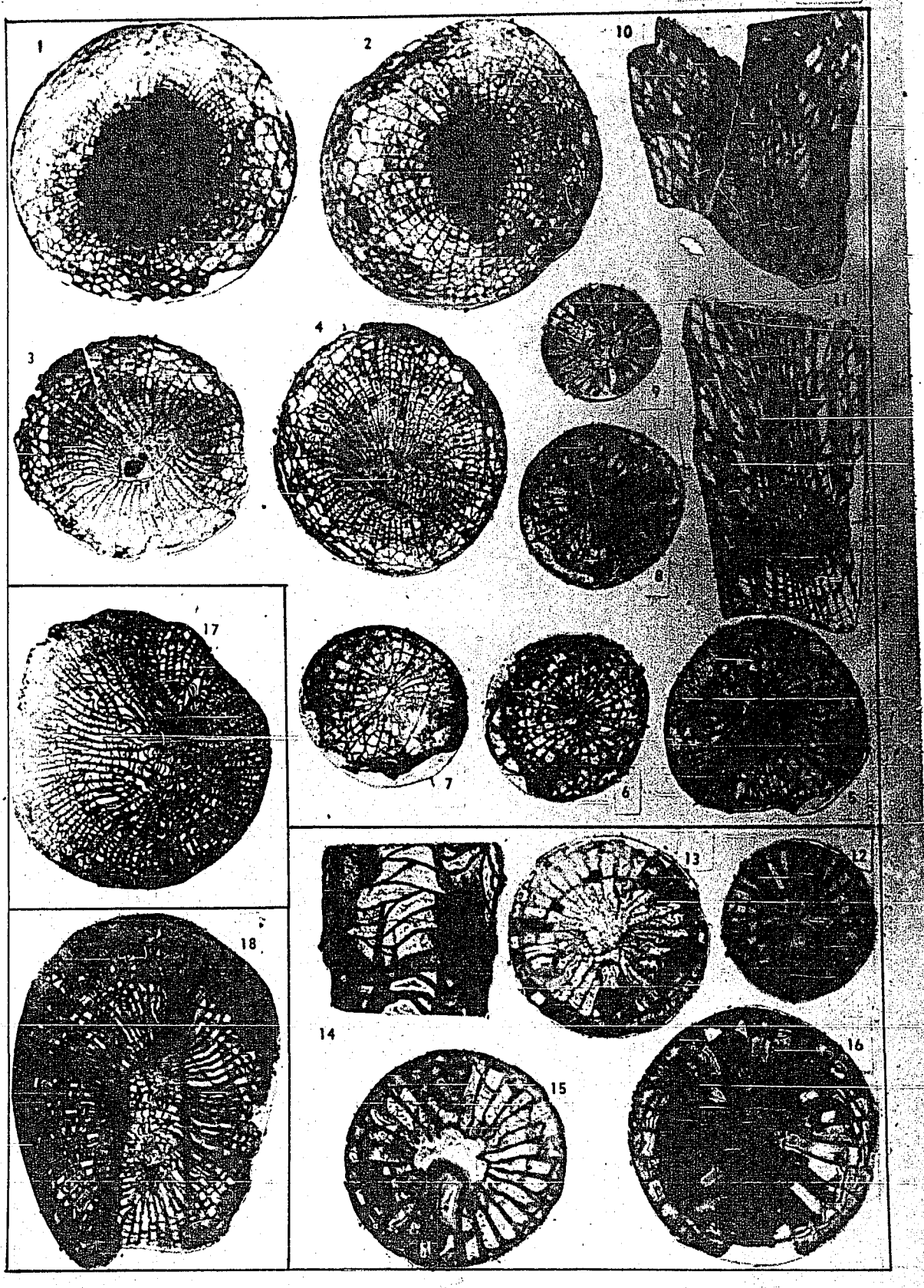

PLATE 9

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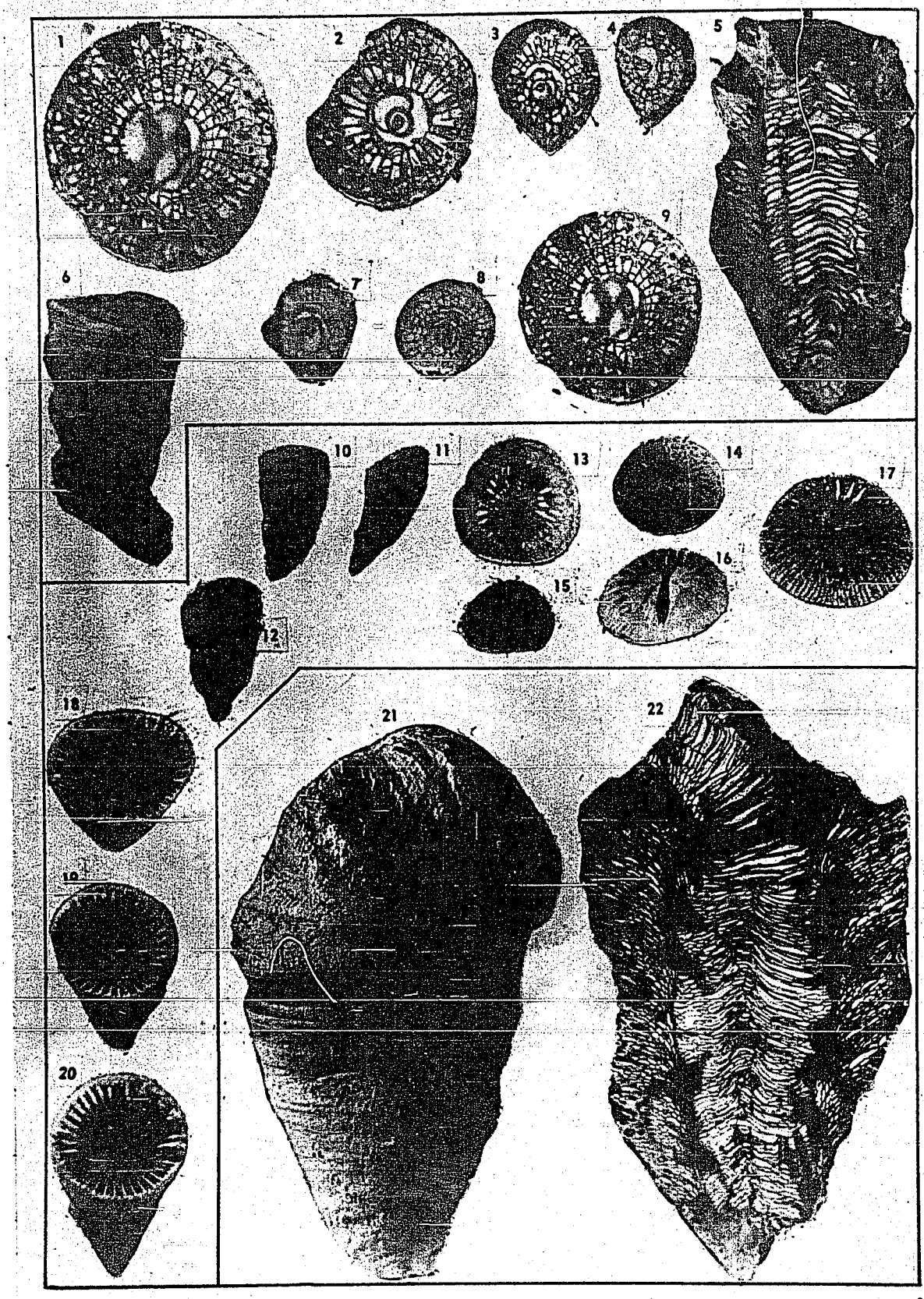
1-9. Koninckophyllum elpasoensis, n. sp. X 2, 1-4. series of transverse sections from late ephebic to the late neamic stage; 5. longitudinal section; X 1, side view of weathered corallite, X 2, 7. series of transverse sections from late neamic to late ephebic stage. Helms formation (Chester age), Franklin Mountains, Texas . . 145

10-20. Homalophyllites calceolous (White). X 1.5, 10, 12. cardinal side of corallite, 11. side view of corallite; X 2, 13, 14. transverse sections of sphebic stage; 15, 16. transverse sections of early ephebic stage; 17. late ephebic stage; X 2, 18-20. views of calyx of three etched specimens. All from member A, Keating formation, Escabrosa group. 13-17. Blue Mountaain, Chiricahua Mountains, Arizona; 10-12, 18-20, Klondike Hills, New Mexico . . . 113

21-22. Dibunophyllum bipartitum konincki (Edward and Haime) X 1, 21. view of weathered corallites; 22. longitudinal section of a mature specimen, note rejuvenescence. Helms formation (Chester age), Franklin Mountains, Texas 140

PL 9



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1-7. Dibunophyllum bipartitum konincki (Edward and Haime) · X 1.5, 1-6. serial longitudinal sections of holotype from late ephebic to neamic stage, figure 6 is X 2; 7 X 1.5, longitudinal section of another individual at the ephebic stage of growth; Helma formation (Chester age), Franklin Mountains, Texas 140

PL 10

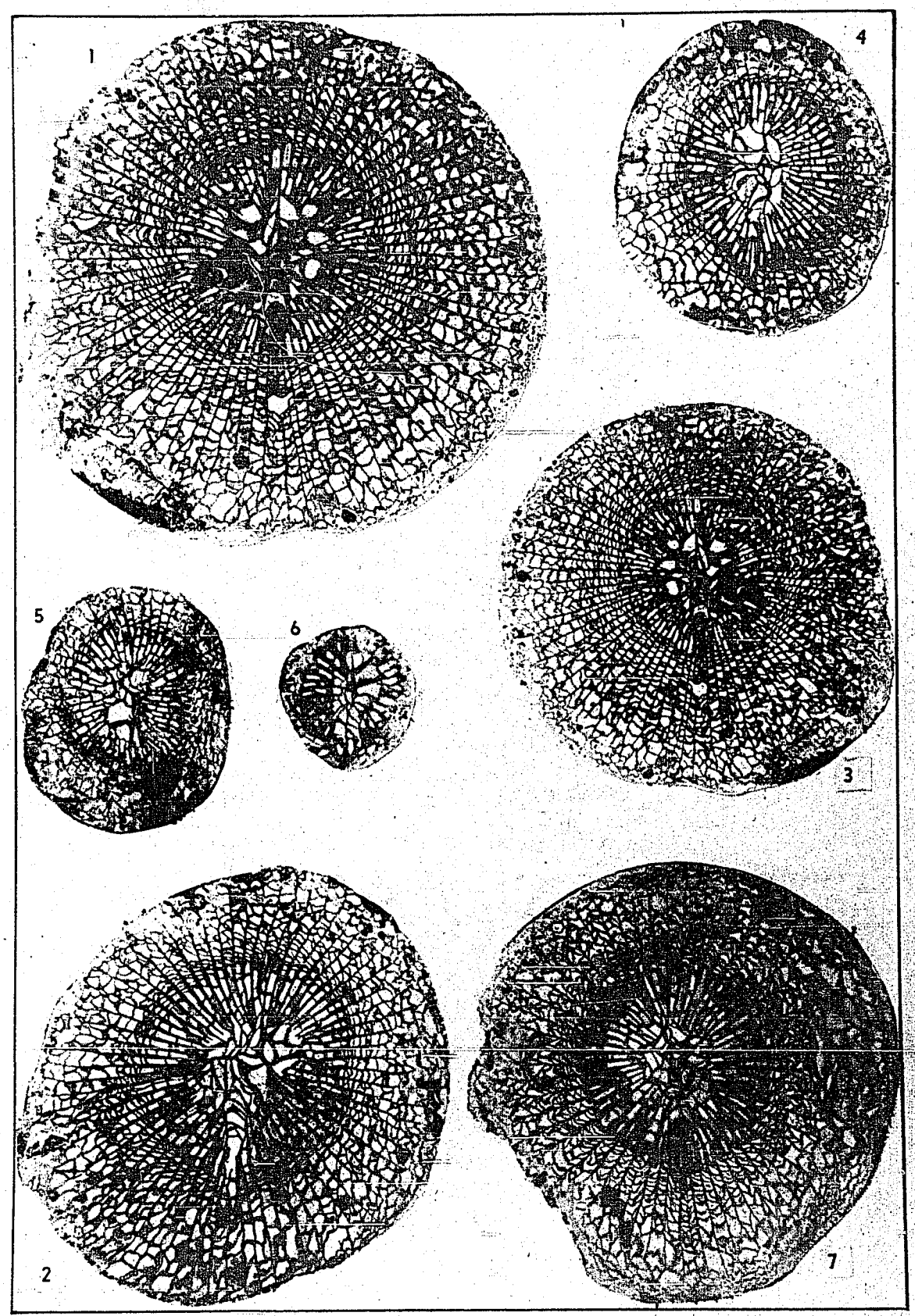
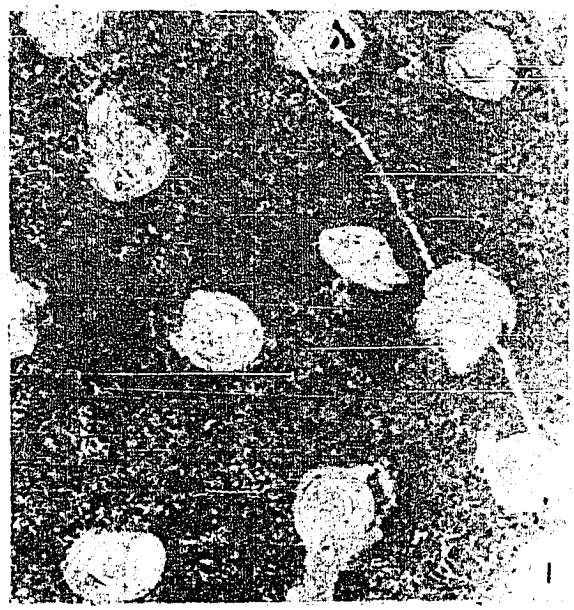


PLATE 11

PL 11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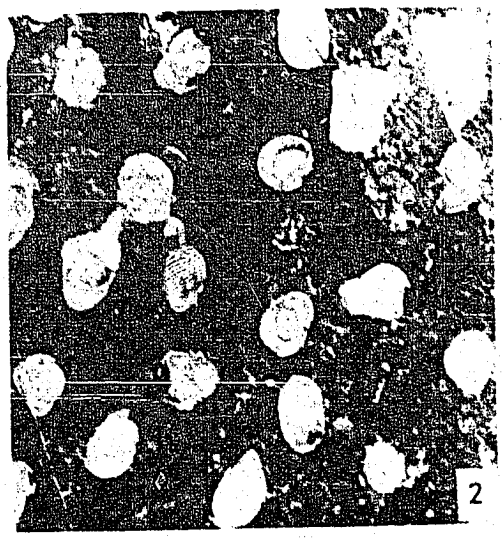
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PLATE 12

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1-8. Cryptoblastus melo (Owen and Shumard), X 4, 1-3, ventral, interray and ambularcral view of one specimen; 4-6. dorsal, ambularcral and interray view of one specimen; 7-8. ambularcral and dorsal view of one specimen; member A, Keating formation, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona 286

9-10. Cryptoblastus melo (Owen and Shumard), X 3, ventral and ambulacral view of one specimen; Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona 286

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14. Endothyria symmetrica E. J. Zeller. X 50, vertical axial section; upper Hachita formation of Meramec age, Escabrosa group, Blue Mountain, Chiricahua Mountains, Arizona. . 84

15. Paraendothyra sp. X 50, oblique section, member A, Keating formation, Escabrosa group, Klondike Hills, New Mexico 92

16-17. Endothyra sp. X 50, vertical axial section, 16. inked drawing made from observations through the microscope; 17. a photomicrograph of the same individual; member A, Keating formation (Fern Glen age), Escabrosa group, Klondike Hills, New Mexico 86

PL 12

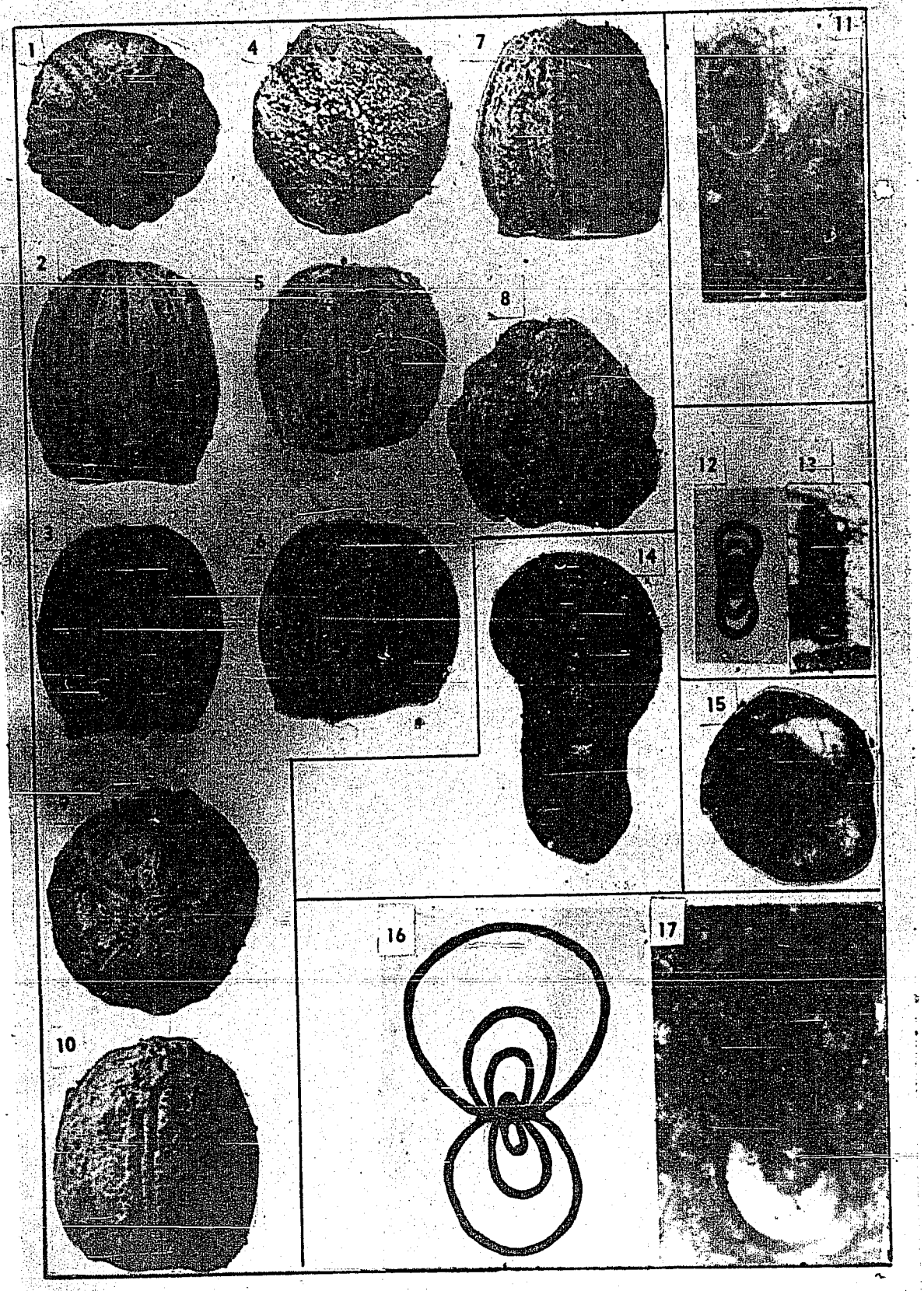

PLATE 13

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1-7. Werriea keokuk (Hall and Whitney) X 1. 1. exterior of pedicle valve; 2. poorly preserved interior of pedicle valve; 3. mold of the interior of a pedicle valve; 4. partly exfoliate pedicle valve; 5. exterior of an incomplete immature brachial valve; 6. mold of an incomplete pedicle valve showing the median septum and dental lamellae; 7. interior of a pedicle valve illustrating the median septum and the muscle scars. Syringothyris subcuspidatus zone, Hachita formation, Blue Mountain, Chiricahua Mountains, Arizona 187

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9. Brachythyris peculiaris (Schumard) X 1.5, incomplete pedicle valve, member A, Keating formation, Blue Mountain, Chiricahua Mountains, Arizona 227

PL 13

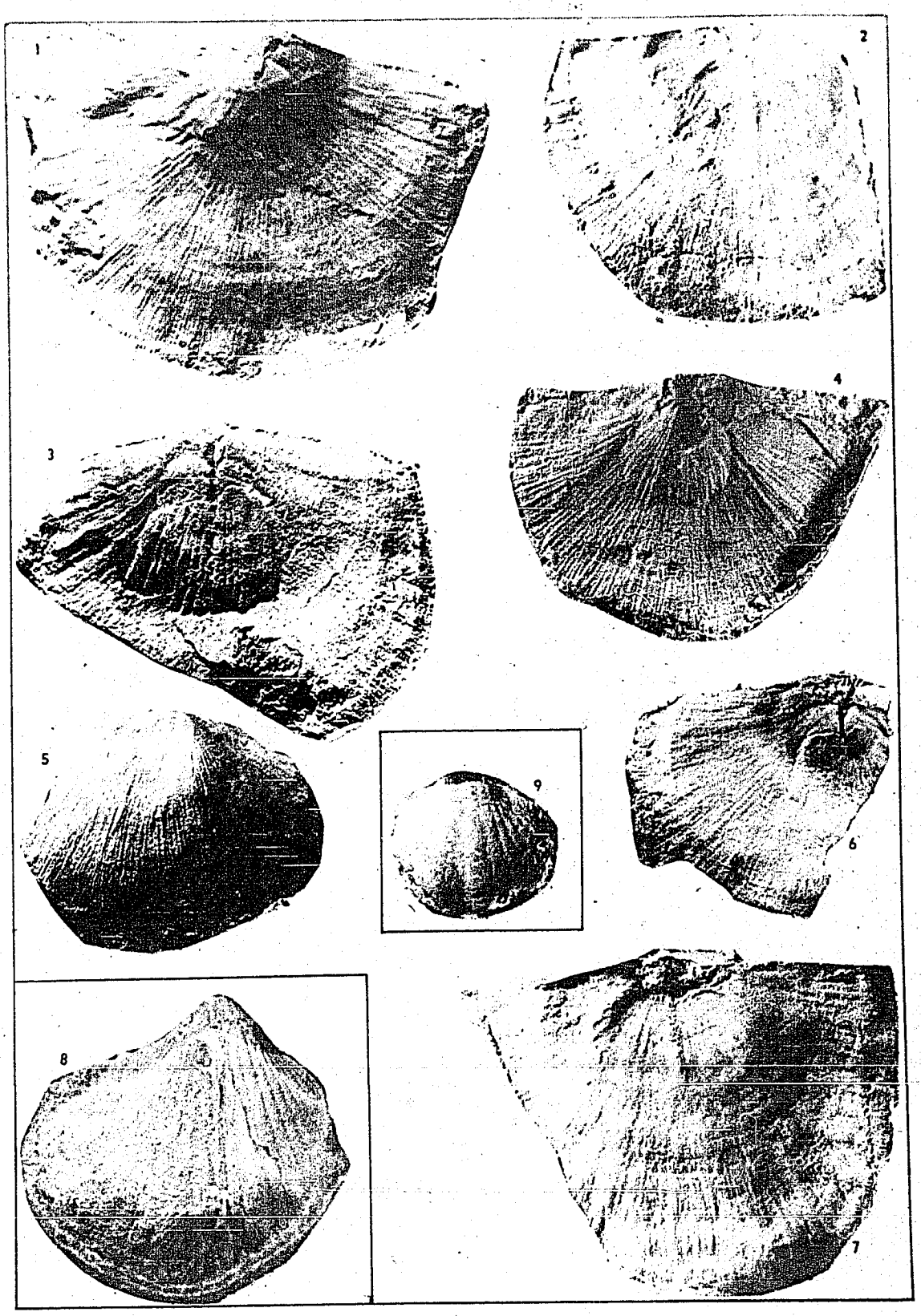

PLATE 14

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1-7. Chonetes klondika, n. sp. X 2, 1. pedicle valve exterior; 2, 3. exfoliated pedicle valve; 4. brachial valve exterior; 5. pedicle valve exterior; 6. brachial valve interior; 7. holotype pedicle valve; upper part of member A, Keating formation, Klondike Hills, New Mexico 192

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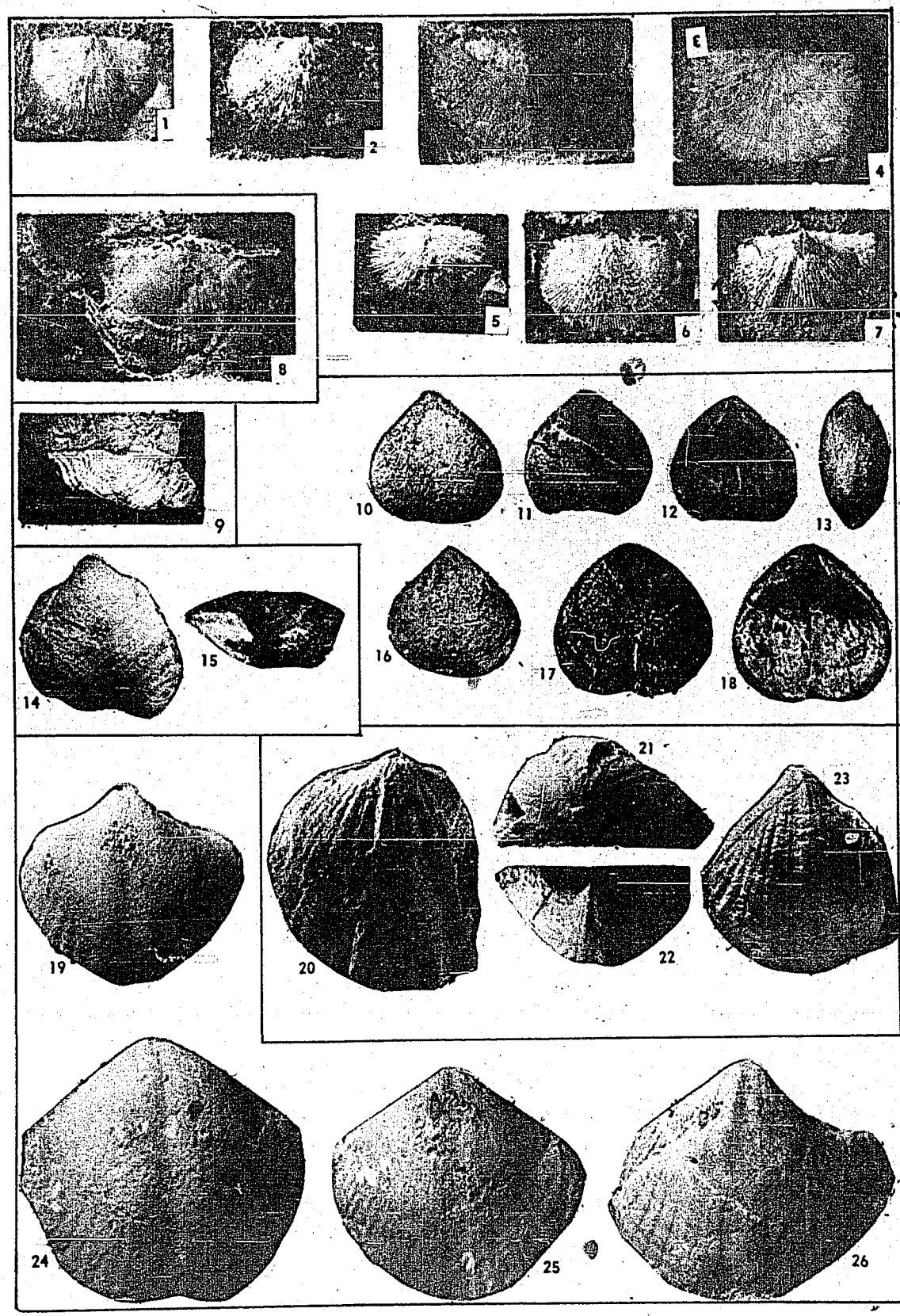

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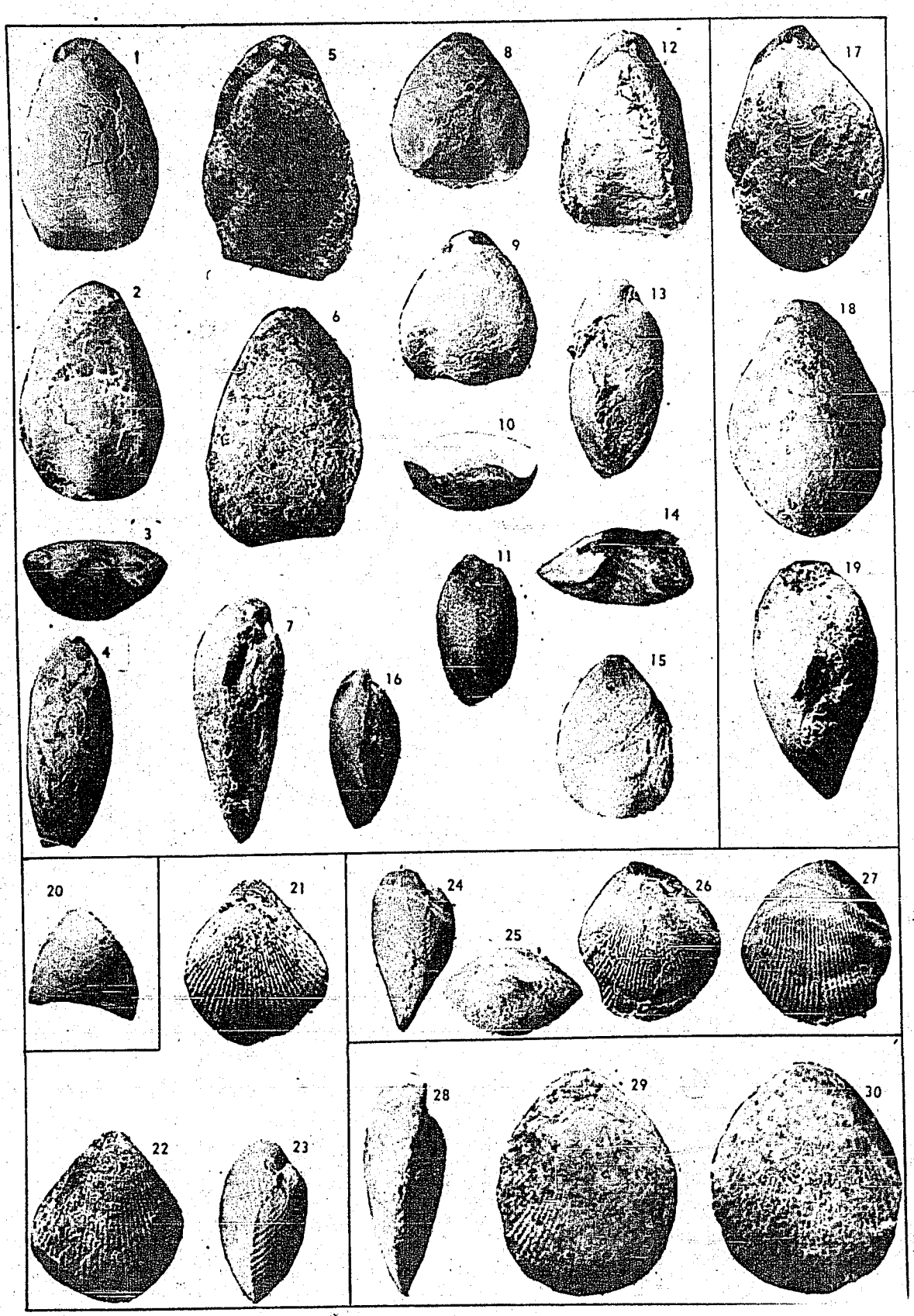

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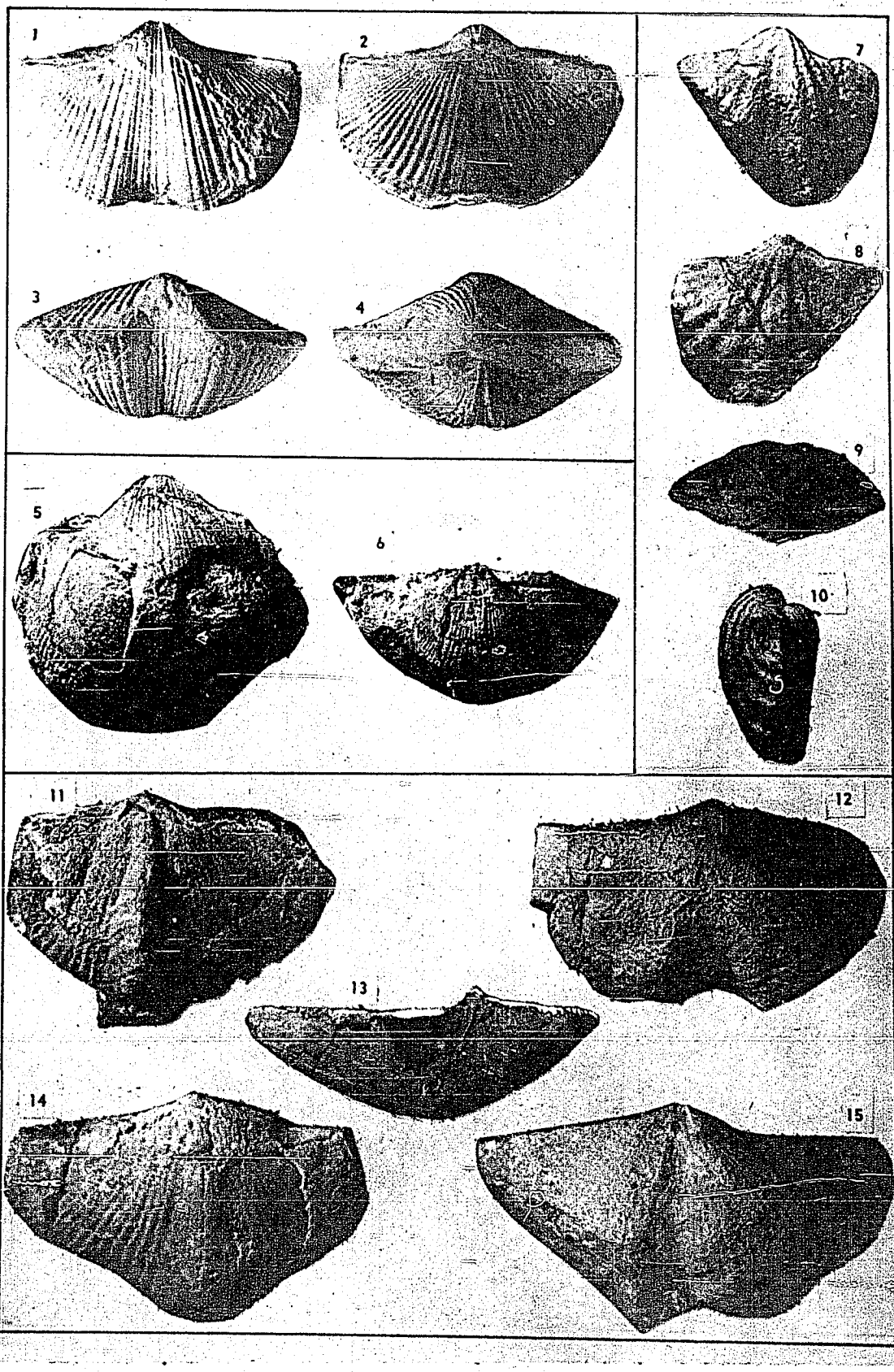

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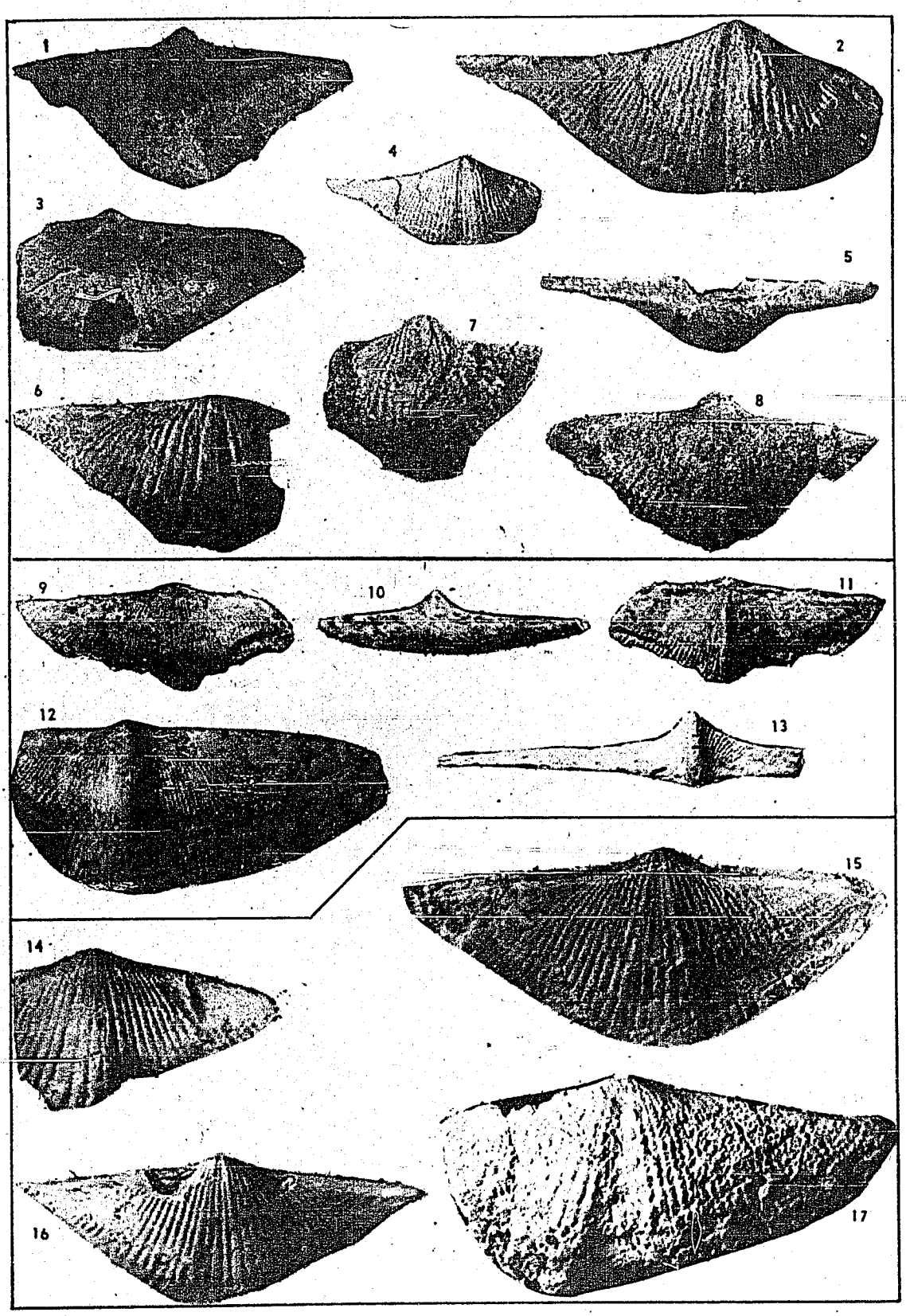
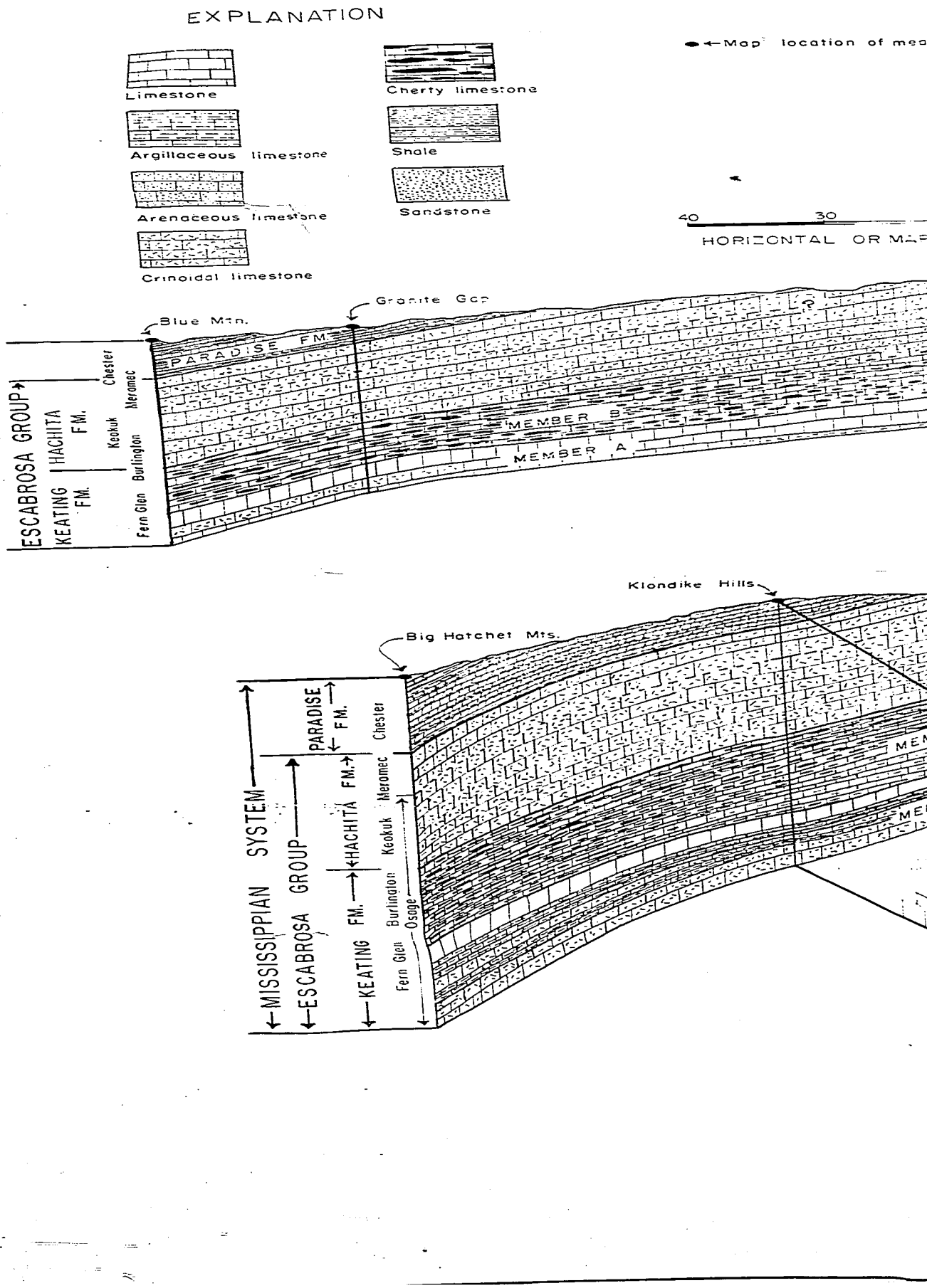
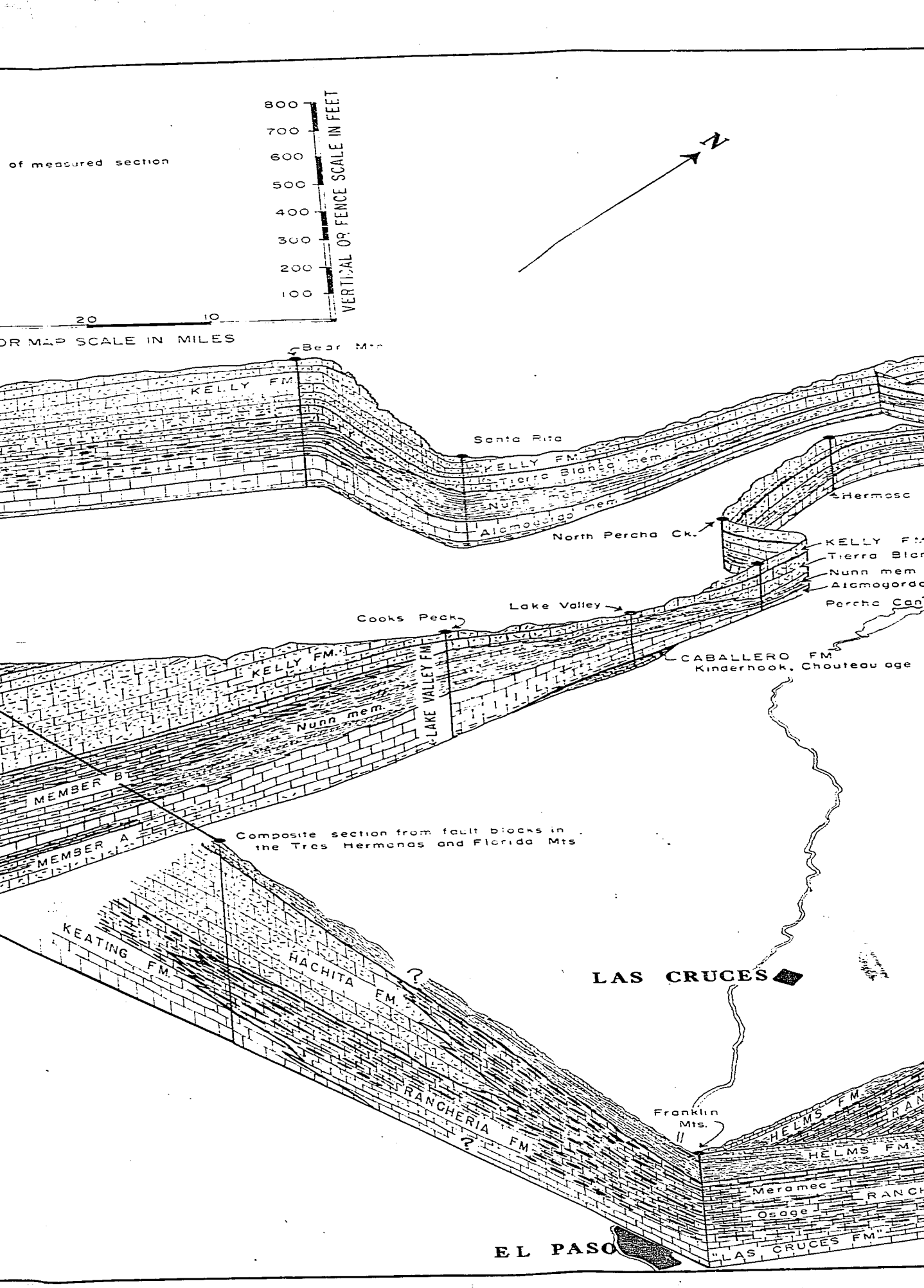
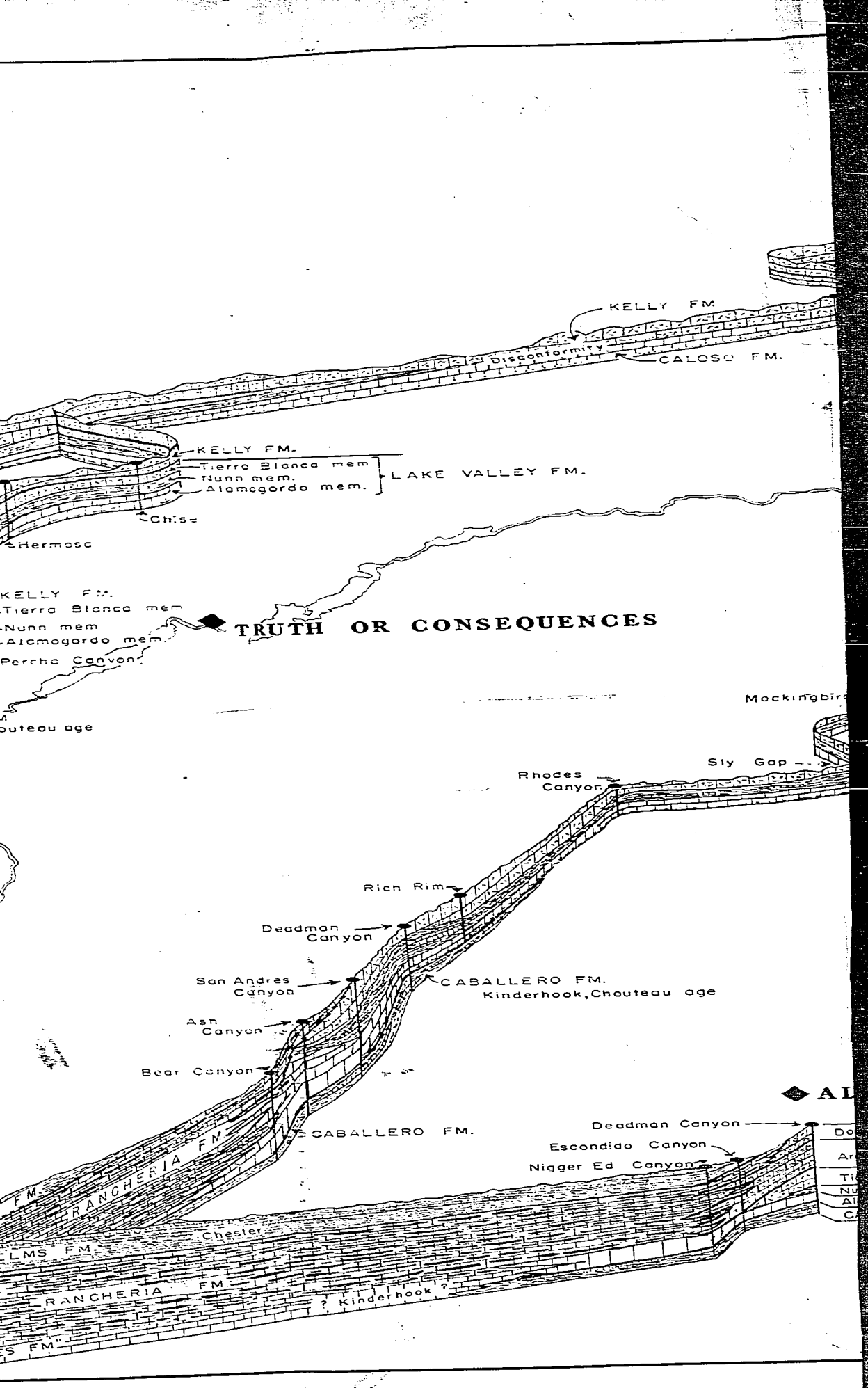
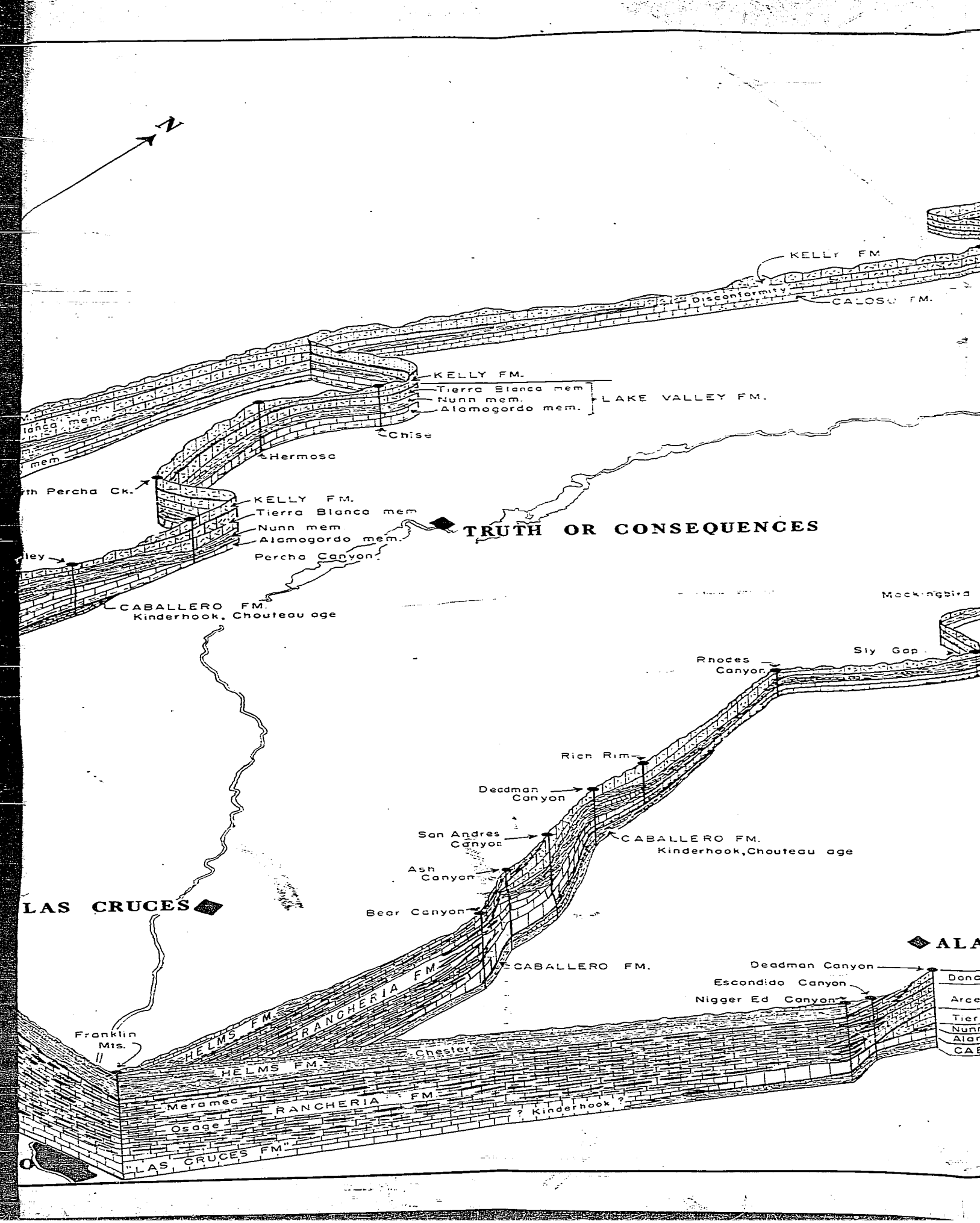




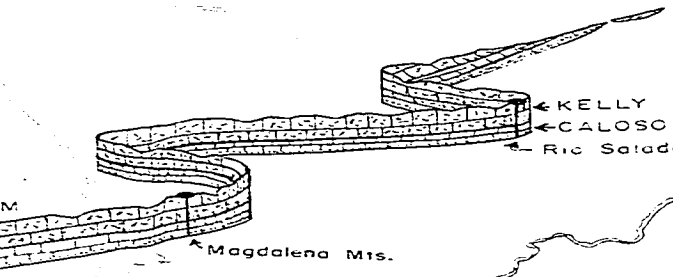






ALBUQUER

BELEN



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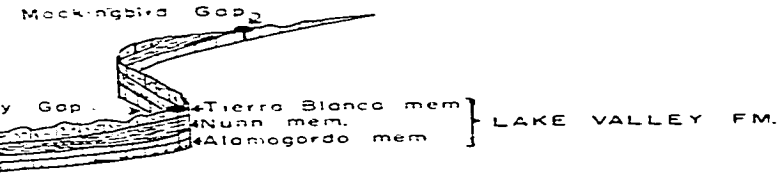

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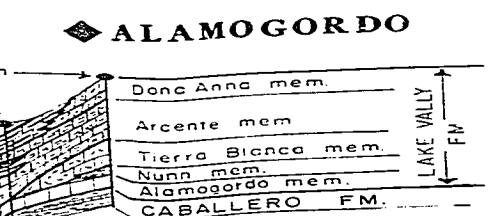
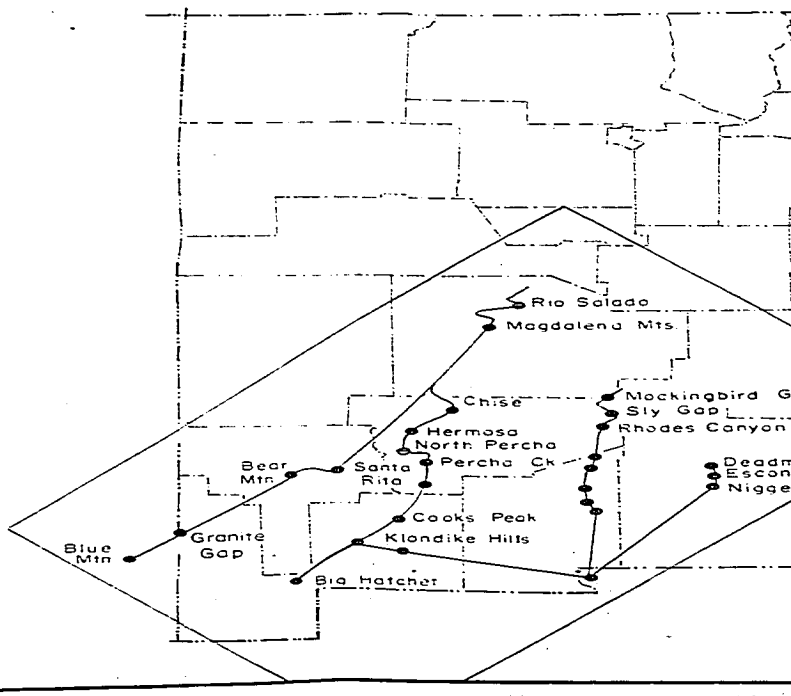




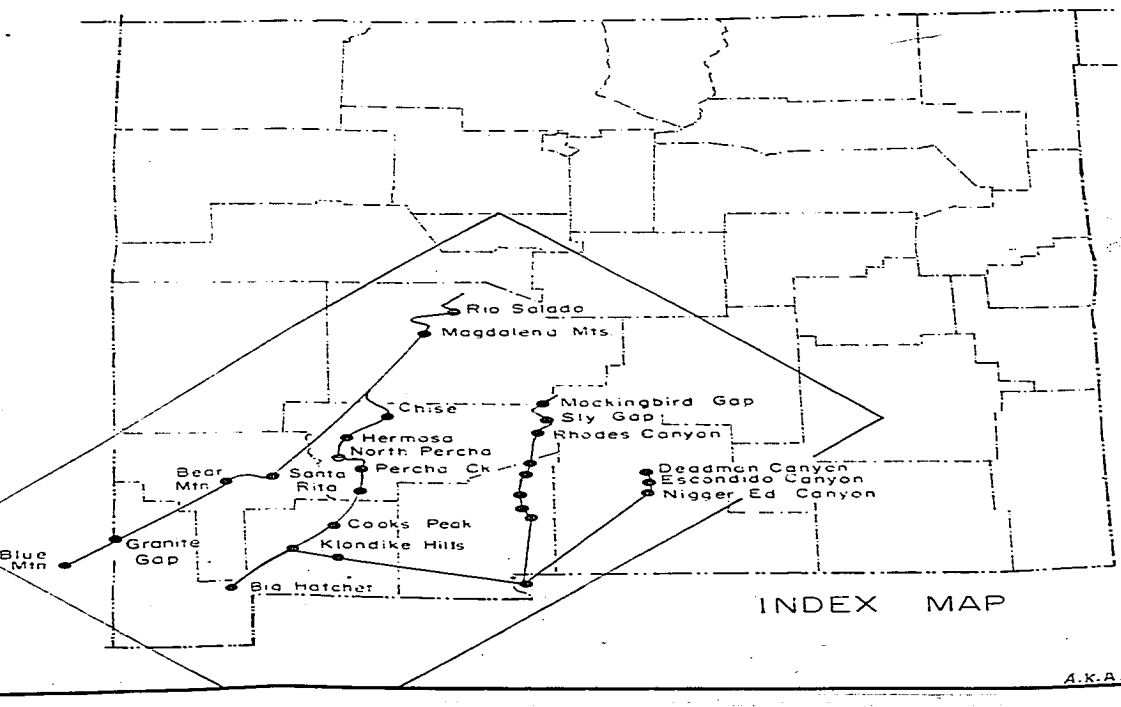
ALBUQUERQUE

BELEN

M Keokuk
M Fern Glen
Southern Ladron Mts.

r FM.

• CARRIZOZO



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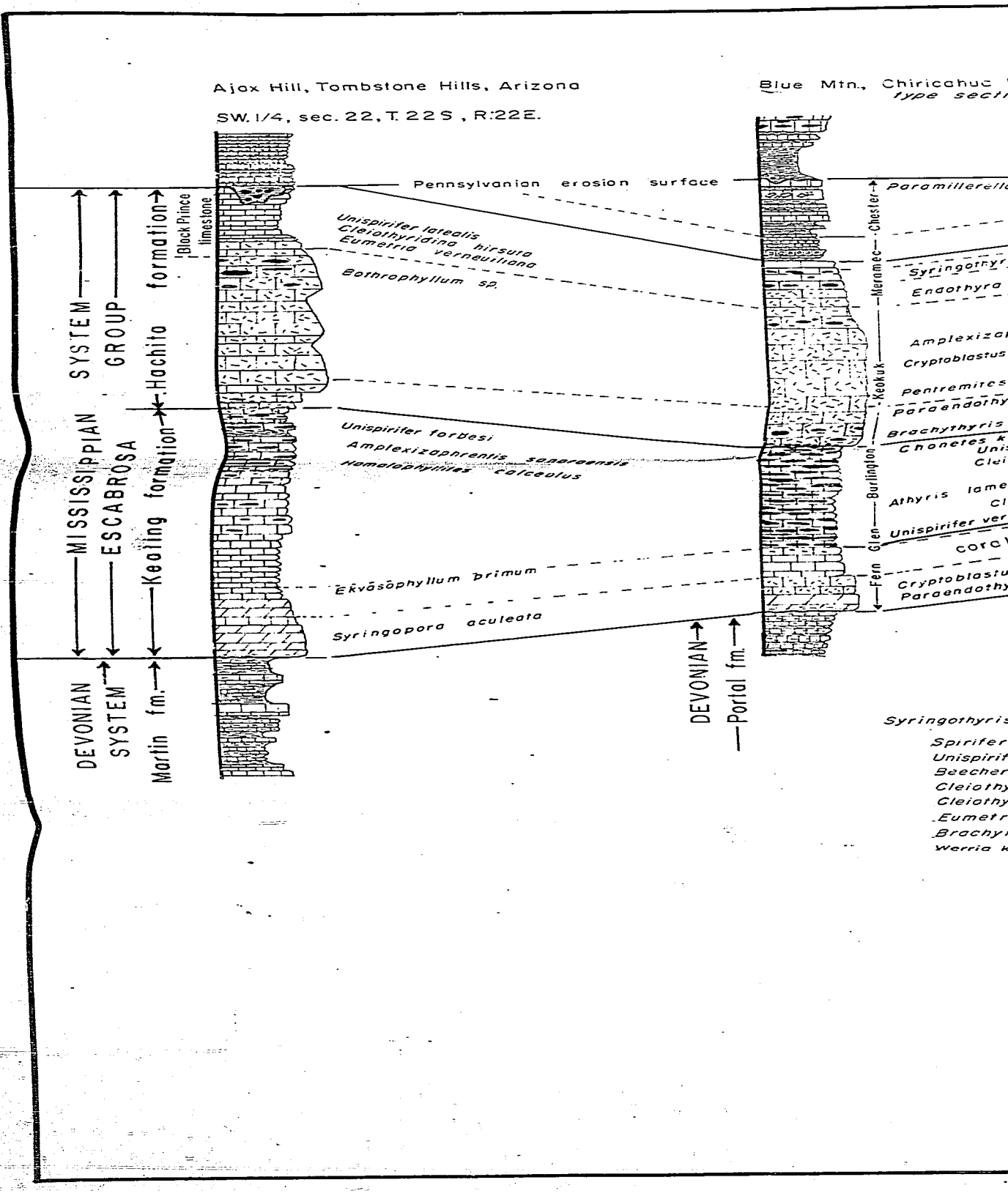
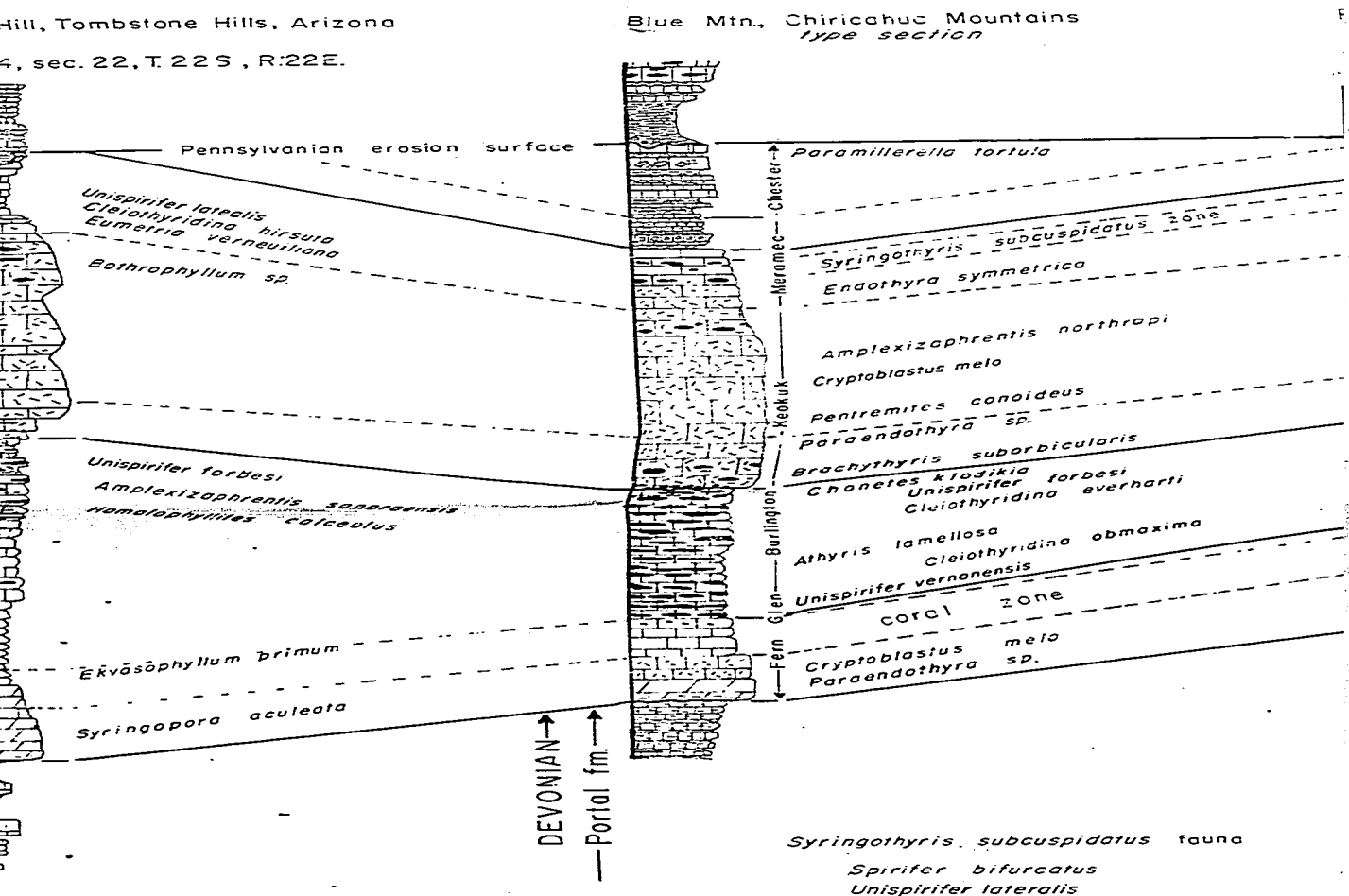
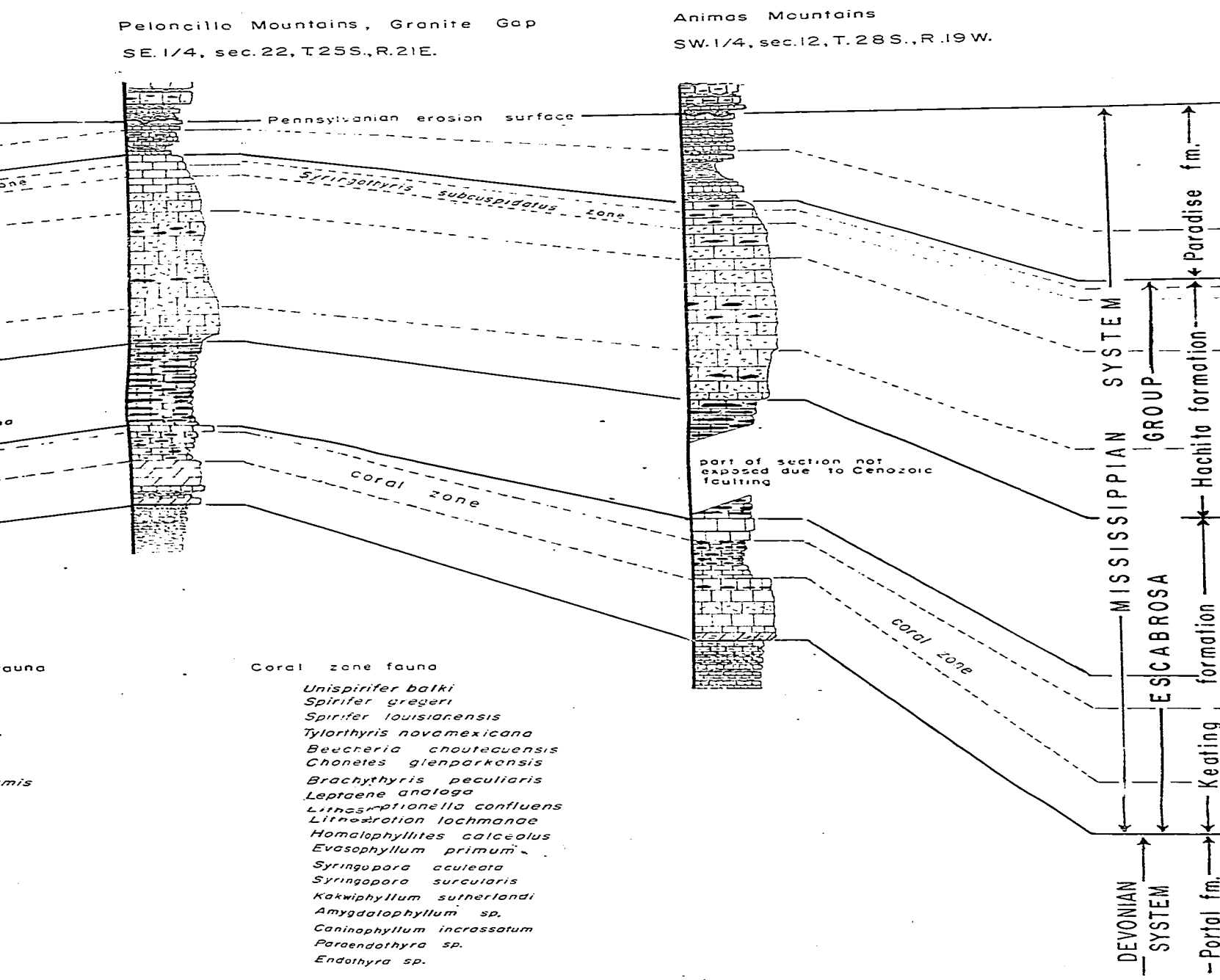
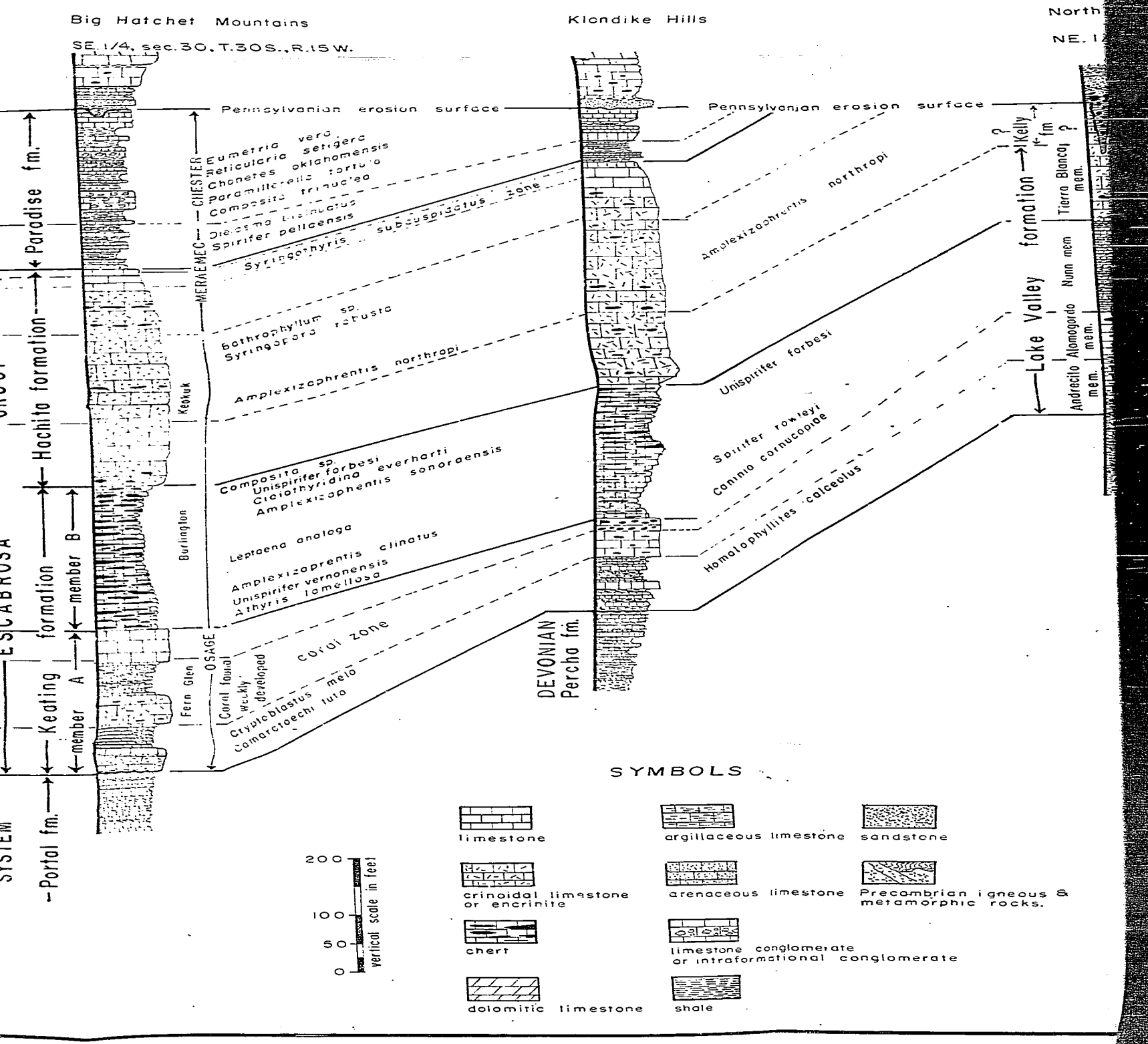
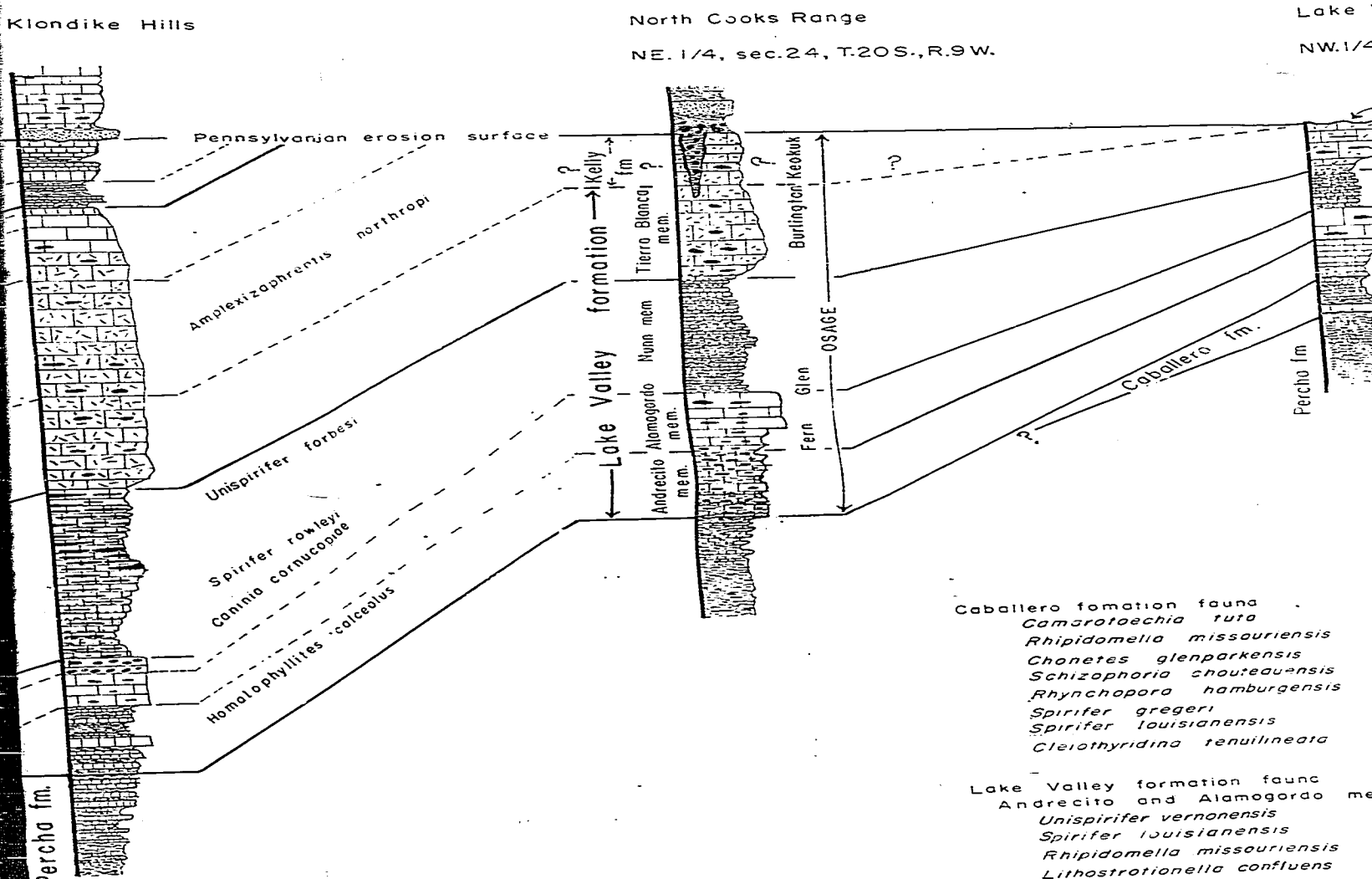










Caballero fomation fauna
- *Camarotoechia tuta*
- *Rhipidomella missouriensis*
- *Chonetes glenparkensis*
- *Schizophoria chouteauensis*
- *Rhynchopora hamburgensis*
- *Spirifer gregeri*
- *Spirifer louisianensis*
- *Cleiothyridina tenuilineata*

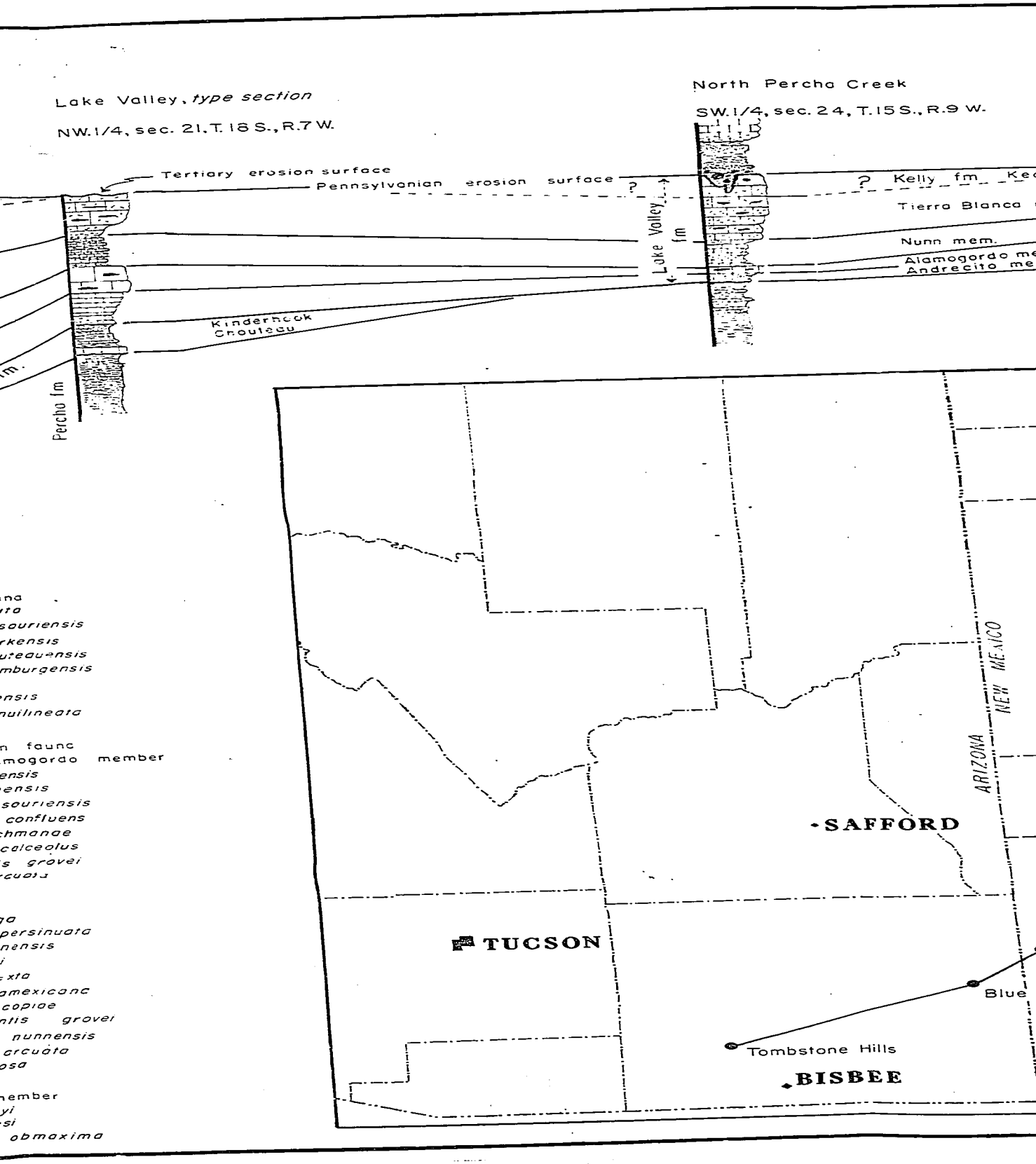
Lake Valley formation faunc
Andrecito and Alamogordo me
- *Unispirifer vernonensis*
- *Spirifer louisianensis*
- *Rhipidomella missouriensis*
- *Lithostrotionella confluens*
- *Lithostrotion lochmanae*
- *Homalophyllite calceolus*
- *Amplexizaphentis grovei*
- *Cyathaxonia arcuata*

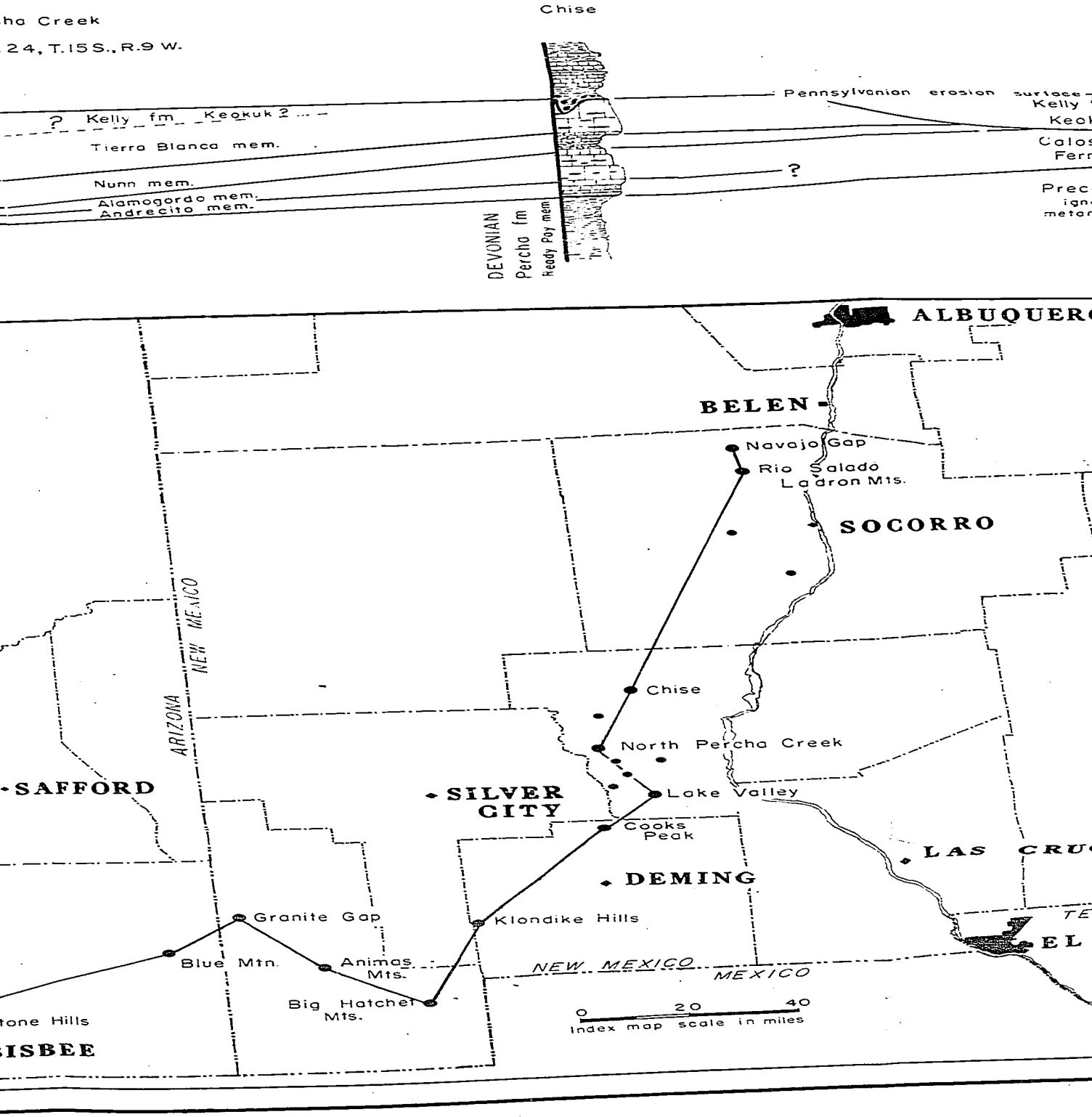
Nunn member
- *Leptaena analoga*
- *Rhynchopora persinuata*
- *Spirifer louisianensis*
- *Spirifer rowleyi*
- *Syringothyris texta*
- *Tylorthyris novamexicana*
- *Caninia cornucopiae*
- *Amplexizaphrentis grovei*
- *Hapsiphyllum nunnensis*
- *Cyathaxonia arcuata*
- *Athyris lamellosa*

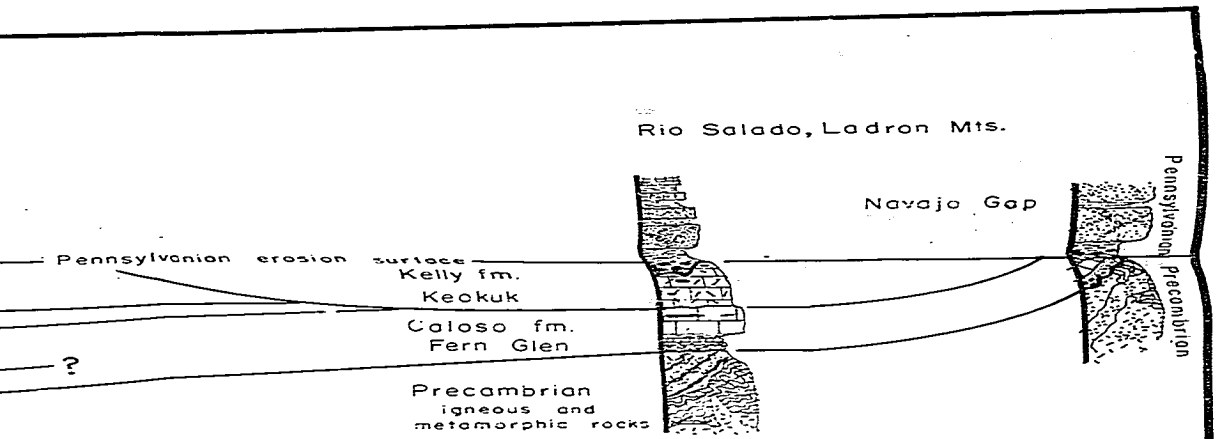
Tierra Blanca member
- *Spirifer rowleyi*
- *Spirifer grimesi*
- *Cleiothyridina obmaxima*

SYMBOLS

argillaceous limestone
sandstone
arenaceous limestone
Precambrian igneous & metamorphic rocks.
limestone conglomerate or intraformational conglomerate
shale







Caloso formation fauna

Camarotoechia tuta
Beecheria chouteauensis
Spirifer centronatus ladronensis
Spirifer louisianensis

Kelly formation fauna

Choneres illinoisensis
Tetracamera cf. *subtrigona*
Tetracamera subcuneata
Rhynchopora persinuata
Spirifer grimesi
Spirifer logani
Spirifer tenuicostatus
Brachythyris suborbicularis
Cleiothyridina hirsuta
Cleiothyridina obmaxima
Dimegelasma neglectum
Pentremites conoideus
Orbitremite floweri
Zaphriphyllum casteri
Paraehdothyra sp.