Stratigraphy and paleontology of the Naco Formation in the southern Dripping Spring Mountains, near Winkelman, Gila County, Arizona

STRATIGRAPHY AND PALEONTOLOGY OF THE NACO FORMATION IN THE SOUTHERN DRIPPING SPRING MOUNTAINS, NEAR WINKELMAN, GILA COUNTY, ARIZONA

by

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ABSTRACT

The Pennsylvanian Naco Formation in the southeastern Dripping Spring Mountains near Winkelman, Arizona, consists of a lower dolomite member and an upper limestone member. A strip approximately one mile wide across the mountains was mapped and two stratigraphic sections of 405 and 538 feet were measured and are described in detail. The formation contains an abundant and varied fauna of Derryan and Desmoinesian age which is described and illustrated.

Thirty species assigned to eighteen genera of brachiopods and seven species assigned to four genera of corals are described and illustrated from the upper limestone member of the Naco Formation. Three species assigned to two genera of corals are described and illustrated from the top of the Escabrosa Limestone which disconformably underlies the Naco Formation. These corals indicate that the age of the Escabrosa Limestone is Late Kinderhookian or Early Osagian.

Thin sections were cut from representative rocks of each unit and studied under a binocular microscope to aid in the interpretation of the paleoecology and depositional environment of the formation.

INTRODUCTION

Location

The area investigated is located in the southeastern end of the Dripping Spring Mountains in the extreme southwestern corner of Gila County, in south-central Arizona. The area of detailed examination is a strip approximately one mile wide across the mountains, along the west bank of the Gila River, one and one-half miles north of Winkelman, as shown in the index map (Fig. 1).

The Gila River has cut a deep canyon through the southern end of the mountains, exposing the folded Mississippian and Pennsylvanian strata. In the steep walls of the canyon the anticlinal structure of the southern Dripping Spring Mountains is well exposed.

Several important mining Districts are located near this area; to the north is the Superior-Globe-Miami District, to the south is the San Manuel District, to the west is the Ray District, and the Banner Mining District borders the area of study on the east. Most of the geologic work done in the Winkelman-Christmas area has been related to this mining activity.

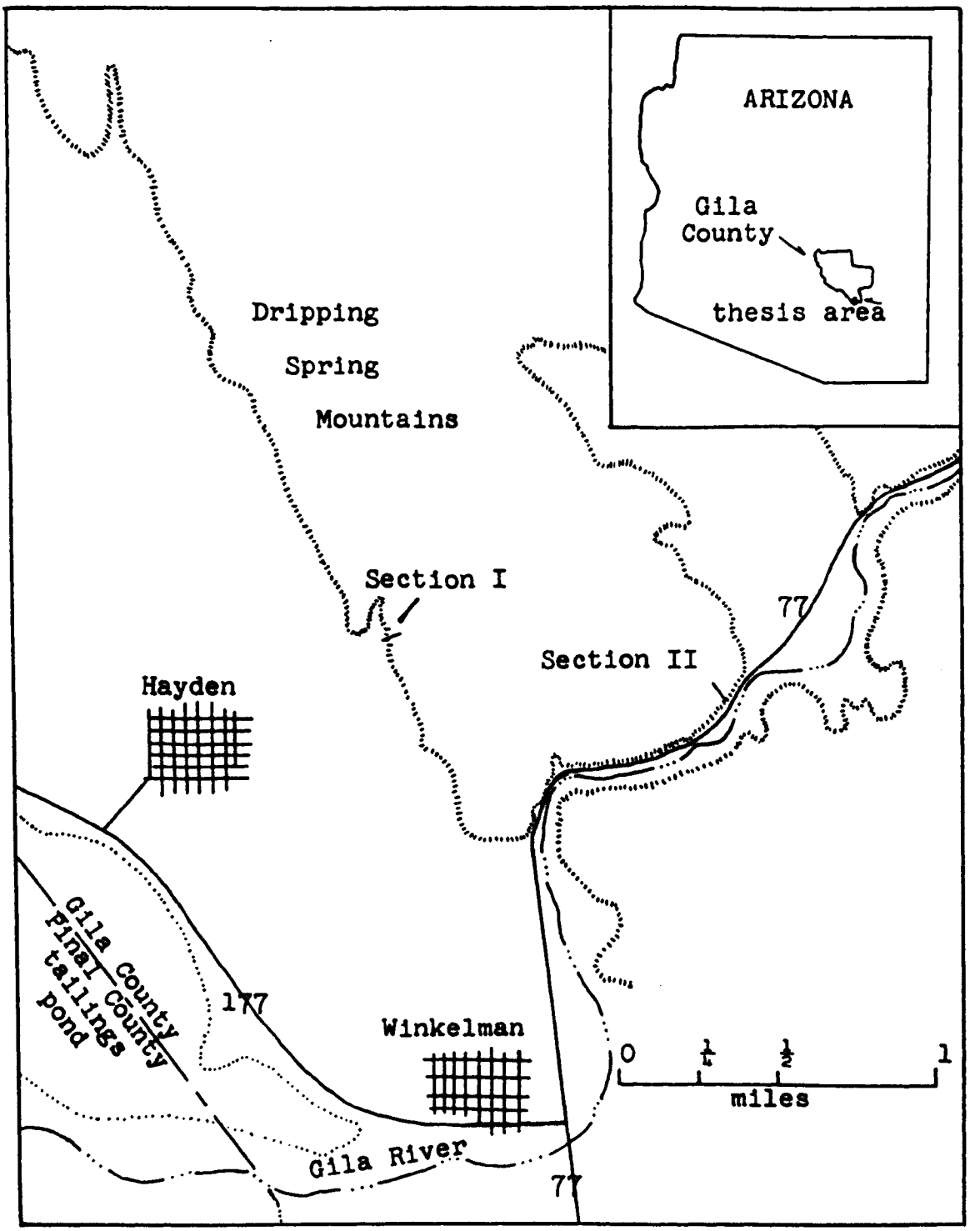

Figure 1. Index map with location of thesis area in southern Gila County, Arizona.

Purpose and scope of investigation

The Naco Formation in the area investigated consists predominantly of light to medium gray carbonate rocks with minor amounts of siltstone. The formation contains abundant chert and is relatively thin bedded, which distinguishes it from other formations in the area. The abundant and diversified fauna includes fusulinids, echinoderms, trilobites, bryozoans, brachiopods, and corals. The faunal study is restricted to the last two groups as they are the best for age determinations and as ecologic indicators with the exception of the fusulinids which have already been studied in this area (Wells, 1965). This study was undertaken to establish a foundation for future stratigraphic and paleontologic investigations in south-central Arizona, since the area is located midway between the Supai deltaic sediments to the north and the thick Horquilla carbonate sequence to the south.

History of Naco Formation in Arizona

The name Naco Limestone was originally proposed by Ransome (1904, p. 44) for all of the Pennsylvanian limestones overlying the Escabrosa Limestone in the Naco Hills near Bisbee, Arizona. This sequence contains both Pennsylvanian and Permian strata, but the Permian System was not recognized by the United States Geological Survey at that

time. Ransome estimated that before erosion the thickness of the Naco Limestone was at least 3,000 feet.

Gilluly, Cooper, Williams (1954, p. 16) elevated the Naco Limestone (as defined by Ransome) from a formation to group status and divided it into six formations. In ascending order these are the Horquilla Limestone, the Earp Formation, the Colina Limestone, the Epitaph Dolomite, the Scherrer Formation, and the Concha Limestone. The type localities for these formations are in Cochise County, Arizona.

In the area described by Ransome, however, the Epitaph, Scherrer, and Concha Formations are not present (Kottlowski, 1960, p. 112). This means that the entire sequence of Pennsylvanian and Permian sediments in southern Arizona, with the exception of the Rainvalley Limestone, is included in the Naco Group, but not the Naco as originally defined by Ransome.

Fossils from the type area of the Naco Formation were examined by Girty for Ransome (1904, p. 46) and found to fall into two age groups; the older fauna indicated an older (true) Pennsylvanian age whereas the younger correlated with the Late Pennsylvanian fauna of the Hueco Formation of Texas, now known to be Permian. On the basis of Girty's fossil identifications and his own studies in southern Arizona Stoyanow (1936, p. 522) advocated the restriction of the term Naco to the lower part of the formation as described by Ransome.

Northward in central and east-central Arizona the Naco Group thins, and the Permian carbonates disappear. In these areas the Pennsylvanian sediments are called the Naco Formation. The first published paper to use the name Naco for the Pennsylvanian limestones near Superior, Arizona, was by Galbraith (1935, p. 49). In 1943, Short et al. (p. 31) used the term for the upper part of the Tornado Limestone (Early Pennsylvanian in age) in south-central Arizona. Farther north the Naco Formation thins and interfingers with the Supai Formation in the Mogollon Rim area.

At the present time there are two uses for the term Naco, one as the Naco Formation of Pennsylvanian age in central and northern Arizona, as intended by Ransome, and the other as the Naco Group, embracing almost all of the late Paleozoic sediments in the southeastern part of the state. The dual use of this term has continued to the present, as illustrated by Huddle and Dobrovolny (1945), Jackson (1951), Wilson (1952), Wanless (1955), Peterson and Swanson (1956), Kottlowski (1960), Horvath (1960), Winters (1963), and Willden (1964). To date, however, no one has described and designated a typical section for the Naco Formation of south-central Arizona.

History of Naco Formation in south-central Arizona

Most of the geologic work done in south-central Arizona has been done in the interest of the mining industry of the area. For this reason the stratigraphy has received little attention. The first detailed stratigraphic work was done in this area by Ransome (1903), who named the Devonian, Mississippian, and Pennsylvanian rocks of the Globe-Miami area the Globe Limestone. In 1916 (p. 142) he renamed the Mississippian and Pennsylvanian rocks of the Ray-Superior-Globe area the Tornado Limestone from the exposure on Tornado Peak in the Dripping Spring Mountains. Ransome divided this formation into three parts and collected fossils from each part. Girty (in Ransome, 1916, p. 140) identified the faunal collections and reported that the upper member contained a Lower Pennsylvanian fauna similar to the Naco fauna near Bisbee, while the lower two members contained a Mississippian fauna similar to the Escabrosa Limestone of the Bisbee region. In 1925 Ross mapped the Christmas quadrangle, and identified the Tornado Limestone in that area. Girty identified the fauna and assigned an Early Pennsylvanian age to it.

Webber (1925) and Stoyanow (1936, p. 517), used the name Galiuro Limestone for the Pennsylvanian portion of the Tornado Limestone, from the exposure on Saddle Mountain in the Galiuro Mountains southeast of Winkelman, Arizona. Stoyanow reported 950 feet of fossiliferous,

vari-colored limestones and shales with an abundant Lower Pennsylvanian fauna in the Galiuro Mountains.

Two other papers have recently been published on this area, concerning the mineral deposits. Peterson and Swanson (1956, p. 358) measured a section one mile north of Christmas, Arizona, and stated that the fusulinid fauna indicates a Late Pennsylvanian age. Willden (1964, p. 24) stated that the Naco Formation in the Mescal Mountains attains a thickness in excess of 1500 feet with a Virgilian fusulinid fauna 30 feet from the top.

The last paper written on the area was by Wells (1965), who stated that the series represented in the Naco Formation in the southern Dripping Spring Mountains are Upper Derryan (Upper Atokan), Lower Desmoinesian, and Lower Missourian. Wells also delineated several persistent and easily dated fusulinid zones in this area.

Methods

The area investigated was mapped by the Brunton and pace method, using the Ray Quadrangle Topographic map as a base. The mapping delineated major faults and igneous intrusions, thus indicating the best localities for measuring the two stratigraphic sections. The sections were measured with a Brunton compass and broken up into units of continuous or closely related lithologic characteristics. A sample

was collected from each of these units and thin-sectioned for microscopic examination. The carbonate sediments were classified according to Folk's carbonate classification (1959) as modified by Wilde (1962). Figure 2 is a slight revision of Wilde's classification which was used in this report. Rock colors are designated after comparison with the National Research Council Rock-Color Chart (Goddard, 1948).

The fauna was collected and taken to the laboratory for identification. Silicified fossils were removed from the limestone matrix by leaching in weak acetic acid. Poorly silicified or non-silicified specimens were removed from the matrix with hammer and chisel. Corals were thin-sectioned for identification when silicified, and acetate peels were used for unsilicified specimens.

Thin sections of rock samples were stained to determine the presence and relative abundance of dolomite. Dolomite crystals were then measured to determine their size.

Several samples of shale and poorly consolidated limestones were disaggregated and examined microscopically for Foraminifera, but none were found.

CLASSIFICATION OF CARBONATE ROCKS (Simplified from Folk, 1959)			
Allochems (Grain Types)	TYPE I Sparry Matrix	TYPE II Microcrystalline	TYPE III Microcrystalline
1. Intraclastic Rocks Sand-sized grains (<2mm) Gravel-sized grains (>2mm)	 Intrasparite Intrasparudite	 Intramicrite Intramicrudite	Micrite (90% Microcrystalline Material)
2. Oolitic Rocks Sand-sized grains	 Oosparite	 Oomicrite	
3. Fossiliferous Rocks Sand-sized fossil fragments Gravel-sized and larger	 Biosparite Biosparrudite	 Biomicrite Biomicrudite	
4. Pellet Rocks Sand-sized pellets Fossiliferous pellet Rocks Sand-sized grains	 Pelsparite Biopelsparite	 Pelmicrite Biopelmicrite	

Intraclasts - refers to fragments of penecontemporaneous sediments redeposited to form new sediment.
Calcilithite - terrigenous rock whose silt-sand-gravel fraction contain more than 50% carbonate rock fragments (siltstone - sandstone - conglomerate).
Biolithite - (TYPE IV) - In-place reef rock, non-fragmented. (Ex: algal biolithite).
Dismicrite - sack term for micritic rocks containing patches of sparry cement (diverse origin).
Dominant fossil name prefixed to "bio" rocks as in "Brachiopodal biosparite."

- slightly revised from Wilde (1962)

Figure 2

GENERAL GEOLOGY

General statement

Several formations are exposed in the mountain ranges in the vicinity of the area studied, ranging in age from Precambrian to Tertiary. Northwest in the Dripping Spring Mountains the Younger Precambrian Apache Group and the Troy Quartzite are exposed, unconformably overlain by Cambrian quartzites (Kiersch, 1958, p. 97). The Upper Devonian Martin Limestone, the Lower Mississippian Escabrosa Limestone and the Naco Formation are also present. Where erosion has not removed them Cretaceous volcanics overlie the Paleozoic section unconformably.

In the Mescal Mountains to the north, the Older Precambrian Pinal Schist and Younger Precambrian Apache Group and Troy Quartzite are widely exposed (Willden, 1964, p. 9-20). Unconformably overlying the Precambrian formations are undifferentiated Cambrian quartzites, shales, and carbonates. The Martin, Escabrosa, and Naco limestones are also present, each separated by an unconformity. Overlying the Paleozoic section are unnamed Cretaceous sediments and volcanics (Willden, 1964, p. 25).

In the valleys between the mountain ranges the Gila Conglomerate crops out extensively (Ransome, 1923), overlain in many areas by Quaternary and Recent alluvial gravels and sands.

Heindl (1963, p. 14-26) has studied the Tertiary sediments in the San Pedro valley near Mammoth, southeast of Winkelman, and raised the term Gila Conglomerate to Gila Group with three distinct formations. Each formation contains several members and represents a change in sedimentation conditions. The sediments here referred to the Gila Conglomerate are probably equivalent in part to the three formations of the Gila Group.

Stratigraphy of the Naco Formation

The Naco Formation overlies the Escabrosa Limestone disconformably. The eroded upper surface of the Naco Formation dips eastward under a thick sequence of brown, brownish black, or dark gray, fine-grained volcanic rocks. Ross (1925, p. 11-14) assigns this volcanic sequence a Cretaceous age on the basis of stratigraphic correlations with known Cretaceous sediments farther south and east. The formation appears to have been truncated by erosion from west to east and from north to south prior to the deposition of the volcanics. On the southwestern side of the area studied, any Paleozoic sediments that might

be present are covered by valley fill. The predominant formation is a Tertiary conglomerate, termed the Gila Conglomerate (Ransome, 1923).

The Naco Formation attains a maximum thickness of 538 feet in the area studied, as only the lower portion of the formation is preserved. Farther north, near Christmas, a higher portion of the Naco Formation was described by Wells (1965, Appendix). Sections measured in adjacent mountain ranges by Wilden (1964, p. 24), and Stoyanow (1936, p. 518), indicate an original thickness for the Naco Formation in the Dripping Spring Mountains in excess of 1,000 feet. Huddle and Dobrovolny (1945) reported that the Naco Formation of south-central Arizona ranges from 400 to 800 feet in thickness.

In south-central Arizona the Naco Formation consists of thin to medium bedded limestone, shale, and sandstone which typically forms a ledge and slope topography (Huddle and Dobrovolny, 1945). In the area of study the basal 70 to 75 feet of the formation consists of brown dolomite. The rest of the formation is limestone which becomes increasingly silty higher in the section, and contains abundant thin bands and nodules of red chert.

The Naco Formation in this area is a correlative of the Horquilla Limestone of southeastern Arizona.

Structure

The Dripping Spring Range is reported by Ransome (1923) and all subsequent authors to be a complexly faulted, anticlinal structure. In the area studied, the northeastern limb is steeply folded, the southwestern limb is faulted, and the structure plunges to the southeast. The dominant structural features are a series of normal faults that trend northwest and a series of steeply dipping feldspar-mica porphyry dikes that trend northeast.

The southwestern border of the southeastern Dripping Spring Mountains appears to be a normal fault. Wherever mining operations have removed the Gila Conglomerate from the face of the scarp, slickensides are exposed. In a few areas fault breccia may be observed. Owing to the plunge of the anticline, older formations are exposed to the northwest, while the Naco is thinned by erosion.

The northeastern border of the range is formed by a dip slope of limestone which plunges under the Cretaceous volcanics in the Dripping Spring Valley. The beds dip 30° to 40° near the top of the slope, the dip increases to approximately 70° near the base, then returns to about 30°. This side of the anticline contains distorted bedding and small folds which are parallel to the main fold axis.

A series of dikes trending approximately N. 70° E. cuts across the anticlinal structure. These dikes dip steeply either to the north or

south and range up to 10 feet in thickness. They are composed of feldspar-mica porphyry (Willden, 1964, p. 28), as are the numerous sills injected between the limestone beds. The dikes appear to be filling fractures along which minor vertical and horizontal displacement has occurred. Biotite from a feldspar-mica porphyry dike in the Christmas mine has been dated as 62 million years old by the potassium-argon method (Willden, 1964, p. 30). This date indicates an early Tertiary age for the intrusion of the dikes.

The attitude of the Naco Formation in the area studied varies greatly due to faulting and folding. The average strike is N. 30° W. The beds along the southwestern portion of the mountain range dip gently to the northeast or southwest. Along the northeast border the dips are much steeper to the northeast. The central axis of the mountain range is broadly synclinal, with the dips not exceeding 6° except when affected by minor structures (Fig. 4).

DISCUSSION OF MEASURED SECTIONS

Lithologic and Paleontologic correlations

The Naco Formation in the area studied is divided into two members: a basal dolomite member and an upper limestone member. Although several distinctive units are described which may prove useful in correlating between adjacent mountain ranges, it is believed that the members themselves will not be usable over a large area.

The Escabrosa-Naco contact is exposed in both of the measured sections, and in many localities between the sections. The Escabrosa Limestone is a crinoidal biosparite with a Lower Mississippian fauna. Several specimens of Vesiculophylum sedaliense were found in the upper two feet of the formation, identifying the time of deposition as Late Kinderhookian or Early Osagian age.

The contact is a disconformity and the bedding of the adjacent strata is essentially parallel within the two formations. The eroded surface of the Escabrosa Limestone shows up to two feet of relief with solution pits and crevices. The basal dolomite of the Naco Formation fills these holes and irregularities. Sub-rounded clasts of the Escabrosa Limestone which have not been dolomitized, are found in the lowest Naco beds. Lenses and stringers of calcite grains, crinoid columnals, and coral fragments believed to be weathered from the Escabrosa Limestone

may also be found, partly silicified, but not dolomitized. With the exception of material believed derived from the underlying formation, the basal dolomite member of the Naco Formation is barren of fossils. The member could be either Morrowan or Derryan (Atokan) in age, but is probably Derryan as there are no Morrowan rocks known from this part of Arizona.

In section II the top 5 1/2 feet of the 75 foot thick dolomite member consists of chert bands and a chert pebble conglomerate. This unit is missing in section I where a feldspar-mica porphyry sill has been injected at this horizon. The conglomerate crops out again, however, a few hundred yards to the northwest of section I at the same stratigraphic position.

The contact between the basal dolomite member and the upper limestone member appears to be conformable at all exposures investigated. Approximately 18 feet above this contact a conspicuous band of Chaetetes eximius occurs throughout the area. The coral colonies have been transported, or rolled around as the outer surfaces are abraded. The unit they are found in consists of 4 to 8 feet of laminated biomicrite with red chert nodules, in which the chert appears to have hardened before the calcite as the micrite laminae bend to conform to the shape of the nodules.

The thin bedded limestones and shales above and below the Chaetetes eximius zone in section II are abundantly fossiliferous. The equivalent beds in section I contain almost no identifiable fossils.

Units 12 and 13 in section I, unit 17, and the basal half of unit 18 in section II are composed of oosparite and oolitic biosparite. The oolite

zone may be seen throughout the area but appears to thicken toward the southeast (Fig. 3).

The top of unit 17 in section I and the base of unit 21 in section II consists of 0 to 1 1/2 feet of orange-weathering dolomite. The bed appears to thin by non-deposition and storm erosion on the upper surface during deposition, as indicated by intraclasts.

From the dolomite bed up to unit 33 in both sections, the limestones are shaly and silty. In section II over 90 feet is covered, unit 28, with feldspar-mica porphyry float near the middle which indicates a sill. Since the marker beds in section II were no longer at the same stratigraphic level as in section I, 60 feet was gaped out of unit 28 in section II in Figure 3. This is probably close to the thickness of the sill, as the marker beds were then at the same stratigraphic level (Fig. 3).

Unit 34 in both sections consists of fossiliferous micrite nodules and siltstone which weathers mottled grayish orange pink and light gray.

Unit 36 in section I and units 38 and 40 in section II are similar to unit 34, mixed micrite and siltstone. The reddish brown beds form a thick, conspicuous band that stands out well against the gray limestones above and below it. This band can be seen easily at a distance and is useful in correlating beds that have been displaced by the numerous small faults in the area. In both sections this band contains abundant fossils, but identifiable specimens are hard to remove in section I. Large

rugose corals including the genus Pseudozaphrentoides are especially abundant at this horizon.

Unit 34 in both sections exhibits the same lithology, but is usually covered with float from higher units. The entire silty micrite sequence contains a higher proportion of clastic to carbonate material in section I than in section II.

Units 37 through 50 in section I consist of massive limestone near the base, becoming more silty and cherty higher in the section. This resembles closely the lithology of units 41 through 57 in section II, although section II contains less clastic material.

A silty band with reddish brown chert nodules occurs near the middle of unit 50 in section I and unit 57 in section II, and at two localities between the sections, indicating that it is continuous in much of the area.

The rest of section I becomes increasingly silty towards the top, while section II contains little clastic material in the relatively pure carbonate sequence. The highest fossils in section II are Desmoinesian age, and none indicate an age younger than Desmoinesian.

Faunal zonation

The fauna identified from the area investigated indicates that the rocks belong to the Derryan and Desmoinesian Series of the Pennsylvanian System. The lower parts of the sections are Derryan in age and the upper parts are Desmoinesian.

Spirifer rockymontanus, S. occiduus, S. opimus, and Neospirifer cameratus are known to be restricted to the Morrowan through Desmoinesian Series. Unit 68, near the top of section II yielded Spirifer occiduus and Neospirifer cameratus, indicating that no Missourian or Virgilian strata are present in the area investigated.

The fauna identified from the beds immediately below the Chaetetes eximius zone in section II is probably Derryan in age. Composita derrya and C. malaya were previously known only from the Derryan of New Mexico (Gehrig, 1958). Composita ovata is not known to range below the Derryan. Hustedia miseri, found in unit 12, section II, was previously believed to be restricted to Morrowan rocks (Dunbar and Condra, 1932, p. 358), but has been reported from the Derryan of Nevada (Coogan, 1962, p. 26). Schizophoria texana and S. resupinoides are typical of the Derryan or Lower Desmoinesian in the south-central United States, but have also been reported from the Morrowan of Nevada (Lane, 1962, p. 18). For the above mentioned reasons, the fauna seems to be Derryan, although a Morrowan age can not be eliminated.

The fauna identified from the upper beds is Desmoinesian in age. Phricodothyris perplexa which first appears in unit 38 of section I and unit 43 of section II, is typical of the Desmoines Series although it occurs in the Derryan of Colorado. Desmoinesia muricatina appears in unit 43 of section II, and is restricted to rocks of Desmoinesian age.

The exact Derryan-Desmoinesian boundary was not located for the same reasons that satisfactory fossil zones were not established. The fauna was too scarce in many critical units. In order to set up a zonation on the basis of the megafauna it would be necessary to collect from a much larger area. Wells (1965, Fig. 2) was able to locate the Derryan-Desmoinesian boundary by means of fusulinids. By comparison with this work the boundary should occur between units 31 and 36 of section I and units 31 and 40 of section II. This agrees with the megafauna interpretation.

On the basis of this boundary determination the age range for three brachiopods and one coral species may be extended. These species with their extended ranges are listed in Table I.

TABLE I

Faunal Age Ranges

Species	Previous range	Extended range
Composita derrya	Derryan	Derryan-Desmoinesian
Composita malaya	Derryan	Derryan-Desmoinesian
Retaria lasallensis	Desmoinesian-Missourian	Derryan-Missourian
Lophophyllidium idonium	Morrowan	Morrowan-Desmoinesian

Regional correlations

North of the area investigated, near Superior, Arizona, the Naco Formation has been studied by many authors. Harshman (1939, p. 48) measured a section in the Queen Creek area and described a chert pebble conglomerate up to 4 feet thick at the base of the Naco. The alternating shales and limestones underlying the conglomerate were included in the Escabrosa Limestone. Short et al. (1943, p. 30) measured 71 feet of alternating pink and white limestones and purple siliceous shale beneath the conglomerate bed and included them in the Escabrosa Limestone. Huddle and Dobrovolny (1945) have placed all of the beds here described in the Naco Formation. The total thickness of these beds ranges from 0 to 60 feet, and they consist of reddish sandy shale, purple siliceous shale, and chert breccia. This material appears to be reworked residual sediments derived under karst conditions from the underlying Escabrosa Limestone. These basal sediments resemble the Molas Formation of similar origin in southwestern Colorado, which is also of Derryan age.

The basal member of the Naco Formation near Winkelman appears to be equivalent to the basal portion of the Superior section. These beds are not present in all areas, probably reflecting the Early Pennsylvanian topography developed on the Escabrosa Limestone. As the Pennsylvanian sea encroached over the post-Mississippian land surface, residual soils

were washed from high areas, and deposited in the intervening valleys. These beds are missing on Tornado Peak, only 3 miles northwest of the area investigated.

Stoyanow (1936, p. 518) measured a section of the Naco Formation at Saddle Mountain in the Galiuro Mountains. The basal 40 feet of this section consists of alternating arenaceous and argillaceous shales, with layers of limestone near the top. The upper limestone beds contain fusulinids, but the lower arenaceous beds are probably in part equivalent to the unfossiliferous basal dolomite beds near Winkelman.

In southeastern Arizona, the Black Prince Limestone appears to indicate a similar environment and mode of deposition, but is of Morrowan age, according to Nations (1963).

The upper member of the Naco Formation near Winkelman resembles the sections at Queen Creek, Tornado Peak, and Saddle Mountain very closely. The limestones become increasingly silty upwards in the section and contain abundant reddish brown chert nodules. In general, the entire Pennsylvanian section becomes increasingly silty to the north, and less silty to the south and west.

Many of the brachiopods collected by Stoyanow (1936, p. 519) at Saddle Mountain are the same species as those collected near Winkelman, and indicate a Derryan and Desmoinesian age. The writer has collected brachiopods from the Superior section, and these also indicate a Derryan and Desmoinesian age.

DEPOSITIONAL ENVIRONMENT

Sedimentation and Paleoecology

The Pennsylvanian sediments near Winkelman, Arizona, were deposited mainly in shallow water a few miles from the nearest land. The fauna indicates a marine environment with little influence from terrestrial sources. This environment changed throughout Pennsylvanian time in response to structural controls elsewhere in the state.

Thin sections were cut from each unit of the dolomite member at the base of the Naco Formation, and examined under both binocular and petrographic microscopes. The bulk of this material falls in the finely crystalline class, 0.0156 mm to 0.0625 mm in diameter. The grains replacing fossil fragments are dominantly in the medium crystalline class, 0.0625 mm to 0.250 mm. Folk (1961, p. 153) stated that most dolomite with greater than 0.01 mm grain size is formed by secondary replacement, while dolomites with an average grain size less than 0.01 mm may be primary in origin. This agrees with the observations of Alderman and Skinner (1957, p. 562-565) who found extremely fine-grained dolomite being precipitated at the present time in small saline lakes and the shallow end of the Coorong along the southeast coast of Australia.

The lowest beds of the dolomite series contain rounded clasts of Escabrosa Limestone which show little or no dolomitization. Individual rounded sparite grains up to 2 mm in diameter form lenses and stringers in these lower units. Fossil fragments in the higher beds have been replaced completely by dolomite, but the outlines are still visible.

In general, the beds become more calcareous toward the top of the lower member, although the allochems have been replaced by dolomite. The calcite seems to be concentrated between the crystal faces of the dolomite grains. The only fossil fragments recognized in this member are crinoid columnals and rare coral fragments. The abundant fauna of the upper limestone member does not appear in these lower beds.

The disconformable basal contact with the underlying Escabrosa Limestone is extremely sharp. The finely crystalline dolomite fills depressions and irregularities in the Escabrosa, and contains no calcite except fragments of limestone from the underlying Mississippian rocks. Thin sections cut across the contact show Naco dolomite in direct contact with Escabrosa biosparite with almost no transition zone, although the top 5 to 10 mm of biosparite has dolomite between the sparite grains. No terriginous material was observed in the lower member of the Naco Formation.

The presence of calcite intraclasts from the Escabrosa Limestone included in the dolomite of the lower member of the Naco Formation, in

addition to the characteristics of the lower contact, indicates that either the dolomite was precipitated directly, or that the dolomite formed by replacement before consolidation. The complete absence of typical Naco fossils indicates that the depositional environment was hostile to normal marine life as it is in areas where dolomite is forming today (Alderman and Skinner, 1959, p. 3-9). The presence of dolomitized allochems and the size of the dolomite crystals is against the idea that the dolomitization took place after deposition, but the other factors cited above appear to indicate a primary origin for the basal Naco dolomite, or replacement by dolomite shortly after deposition.

The top 10 feet of the lower dolomite member consists of dark, banded cherts and thin dark shales, with a chert pebble conglomerate one foot thick at the top. The change from dolomite to chert is gradational, and the chert does not occur in all areas. Although the chert pebble conglomerate is still present, the banded chert disappears less than a mile to the northwest from section II, probably due to non-deposition. The change from dolomite to cherts and conglomerate indicates a change in the depositional environment, possibly due to the advance of the Pennsylvanian sea which broached the restricted environment in which the lower member probably was deposited.

The base of the upper limestone member is gradational from limy shale to biomicrite and overlies the chert pebble conglomerate with

apparent conformity. The alternating biomicrite and biosparite beds above this transition zone are abundantly fossiliferous. Ecologic conditions were favorable to benthonic marine life, with a relatively hard bottom and a rate of sedimentation slow enough to allow bryozoans, crinoids, corals, and brachiopods to survive. These organisms are attached to the substratum and cannot survive well on an unstable bottom. Pelecypods are rare, supporting the idea that the depositional environment was not adjacent to a land area. Wave and current action must have been fairly strong, as illustrated by the transported and abraded Chaetetes eximius colonies found near the base of this member. A few units have intraclasts, and several feet of oolitic beds occur in the lower half of the member.

Approximately 20 feet above the base of the upper limestone member is a 5 to 10 foot zone of reddish brown chert nodules in laminated biomicrite and biosparite. The limestone laminae conform to the shape of the chert nodules, indicating that the chert formed before the carbonates were consolidated. This indicates that the sea water from which these beds were deposited was rich in silica.

Approximately 80 feet above the base of the limestone member the proportion of clastic material begins to increase. Shales and silty limestones are more common, with lenses and stringers of silt and sand appearing sporadically. The increase in clastic material reaches a

maximum in units 34 to 36 of section I and units 34 to 40 of section II, where thick units of calcareous siltstone crop out. These units comprise the red marker band that may be seen throughout the area. Although the clastic content increased sharply, bottom conditions must have remained essentially the same, as corals, bryozoans, and brachiopods were still abundant. Even though silt-size clastic particles were being deposited, the water was still clear enough to allow these filter feeders to survive. This indicates that the source of the clastic material was still some distance away, allowing time for sorting and winnowing by wave and current action.

The age of these siltstones is uppermost Derryan and lowest Desmoinesian. The increase in clastic material probably indicates a slight regression of the advancing Pennsylvanian sea. The decrease of clastic material in the top of section II as compared with the amount in section I is difficult to explain with the limited stratigraphic control, but it is probably due to local controls.

Paleogeography

In Late Mississippian and Early Pennsylvanian time a karst topography was developing on the Escabrosa Limestone, which had been deposited in Early Mississippian time. Pennsylvanian seas encroaching from southeastern Arizona apparently deposited Morrowan rocks as far

north as the Johnny Lyons Hills in southeastern Arizona (Nations, 1963). By the end of Derryan (Atokan) time the Pennsylvanian sea had advanced as far north as Superior, Arizona and by the end of Desmoinesian time most of Arizona was submerged, except that the Defiance Uplift remained above sea level, as did most of northwestern Arizona (Havenor, 1958, p. 52). During Missourian and Virgilian time all of Arizona was inundated by the advancing sea except for part of the Defiance Uplift. During Virgilian time, however, the transgression was stopped and the sea was being pushed back by the deposition of red siltstones and sandstones of the Supai Formation. This material, eroded from the actively rising Uncompahgre-San Luis Uplifts of Colorado and New Mexico, spread southward over Arizona like a blanket.

In central and east-central Arizona Desmoinesian and younger rocks grade laterally northeastward into the Supai redbeds (Jackson, 1951, p. 14). These sediments were spreading south and southwest across Arizona during Late Pennsylvanian time, and reached as far south as the Salt River in central Arizona and even farther south in eastern Arizona during Virgilian time. This southward advance of deltaic material was not recorded in southern Arizona until Early Permian time.

SUMMARY

The top beds of the Escabrosa Limestone in the area investigated are crinoidal biosparite with an abundant coral fauna. Identification of the coral fauna allows a date of Late Kinderhookian or Early Osagian, or both, to be assigned to the formation which agrees with the age determinations for the Escabrosa Limestone in most other areas of Arizona.

The Escabrosa Limestone underwent subaerial erosion during Late Mississippian and Early Pennsylvanian time to produce a karst topography which was buried under sediments deposited by the advancing Pennsylvanian sea. The contact between the Escabrosa Limestone and the Naco Formation is disconformable.

The basal 75 feet of the Naco Formation near Winkelman, Arizona, is finely crystalline dolomite with inclusions of weathered Escabrosa Limestone. This dolomite appears to be primary, or formed shortly after deposition, and prior to consolidation.

The basal portion of the upper limestone member was deposited in a shallow marine environment with a moderately hard bottom. The water was clear and bottom life was diversified and abundant. Constant clean, well-oxygenated water was supplied by wave and current action. The sea water was apparently rich in silica at this time since chert nodules formed before the limestones were consolidated.

Near the middle of the upper member the limestones become increasingly silty, possibly indicating a slight regression of the Pennsylvanian sea. The terriginous material is fine grained, and did not affect the coral, bryozoan, and brachiopod fauna adversely.

The fauna indicates that the age of the Naco Limestone in this area is Late Derryan and Early Desmoinesian.

The geologic history of the area from the Late Pennsylvanian to the Cretaceous is not known, as there are no sediments representing this interval of time remaining today. Before the Cretaceous volcanics on the northeast flank of the mountains were deposited, the upper part of the Naco Formation and any sediments which may have overlain it were uplifted and eroded. In Early Tertiary time the rocks in the area were folded and intruded by feldspar-mica porphyry dikes and sills. Overlying the Cretaceous volcanics, and filling the valley on the southwest side of the mountain range are Tertiary sediments of the Gila Group, and Quaternary alluvium.

SYSTEMATIC PALEONTOLOGY

Phylum BRACHIOPODA

Class INARTICULATA

Order ATREMATA

Family LINGULIDAE

Genus LINGULA Bruguiere 1792

Lingula carbonaria Shumard

Plate I, no. 1

Lingula carbonaria Shumard, 1858, St. Louis Acad. Sci. Trans., vol. I, p. 215.

Description--The shell is small, elliptical in outline, with the greatest width near the midlength. The same proportions are kept throughout growth, as shown by the regular growth lines. The shell is slightly over half as wide as long. Measurements of one specimen are:

Specimen	1
Length (mm)	13.5
Width (mm)	7
Thickness (mm)	2.5

The valves are ornamented by closely spaced, fine growth lines and by exceedingly fine radial striae.

Discussion--There is no other Pennsylvanian Lingula with which this species might be confused.

Material and occurrence--This species ranges throughout the Pennsylvanian in the Mississippi Valley region and is found throughout much of the western United States.

One specimen was collected from unit 12 of section II, and is Derryan in age.

Order NEOTREMATA

Family DISCINIDAE

Genus ORBICULOIDEA D'Orbigny 1847

Orbiculoidea capuliformis (McChesney)

Plate I, no. 2

Discina capuliformis McChesney, 1860, Desc. of New Paleozoic Fossils, p. 72; (extract from: Chicago Acad. Sci. Trans., vol. 1; privately printed).

Discina convexa White, 1884, Indiana Geol. Survey, 13th Rept., p. 121, pl. 25, fig. 9.

Orbiculoidea capuliformis (McChesney) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 46-47, pl. 1, figs. 20-22

Description--The shell is large for species of this genus, and circular in outline. Measurements of two brachial valves are:

Specimen	1	2
Length (mm)	36	26
Width (mm)	35.5	26.5

The brachial valve is broadly subconical, approaching dome shaped. The prominent apex is situated a little to one side of the center, slightly inflated on the anterior slope and contracted on the posterior slope, giving the beak an appearance of being incurved.

The surface is marked by fine, irregular concentric lines, apparently of growth, but no radiating striae. The internal shell layer consists of thin laminae and the external layer is mainly exfoliated.

No pedicle valves were collected.

Discussion--This species is differentiated from other Pennsylvanian Orbiculoidea species by the circular outline, lack of radiating striae, and the presence of concentric growth lines.

Material and occurrence--This species is widely distributed and ranges throughout the Pennsylvanian rocks of the United States.

Three specimens were collected from silty and shaly limestones, one from unit 12, section II, of Derryan age, and two other specimens were found as float, just below unit 40, section II.

Class ARTICULATA

Order ORTHIDA

Superfamily DALMANELLACEA

Family SCHIZOPHORIDAE

Genus SCHIZOPHORIA King 1850

Schizophoria resupinoides (Cox)

Plate I, no. 3-5

Orthis resupinoides Cox, 1857, Geol. Survey of Kentucky, vol. 3, p. 570. pl. 9, figs. 1-1b.

Schizophoria resupinoides (Cox) Mather, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 145-146.

Description--The shell is large, strongly biconvex, slightly wider than long, with a rounded-subquadrate outline. The greatest width is anterior to the midlength and the greatest thickness is posterior to it. The hinge line equals about half the width of the shell and the cardinal extremities are broadly rounded. The dimensions of one specimen are:

Specimen	1
Length (mm)	28
Width (mm)	31
Thickness (mm)	17

The brachial valve is strongly and regularly convex from beak to anterior margin, with a broad umbo and steep posterolateral slopes. No

fold is present, even where the pedicle sinus is produced into the brachial valve. The beak is large, arching over a broadly triangular cardinal area which curves beneath it.

The pedicle valve is moderately convex from beak to umbo, and slopes gently to the anterior margin. It is gently convex transversely, with the posterior slopes becoming slightly steeper and curving under the prominent beak which arches over the broadly triangular flat interarea. A shallow sinus originates high on the anterior slope, becoming very broad but still shallow at the anterior margin. This sinus is produced into an emargination at the line of commissure.

The ornamentation consists of fine, tubular, radial costae which have minute holes along the crests, where spines were attached.

Discussion--This species resembles S. texana, but at a comparable growth stage S. texana has a well developed pedicle sinus whereas S. resupinoides does not, and S. resupinoides attains nearly twice the size of S. texana at maturity.

Material and occurrence--This species appears to be restricted to Lower Pennsylvanian rocks, where it is rare (Dunbar and Condra, 1932, p. 58), and is known to occur in the central and south-central United States.

Two specimens were found in unit 12 of section II, and are Derryan in age.

Schizophoria texana Girty

Plate I, no. 6-9

Schizophoria texana Girty, 1927, U. S. Geol. Survey Prof. Paper 152, p. 432, pl. 27, figs. 1-8.

Description--The shell is small to medium sized, broadly subcircular in outline, and unequally biconvex, with the brachial valve most inflated. The greatest width is anterior to the midlength, with the hinge a little more than half the width of the shell. The greatest thickness is posterior to the midlength. Measurements of one specimen are:

Specimen	1
Length (mm)	20.5
Width (mm)	25
Thickness (mm)	11

The brachial valve is moderately and evenly convex from beak to anterior margin. The posterolateral slopes are moderately steep, and the beak is small, projecting about 2 mm beyond the narrow, flat interarea which is in the plane of the valve. No fold is present.

The pedicle valve is gently concave from beak to umbo, sloping gently to the anterior and posterolateral margins, and curving under the large, elevated beak which overarches the high, triangular interarea. The interarea is inclined at about 45^{o} to the plane of the valves, is flat near the bottom, curving gently under the beak, with an open delthyrium

that is triangular and almost as wide as high. The sinus begins on the umbo, and becomes broad, shallow and gently concave on the anterior portion of the shell.

The surface of each valve is covered with fine, radial costae, with small, linear holes along the crests. Growth lines are widely spaced.

Discussion--This species resembles S. resupinoides, which is about twice as large, but has a distinct sinus which S. resupinoides lacks at a comparable growth stage.

Material and occurrence--This species seems to have the same geographic distribution and stratigraphic range as S. resupinoides.

One specimen was found in unit 12 of section II, of Derryan age.

Order SPIRIFERIDA

Superfamily PUNCTOSPIRACEA

Family RHYNCHOSPIRINIDAE

Genus HUSTEDIA Hall and Clarke 1893

Hustedia mormoni (Marcou)

Plate I, no. 10-13

Terebratula mormoni Marcou, 1858, Geology of North America; p. 51, pl. 6, figs. 11-11c.

Hustedia mormoni (Marcou), Weller, 1898, U. S. Geol. Survey Bull. 153, p. 308.

Description--The shell is small, longer than wide, and sub-ovate in outline. The greatest width is anterior to the midlength, the greatest thickness is posterior to it. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	12	10	8
Width (mm)	10	8.5	7
Thickness (mm)	7	7	4.5

The brachial valve is usually as deep or deeper than the pedicle valve. It is strongly convex transversely, moderately convex from beak to umbo and gently convex from the umbo to the anterior margin. The beak is small and inconspicuous, mostly hidden by the pedicle beak.

The pedicle valve is similar in shape to the brachial, but has a median flat area running the length of the shell, which is depressed into a faint sinus on the anterior slope. The umbonal slopes are steep. The beak is narrow, elevated, with a terminal round foramen, and arches over a small, triangular symphytium.

The surface of the brachial valve is ornamented by 13 to 17 sharp, angular plications, and the pedicle valve has 12 to 16 similar plications. All of the plications on both valves radiate from the beaks, except on the anterior margins of large shells where one plication may bifurcate on each valve. The plications cause a jagged line of commissure.

Discussion--This species resembles H. miseri, but has fewer and coarser plications.

Material and occurrence--H. mormoni ranges throughout the Pennsylvanian in the Mississippi Valley region, and is found in many of the western states.

Several specimens were found, but the most abundant occurrence was in unit 12 of section II. One specimen was found in unit 62 of section II, illustrating that the species ranges throughout the section and spans the Derryan-Desmoinesian boundary.

Hustedia miseri Mather

Plate I, no. 14-16

Hustedia miseri Mather, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 196, pl. 13, figs. 5-6c.

Description--The shell is small, subovate, longer than wide, with the greatest width near midlength and the greatest thickness slightly posterior to the midlength. The dimensions of three specimens are:

Specimen	1	2	3
Length (mm)	10.5	10	10
Width (mm)	8.5	8.5	7.5
Thickness (mm)	5	6	5.5

The brachial valve is most convex from beak to umbo, and less convex to the anterior margin. The umbonal slopes are steep, curving back to the small beak which is incurved beneath the pedicle beak.

The pedicle valve is most convex from beak to umbo, and less convex to the anterior margin. The umbonal slopes are steep and curve back to the small symphytium. The beak is prominent, narrow, and arches over the interarea strongly. At the apex of the beak is a small, round, terminal foramen. A faint median sinus runs from the umbo to the anterior margin, caused by the depression of the middle two plications.

Ornamentation on the pedicle valve consists of 20 to 22 even, subangular plications which radiate from the beak and become faint toward the posterolateral margins. The brachial valve has 19 to 23 identical plications which also radiate from the beak.

Discussion--This species resembles H. mormoni but has more numerous plications which are smaller and finer.

Material and occurrence--This species is not known to range into rocks younger than Morrowan in Arkansas and Oklahoma (Dunbar and Condra, 1932, p. 358). H. miseri is abundant in unit 12 of section II, of Derryan age, but was not found anywhere above it.

Family SPIRIFERINIDAE

Genus PUNCTOSPIRIFER North 1920

Punctospirifer kentuckyensis (Shumard)

Plate I, no. 17-20

Spirifer kentuckyensis Shumard, 1855, Geol. Survey of Missouri, Ann. Rept. II, p. 203.

Spiriferina kentuckensis (Shumard) Meek, 1872, U. S. Geol. Survey of Nebraska, Final Rept., p. 185, pl. 6, figs. 3a-d, pl. 8, figs. 11a-b.

Punctospirifer kentuckyensis (Shumard) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 351-355, pl. 38, figs. 1-5.

Description--The shell is small, about twice as wide as long, widest at the hingeline, and strongly biconvex. The cardinal extremities are extended or truncated, depending on the individual. Dimensions of three specimens are:

Specimen	1	2	3
Length (mm)	9	10	8
Width (mm)	19	16	16
Thickness (mm)	9.5	8	8

The brachial valve is moderately convex from beak to umbo, and gently convex from the umbo to the anterior margin. The valve slopes gently from the narrow, high, flat-topped fold to the cardinal extremities.

The beak is small, barely projecting beyond the hingeline, and the cardinal area is narrow and linear. The fold may have a slight depression or groove along the middle in mature specimens.

The pedicle valve is strongly and regularly convex from beak to anterior margin and slopes moderately to the cardinal extremities. The beak is conspicuous and arches over a high, triangular, interarea that is flat except where it curves slightly at the apex under the beak. A deep, narrow sinus begins at the beak and continues to the anterior margin, with a slight ridge along the middle.

On each lateral slope of the pedicle valve there are 5 to 9 coarse, subangular plications, while on the brachial valve there are rarely more than 7. Only the innermost 3 or 4 plications radiate from the beak. The surface of both valves is covered with very closely spaced, fine, regular growth lamellae, which are finely fimbrate. There are 4 or 5 of these per mm along the summit of the plications at midlength of the valve. The shell substance is coarsely punctate, with the punctae appearing as little granules when the surface of the shell is weathered.

Discussion--The only other species with which this might be confused in the Pennsylvanian is P. transversus, which is wider, and has more numerous and finer plications. All Spiriferina and Reticulariina lack the distinctive surface ornamentation of this species.

Material and occurrence--This species is widely distributed throughout the midwestern and western United States and ranges throughout the Pennsylvanian.

Specimens were collected from units 12, 27, and 43 of section II, of Derryan and Desmoinesian age.

Genus RETICULARIINA Fredericks 1916

Reticulariina aff. R. campestris (White)

Plate I, no. 21-24

Spiriferina spinosa var. campestris White, 1874, U. S. Geog. and Geol. Survey W. of 100th Mer. (Wheeler), Prelim. Rept. Inv. Fossils, p. 21

Spiriferina octoplicata White, 1877, U. S. Geog. Explor. W. 100th Mer., vol. 4, p. 139, pl. 10, figs. 8a-c.

Spiriferina gonionota Meek, 1877, U. S. Geol. Explor. of 40th Par., vol. 4, p. 85.

Spiriferina campestris White, Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 396.

Reticulariina campestris (White) Easton, 1962, U. S. Geol. Survey Prof. Paper 348, p. 84.

Description--The shell is small, strongly biconvex, wider than long, with the greatest width at or just anterior to the hingeline. The

cardinal extremities are either pointed or slightly rounded. The greatest thickness is slightly posterior to the midlength. Dimensions of four specimens are:

Specimen	1	2	3	4
Length (mm)	10	10	10	9
Width (mm)	15	15	15	13
Thickness (mm)	7.5	7	8	6

The brachial valve is less convex than the pedicle valve, with a small, but distinct, beak barely projecting beyond the hingeline. A high, round-topped fold originates at the beak and widens anteriorly. The fold has very little longitudinal curvature from the umbo to the anterior margin, at which point it is much higher than any other part of the valve. The interarea of this valve is reduced, and lies in the same plane as the valve.

The pedicle valve is strongly and regularly convex from the beak to the anterior margin, and slopes moderately to the cardinal extremities. The beak is large, prominent, and elevated over the broadly triangular interarea. This area is flat near the bottom, but gently concave under the beak, meeting the plane of the valves at about 45°. An open triangular delthyrium is present. A deep, round-bottomed sinus begins on the beak and widens toward the anterior margin where it is produced in a tongue-like extension in the corresponding fold.

The pedicle valve has 6 or 7 high, subangular plications on each lateral slope, with the two bounding the sinus being much larger than the rest. The outer plications are low and do not reach the beak. The same number and type of plications occur on the brachial valve, but the round-bottomed grooves bounding the fold are not disproportionately larger than the other grooves.

The surfaces of both valves are ornamented with rows of fine spines which are parallel to the obscure and rare growth lamellae. These spines seem to grow out of punctae. There are 10 to 15 of these spine rows per mm on the anterior slope of the brachial valve. Although the growth lamellae are indistinct and rare on the valve surfaces, they are common and finely fimbrate at the anterior margins. The spines and corresponding punctae on the pedicle valve are coarser than those on the brachial valve. There are only 6 to 8 rows of spines per mm on the pedicle valve.

Discussion--The specimens collected closely resemble the descriptions and illustrations of R. campestris. One major difference is that this species normally exceeds 20 mm in diameter (Easton 1962, p. 84), whereas none of the specimens collected during this study exceeds 10 mm in diameter. R. campestris closely resembles R. spinosa, but has finer spines, a higher interarea, more angular plications, and is larger and proportionately wider than R. spinosa.

Material and occurrence--This species is known from Morrowan rocks of Arkansas and Oklahoma, and has been reported from the Hermosa and Weber Formations of Morrowan, Derryan, and Desmoinesian age in Colorado, New Mexico, and Nevada.

Several specimens were collected from unit 12 of section II, of Derryan age.

Reticulariina aff. R. spinosa (Norwood and Pratten)

Plate I, no. 25-26

Spirifer spinosus Norwood and Pratten, 1855, Philadelphia Acad. Nat. Sci. Jour., ser. 2, vol. 3, p. 71, pl. 9, figs. 1a-d.

Spiriferina spinosa (Norwood and Pratten) Hall, 1883, New York State Geologist Rept. (1882), pl. 60, figs. 26-29.

Reticulariina spinosa (Norwood and Pratten) Fredericks, 1916, Geol. Kom. Trudy, novaia ser., vol. 156, p. 16 (designated genotype of Reticulariina).

Spiriferina browni Branson and Gregor, 1918, Geol. Soc. of America Bull., vol. 29, p. 312, 316, pl. 18, figs. 15, 17.

Reticulariina spinosa (Norwood and Pratten) Easton, 1962, U. S. Geol. Survey Prof. Paper 348, p. 83-85, pl. 10, figs. 12-16.

Description--The shell is small, subtriangular in outline, biconvex, widest at the rounded cardinal extremities, and slightly wider than long.

The greatest width is slightly anterior to the hingeline and the greatest thickness is at midlength. The measurements of one specimen are:

Specimen	1
Length (mm)	9.5
Width (mm)	11
Thickness (mm)	7

The brachial valve is slightly less convex than the pedicle valve, with a small beak which barely projects over the hingeline. A very narrow, high, round-topped fold runs from the beak to the anterior margin, with a deep, wide groove on each side. There are 5 rounded plications on each lateral slope, with the outer ones becoming less distinct.

The pedicle valve is strongly convex from beak to umbo and moderately convex from the umbo to the anterior margin. The lateral slopes are steep and curve in to the large, pointed, elevated beak which arches over the high, curved interarea. A deep, round-bottomed sinus originates at the beak and widens to the anterior margin where it is produced in a tongue-like extension with the corresponding brachial fold. The plications bounding this sinus are the largest on the valve. There are six rounded plications on each lateral slope of the valve, diminishing in size towards the extremities, and the outer two do not reach the beak.

The surfaces of both valves are ornamented with irregularly disposed lamellose growth lines which loop posteriorly over the plications. Prominent punctae occur in rows parallel to the growth lamellae, and there appear to be 6 or 7 rows of punctae per mm. The punctae have small spines growing out of them, but these may only be seen in the grooves between plications where sediment still protects them.

Discussion--This species resembles some species of Punctospirifer, but lacks the close, regular spacing of the growth lamellae and the extreme width of that genus. R. spinosa also resembles R. campestris rather closely, but the latter is usually larger, with a greater width to length ratio, is more tumid, has only rare growth lamellae and smaller, more numerous punctae and spines.

Material and occurrence--This species is widely distributed in rocks of the Chester Series in the midcontinent region. The species is also known from the Amsden Formation of Wyoming, and the Cameron Creek Formation and Alaska Bench Limestone of Montana. The Montana occurrence may be either Late Mississippian or Early Pennsylvanian (Easton, 1962, p. 15-16).

Only one specimen was found, in unit 12 of section II, and is Derryan in age.

Superfamily ROSTROSPIRACEA

Family ATHYRIDAE

Genus COMPOSITA Brown 1845

Composita argentea (Shepard)

Plate II, no. 1-5

Terebratula argenta Shepard, 1838, American Jour. Sci., vol. 34, p. 152, fig. 8.

Seminula argentea (Shepard) Weller, 1898, U. S. Geol. Survey Bull. 153, p. 561.

Composita argentea (Shepard) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 367, pl. 43, fig. 1-6.

Description--Individuals of this species may be large or small, are subovate to subcircular in outline, and have their greatest width and thickness at or near the midlength of the valve. Measurements of four specimens are:

Specimen	1	2	3	4
Length (mm)	24	20.5	20	19
Width (mm)	21	18	18	17
Thickness (mm)	11	10.5	10.5	10

The brachial valve is subcircular in outline with a small, inconspicuous beak. The valve is moderately convex from beak to umbo,

sloping gently to the anterior margin and more steeply to the postero-lateral margins. A low, rounded fold appears on the umbo and continues to the anterior margin.

The pedicle valve is broadly subovate to subcircular in outline, with a short, blunt beak which terminates in a round foramen. Viewed from above, the outline of the valve is gently concave where the beak projects past the posterior margin. A shallow, narrow sinus developes high on the umbo, continuing to be shallow and narrow to the anterior margin where it may be slightly produced into the corresponding brachial fold.

On well preserved shells fine concentric growth lines and radial striae may be seen. Many specimens exhibit larger sublamellose growth lines, especially near the anterior margin.

Discussion--This species resembles and grades into C. subtilita (Grinnell and Andrews, 1964, p. 242). In its most typical development, however, it is smaller, thinner, more ovate, with the greatest width near the midlength, not anterior to it, as compared with C. subtilita. C. argentea is smaller, thicker, less circular in outline, and has a more pronounced sinus and fold than C. ovata, into which it also grades. The development of the fold and sinus is midway between that of C. ovata and C. subtilita.

Material and occurrence--In the Pennsylvanian rocks throughout the United States, this species is known to range from the base of the Desmoinsian to the top of the Virgilian.

Numerous specimens were collected from units 12, 18, 27, 43, and 68 of section II. These collections show that this species is found in rocks of Derryan as well as Desmoinesian age in Arizona.

Composita derrya Gehrig

Plate II, no. 6-9

Composita derrya Gehrig, 1958, New Mexico State Bur. Mines and Min. Resources, Mem. 3, p. 12, pl. 4, figs. 9-27.

Description--The shell is broadly subovate, wider than long, with the greatest width slightly anterior to the midlength of the shell. The shell is deep, with the greatest thickness occurring at or near the midlength. Measurements of two specimens are:

Specimen	1	2
Length (mm)	16 (reconstructed)	23 (reconstructed)
Width (mm)	19	23
Thickness (mm)	11.5	17

The brachial valve is broadly subovate with a small, inconspicuous beak that barely projects over the hingeline. The valve is strongly convex from beak to umbo, sloping slightly to the anterior margin and curving

sharply to the posterolateral margins. A small, narrow, ill-defined fold develops on the anterior portion of the umbo, widening to the front of the valve where it has a shallow sinus on each side of it and is slightly produced into the corresponding pedicle sinus.

The pedicle valve is deeper and more convex than the brachial valve, with a broadly ovate outline. The convexity is greatest from beak to umbo with a flat steep slope to the anterior margin. The lateral slopes are moderately steep, converging to form a beak which is missing in both the specimens collected. A narrow sinus develops on the umbo, remaining shallow but widening to the anterior margin where it is slightly produced into the corresponding brachial fold.

The surfaces of both valves are ornamented by concentric, sublamellose lines of growth.

Discussion--These specimens resemble closely the description and illustrations of Gehrig. The smaller specimen is immature, which is why the width so greatly exceeds the length (Gehrig,1958, p. 12). This species resembles no other Composita in the section. Its great thickness and sublamellose growth lines differentiate it from other species in the Pennsylvanian.

Material and occurrence--This species has previously been reported only from Derryan and Desmoinesian rocks of New Mexico.

Two specimens were found, one from unit 13, section II and one from unit 37, section I, spanning the Derryan-Desmoinesian boundary.

Composita malaya Gehrig

Plate II, no. 10-16

Composita malaya Gehrig, 1958, New Mexico State Bur. Mines and Min. Resources, Mem. 3, p. 13, pl. 4, figs. 32-36.

Description--Individuals of this species may be large or small, are elongate in outline, and have their greatest width at or just anterior to the midlength of the shell. The shells are thick, with a subcylindrical cross section. Measurements of four specimens are:

Specimen	1	2	3	4
Length (mm)	22	23	21.5	20
Width (mm)	16	17	15	15
Thickness (mm)	14.5	13	14	12

The brachial valve is elongate suboval in outline with a small, inconspicuous beak. The valve is of low but regular convexity from beak to anterior margin, sloping more steeply to the posterolateral margins. A low, poorly defined, rounded fold develops on the anterior slope.

The pedicle valve is suboval in outline, strongly and regularly convex from beak to anterior margin, and hemispherical in outline as seen from the side. The beak is short, blunt, and strongly incurved. The sinus is shallow and narrow, occupying the anterior half of the valve, and is moderately produced into the corresponding brachial fold.

The surfaces of well preserved shells exhibit fine radial and concentric striae, and coarser growth lines which become sublamellose on the anterior portions of the shells.

Discussion--This species closely resembles C. elongata of Missourian age, but is larger, thicker, and has a more regularly curved brachial valve.

Material and occurrence--This species has previously been reported only from the Derryan of New Mexico.

Numerous specimens were found in units 13 and 43 of section II, spanning the Derryan-Desmoinesian boundary. This is the first report of this species in Desmoinesian rocks.

Composita ovata Mather

Plate II, no. 17-20

Composita ovata Mather, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 202, pl. 14, figs. 6a-c.

Description--Individuals of this species may be large or small, are subovate to subcircular in outline, longer than wide, with the greatest width at or slightly anterior to the midlength of the shell. The shells are typically thin for this genus, with the greatest thickness occurring at midlength. Measurements of four specimens are:

Specimen	1	2	3	4
Length (mm)	22	20	20.5	17
Width (mm)	20	20	20.5	16.5
Thickness (mm)	10	9.5	9	8.5

The brachial valve is moderately convex from the beak to the umbo, sloping gently from the umbo to the anterior and lateral margins. A very low, rounded, almost obsolete fold occupies the anterior portion of the valve. The beak is small, barely interrupting the circular outline of the valve.

The pedicle valve is suboval in outline with a slightly longer, incurved, blunt beak which has a round, terminal foramen. The valve is most convex from the beak to the umbo, sloping gently to the anterior margin and more steeply to the posterolateral margins. A shallow median sinus develops near the umbo and continues to the anterior margin where it slightly depresses the line of commissure.

On well preserved shells fine concentric growth lines and radial striae may be seen. A few specimens exhibit larger, sublamellose growth lines, especially near the anterior margin of the shell.

Discussion--This species resembles C. argentea but is larger, less convex, and has a more circular outline with a less pronounced anterior fold and sinus.

Material and occurrence--This species is found in rocks of Morrowan to Wolfcampian age in much of the midwestern and western United States.

Several specimens were found in units 13 and 27 of section II, of Derryan age.

Composita subtilita (Hall)

Plate II, no. 21-26

Terebratula subtilita Hall, 1852, Stansbury's Exped. to Great Salt Lake, p. 409, pl. 4, figs. 1a-2c.

Composita subtilita (Hall) Dunbar and Condra, 1932, Nebraska Geol. Survey, Bull. 5, 2nd ser., p. 363, pl. 43, figs. 7-13

Description--Individuals of this species may be large or small, are subovate in outline and are usually slightly longer than wide. The greatest width is normally about two-thirds the distance from the beak to the anterior margin, while the greatest thickness occurs at midlength. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	30	26	24
Width (mm)	28	26	23
Thickness (mm)	15	13	12.5

The brachial valve is most convex from the beak to the umbo, then slopes gently to the anterior margin and more sharply to the postero-lateral margins. The beak is small and inconspicuous, barely incurved over the hingeline. A low, broad fold occupies the anterior half of the valve.

The pedicle valve is more regularly convex, with the postero-lateral slopes converging to form a prominent, tightly incurved beak which conceals the interarea and terminates in a small round foramen. A narrow, shallow depression appears on the umbo and continues along the bottom of the broad, shallow sinus to the anterior margin of the valve. The broad sinus occupies only the anterior half of the valve and is produced into the corresponding brachial fold at the anterior margin.

On well preserved shells the surfaces of both valves are ornamented with fine radial striations and much more prominent concentric growth lines. The growth lines are more common near the anterior where they may be sublamellose.

Discussion--C. subtilita resembles and intergrades with C. ovata and C. argentea. C. ovata is thinner and more circular in outline than C. subtilita, while C. argentea is most easily distinguished by its smaller size and shallower, narrower, less accentuated sinus.

Material and occurrence--This species is very common in rocks of Derryan to Leonardian age throughout much of the United States.

Several specimens were found in unit 14 of section I, and in units 13, 18, 27, 42, and 43 of section II, spanning the Derryan-Desmoinesian boundary.

Superfamily SPIRIFERACEA

Family SPIRIFERIDAE

Genus NEOSPIRIFER Fredericks 1924

Neospirifer cameratus (Morton)

Plate III, no. 1-4

Spirifer cameratus Morton, 1836, American Jour. Sci., vol. 29, p. 150, pl. 2, fig. 3.

Neospirifer cameratus (Morton) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 334-336, pl. 39, figs. 4, 6-9b.

Description--The shell is large, wider than long, with the greatest width at the hingeline. The cardinal extremities may be pointed or blunt and the greatest thickness is at midlength. Measurements of two specimens are:

Specimen	1	2
Length (mm)	35	30
Width (mm)	56	58
Thickness (mm)	21	23

The brachial valve is strongly convex from beak to umbo, then regularly and gently convex from the umbo to the anterior margin. The lateral slopes are gentle to the posterolateral margins. The beak is small but prominent, and curls over the narrow, linear cardinal area. A fold appears at the beak as a fascicle of plications, which begin to split almost at once. The fold is low and rounded, with 12 to 14 rounded plications on it. Each lateral slope has 8 or 9 plications per centimeter at midlength.

The pedicle valve is similar in shape and convexity to the brachial valve. The prominent beak is large, sharp, incurved, and arches over the wide cardinal area. The cardinal area is linear, about one-tenth as high as wide, gently curved near the top for its entire span. The area is inclined at about 45° to the plane of the valve, vertically striated, with faint horizontal striae, and an open triangular delthyrium. A narrow sinus appears on the beak and becomes broad, shallow, and round-bottomed on the anterior slope. The sinus is produced into the corresponding brachial fold at the anterior margin. The plications on both valves are low and rounded, with excellent fasciculation near the beak, but the fascicles become more obscure on the rest of the valve. There are 12 to 14 plications in the sinus of the pedicle valve and 8 or 9 plications per centimeter on each lateral slope, at midlength.

When well preserved, the surface of the shell shows extremely fine radial striae and slightly coarser concentric striae.

Discussion--This species resembles N. triplicatus, but that species has more angular plications with much stronger fasciculation. The fold and sinus on N. cameratus are more rounded and less pronounced than on N. triplicatus. N. goreii also resembles this species, but has finer and more numerous plications which are more angular. The grouping of the plications into fascicles is sufficient to distinguish members of this genus from any other spiriferid.

Material and occurrence--This species appears to be confined to rocks of Derryan and Desmoinesian age in the midwestern and western United States.

The species is rare, but a few specimens were collected from units 27, 40, and 68 of section II, spanning the Derryan-Desmoinesian boundary.

Neospirifer goreii (Mather)

Plate III, no. 5-6

Spirifer goreii Mather, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 186, pl. 12, figs. 10-11a.

Neospirifer goreii (Mather) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 341-342, pl. 39, figs. 1-3.

Description--The shell is large, about twice as wide as long, with the greatest width along the hingeline, and the greatest convexity near midlength. Dimensions of two crushed specimens are:

Specimen	1	2
Length (mm)	37	26
Width (mm)	52	50

The brachial valve is crushed on all specimens collected so that detail is difficult to see.

The pedicle valve is moderately and regularly convex from beak to umbo, and gently convex from the umbo to the anterior margin. The lateral slopes are gentle, and give a concave profile as the cardinal extremities are approached. The beak is prominent, sharp, and arches over a triangular, open delthyrium in the linear cardinal area. The area is about one-tenth as wide as long, gently concave, vertically and horizontally striated, and has a crenulated base. A well defined sinus appears on the beak, bounded by a strong plication on each side. On the umbo it is still well defined, and contains 2 or 3 plications, but on the anterior slope this sinus becomes shallow and indistinct. The plications are fine, subrounded to subangular, faintly fasciculated, except near the beak, where the fasciculation is strong. There are 11 or 12 plications per centimeter at midlength on each lateral slope.

On well preserved shells, the surface shows fine radial and concentric striae and rare, coarse growth lines.

Discussion--This species resembles N. cameratus, but has finer and more numerous plications. N. triplicatus has larger, less numerous, more angular, and strongly fasciculated plications.

Material and occurrence--This species is known to range from Morrowan to Desmoinesian age in the midwestern United States, and Texas.

A few crushed specimens were found in unit 43, section II, of Desmoinesian age.

Genus PHRICODOTHYRIS George 1932

Phricodothyris perplexa (McChesney)

Plate III, no. 7-10

Spirifer perplexa McChesney, 1860, Chicago Acad. Sci. Trans., vol. I, p. 43.

Reticularia perplexa (McChesney) Weller, 1898, U. S. Geol. Survey Bull. 153, p. 520

Squamularia perplexa (McChesney) Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 392, pl. 6, figs. 8-10a.

Phricodothyris perplexa (McChesney) Shimer and Shrock, 1944, Index Fossils of North America, p. 327-328, pl. 126, figs. 9-10.

Description--The shell is of medium size, subcircular in outline, gibbous, and a little wider than long. The greatest width is at midlength and the greatest thickness is just posterior to the midlength. Measurements of two specimens are:

Specimen	1	2
Length (mm)	13.5	14
Width (mm)	14.5	15
Thickness (mm)	8	damaged

The brachial valve is moderately convex from beak to umbo, and gently convex to the anterior margin. The umbonal slopes are moderately steep to the posterolateral margins, where the cardinal extremities are broadly rounded. The beak is broad and low, barely arching over the hingeline which is approximately equal to half the width of the shell. A distinct hair-like furrow runs from the umbo to the anterior margin.

The pedicle valve is strongly convex from the umbo to the anterior margin, with a large, prominent, moderately sharp beak which arches high over the triangular cardinal area that curves beneath it. The umbonal slopes are steep to the posterolateral margins and curve around under the beak to meet the interarea. The cardinal extremities are broadly rounded. A large, open delthyrium in the shape of an isosceles triangle occupies the pedicle interarea, curving as does the interarea. A thin, hair-like furrow may also occur on this valve, from the umbo to the anterior margin.

The surfaces of both valves are ornamented with concentric bands that become more prominent anteriorly. The bands bear parallel rows of spines which lie flat against the surface and give a faintly striated appearance to the shell. On large individuals the line of commissure may show a faint fold and sinus, but this feature, if present, is very indistinct.

Discussion--The only other Pennsylvanian species with which this species might be confused is P. transversa, and that species is larger, with a greater width to length ratio than P. perplexa.

Material and occurrence--This species is known to occur in rocks of Desmoinesian to Missourian age over most of the United States (Dunbar and Condra,1932, p. 316). It has also been found in Derryan rocks of New Mexico (Gehrig,1958, p. 17).

This species was rare in the sections measured, but was collected from unit 43 of section II, and unit 38 of section I, of Desmoinesian age.

Genus SPIRIFER Sowerby 1815

Spirifer occiduus Sadlick

Plate III, no. 11, Plate IV, no. 1-5

?Spirifer boonensis Swallow, 1860, St. Louis Acad. Sci. Trans., vol. 1, p. 646.

Spirifer boonensis? Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 381, pl. 6, figs. 1-3.

Spirifer opimus Hall var. occidentalis Girty, 1927, U. S. Geol. Survey Prof. Paper 152, p. 433, pl. 27, figs. 28-31.

Spirifer occidentalis Girty Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 322-326, pl. 41, figs. 12-16.

Spirifer occiduus Sadlick, 1960, Jour. Paleont., vol. 34, no. 6, p. 1210-1214.

Description--The shell is broad, about two-thirds as long as wide, of medium size, with the greatest width along the hingeline and the greatest thickness just posterior to the midlength. The cardinal extremities are usually slightly extended. Dimensions of three specimens are:

Specimen	1	2	3
Length (mm)	27	26	22
Width (mm)	39	35	32
Thickness (mm)	18	18.5	15

The brachial valve curves strongly from the beak to the umbo, flattening anteriorly. The lateral slopes are slightly concave from the steep, high umbo and fold to the flat posterolateral margins. The beak is small, arching over a narrow, linear area which contains a low, broad, triangular notothérium. The interareas of the two valves meet at right angles. The prominent rounded fold begins as a single plication on the beak which bifurcates almost immediately. The two plications just formed each bifurcate twice, high on the umbo, forming a total of 6 plications on the fold. The lateral slopes each bear 10 to 12 coarse, subangular to subrounded plications which all radiate from the beak.

The pedicle valve is strongly and regularly convex from beak to umbo, then moderately and regularly convex from the umbo to the anterior margin. The posterolateral slopes are gently convex. The beak is of moderate size, sharp, and arches over the hingeline. The cardinal area is large, linear, and flat except at the top where it curves to meet the beak. This area is horizontally and vertically striated, and has small denticulations on the hinge at the ends of the vertical

striations. A large, open delthyrium in the shape of an isosceles triangle is present. A broad shallow sinus begins at the tip of the beak between two bounding plications. A median plication appears about 2 mm from the beak, remains simple, but increases in size to the anterior margin. The bounding plications bifurcate twice, giving a total of five plications in the sinus. The median plication is the largest on the valve and the sinus is somewhat produced into the corresponding brachial fold. On each lateral slope there are 12 to 13 coarse, subangular to subrounded plications, of which the outermost do not reach the beak.

When the shells are well preserved, fine radial and concentric striae may be seen.

Discussion--This species may be distinguished from both S. rockymontanus and S. opimus by its much greater width to length ratio, even when the cardinal extremities are broken.

Material and occurrence--This species is widely distributed throughout the midwestern and western United States in rocks of Derryan and Desmoinesian age.

Several specimens were collected from units 13, 18, 34, 43, and 68 of section II, and from unit 27 of section I, spanning the Derryan-Desmoinesian boundary.

Spirifer opimus Hall

Plate IV, no. 6-10

Spirifer opimus Hall, 1858, Geol. of Iowa, vol. I, pt. II, p. 711, pl. 28, figs. 1a-b.

Description--The shell is usually slightly wider than long, with the greatest width at or near the hingeline and the greatest thickness approximately at midlength. Measurements of two specimens are:

Specimen	1	2
Length (mm)	26	20.5
Width (mm)	32	24
Thickness (mm)	15	13

The brachial valve is moderately convex, with a small pointed beak that barely arches over the narrow, linear cardinal area. The fold is narrow and of moderate height, starting as a single plication at the beak, bifurcating almost immediately, and each plication bifurcating again to form a total of 4 plications. On some shells the outer plications bifurcate again, giving a total of 6 plications on the fold. Each lateral slope has 9 to 11 broad, rounded, plications with narrow grooves between them.

The pedicle valve is strongly and regularly convex from the beak to the umbo, then less convex to the anterior margin. The lateral slopes are moderately steep from the edges of the broad, shallow sinus

to the curving posterolateral margins. The beak is sharp, tightly incurved, and strongly arches over the triangular interarea. This interarea is flat except where it curves up under the beak, and it contains an open delthyrium in the shape of an isosceles triangle. The interarea shows faint horizontal and vertical striations, and meets the area of the other valve at right angles.

On well preserved shells the surface exhibits very fine and regular concentric and radial striae which form minute nodes where they intersect. Also, the anterior third of the shell bears sublamellose growth lines.

Discussion--This species may be distinguished from S. rockymontanus by the broader and much more rounded plications. Also, the fold of S. opimus usually has only four plications whereas S. rockymontanus has at least 6 and usually 8. S. occiduus has a much higher ratio of width to length than this species.

Material and occurrence--This species is known to range from Derryan to Desmoinesian age in much of the midwestern and western United States.

A few specimens were collected from units 13, 18, and 43 of section II, and unit 27 of section I, spanning the Derryan-Desmoinesian boundary.

Spirifer rockymontanus Marcou

Plate IV, no. 11-16

Spirifer rocky-montani Marcou, 1858, Geology of North America, p. 50, pl. 7, figs. 4c-e, (not figs. 4, 4a, b).

Spirifer rockymontanus Marcou Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 383, pl. 6, figs. 5-7c.

Description--The shell is a little wider than long with the hinge-line equal to or slightly less than the greatest width. The cardinal extremities are obtusely angular or somewhat rounded. The greatest thickness is just posterior to the midlength. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	26	22	10
Width (mm)	32	28	10.5
Thickness (mm)	17	13	6

The brachial valve is semicircular in outline, moderately convex longitudinally with gently sloping posterolateral slopes. A strong, elevated, narrow fold begins on the small incurved beak as a median plication which subdivides immediately. Each plication subdivides twice more within 5 mm of the beak, giving a total of 6 plications on the fold. In large shells the outer plications subdivide again, giving

a total of 8 plications. There are 10 to 12 high, angular plications on each lateral slope.

The pedicle valve is strongly convex from beak to umbo, and less strongly but regularly convex from umbo to the anterior margin, with moderately steep posterolateral slopes. The beak is large, tightly incurved, and strongly arches over the triangular interarea which curves beneath it. This interarea is vertically striated, contains an open delthyrium in the shape of an isosceles triangle, and meets the brachial interarea at right angles. The broad, shallow sinus originates on the beak between two plications. Near the beak a simple, median plication arises and the bounding plications bifurcate. The median plication remains simple to the anterior margin where the sinus is produced into a pointed tongue in the corresponding brachial fold. The two bounding plications bifurcate on the umbo, giving a total of 5 plications in the sinus. On each lateral slope there are 10 to 12 angular to subangular plications, somewhat less sharp than those on the brachial valve.

On the surfaces of well preserved valves fine radial and concentric striae may be seen.

Discussion--This species forms a closely related group with S. opimus and S. occiduus. S. opimus has low, rounded plications,

and fewer plications on the fold than S. rockymontanus. S. occiduus has a much greater width to length ratio than S. rockymontanus.

Material and occurrence--This species is widely distributed in Derryan and Desmoinesian rocks of the midwestern and western United States.

A few specimens were collected from units 13 and 43 of section II, and unit 27 of section I, spanning the Derryan-Desmoinesian boundary.

Order PROTREMATA

Superfamily PRODUCTACEA

Family BUXTONIIDAE

Genus JURESANIA Fredericks 1928

Juresania nebrascensis (Owen)

Plate IV, no. 17-18, Plate V, no. 1-2

Productus nebrascensis Owen, 1852, Geol. Rept. Wisconsin, Iowa, and Minnesota, p. 584, pl. 5, fig. 3.

Pustula nebrascensis (Owen) Girty, 1915, U. S. Geol. Survey Bull. 544, p. 65-68, pl. 10, fig. 7.

Juresania nebrascensis (Owen) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 195-198, pl. 22, figs. 1-9, 13

Description--The shell is of medium size, subquadrangular in outline with the greatest width near the anterior. The hingeline is slightly less than the greatest width and the greatest thickness is just posterior to the midlength. Measurements of two specimens are:

Specimen	1	2
Length (mm)	22	23
Width (mm)	24	24
Thickness (mm)	11	13

The brachial valve is moderately flat over the visceral area but slopes up near the anterior and lateral margins, giving the valve a slight concavity. The surface is ornamented with faint costae and concentric rugae, and with small, flat-lying spines.

The pedicle valve is strongly convex from beak to umbo, and regularly convex from the umbo to the anterior margin. The posterolateral slopes drop steeply from the umbo to the margins, curving gently back to the prominent beak which projects slightly past the hingeline. The ears are small and flat. The posterior surface of the valve is covered with faint costae and rugae. Two types of spines are also present. Individuals of one set are large and project from the shell at a high angle, while the other set contains smaller spines that project from the shell to lie flat on the surface. On the anterior portion of the valve the spines are restricted to concentric bands, with the smaller, flat-lying

spines on the front of the band and the larger spines on the back slope of the band.

Discussion--The only other Juresania with which this species might be confused is J. symmetrica, which is larger and more hemispherical in outline. The flat-lying spines are sufficient to set this species apart from other Pennsylvanian productids.

Material and occurrence--This species ranges through sediments of Desmoinesian to Wolfcampian age in much of the midwestern and western United States.

A few specimens were collected from units 18 and 27 of section II, illustrating that this species occurs in the Upper Derryan of Arizona.

Family DICTYOCLOSTIDAE

Genus ANTIQUATONIA Miloradovich 1945

Antiquatonia coloradoensis (Girty)

Plate V, no. 3-7

Productus inflatus McChesney, 1860, Chicago Acad. Sci. Trans., vol. I, p. 40.

Productus inflatus var. coloradoensis Girty, 1910, New York Acad. Sci. Annals, vol. 20, no. 3, pt. 2, p. 215.

Dictyoclostus inflatus var. coloradoensis (Girty), Muir-Wood, 1930, Ann. Mag. Nat. Hist., ser. 10, vol. 5, no. 25, p. 100-108.

Antiquatonia coloradoensis (Girty) Miloradovich, 1945, Acad. Sci. USSR Bull., Biol. Ser., no. 4, p. 485-500 (in Russian with English summary).

Description--The shells are of medium size, a little wider than long if the trail is not preserved, longer than wide if it is. The greatest width is at the hingeline and the greatest thickness is just anterior to it. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	38	38	35
Width (mm)	35	40	39
Thickness (mm)	22	18	(embedded in sediment)

The brachial valve is flat or gently concave and sharply geniculated anteriorly. The depressed beak is minute and a median groove runs from the umbo almost to the line of geniculation. The ears are relatively large and flat, and small spines may be visible on the costae. The interior of the valve contains a broad, low, triangular elevation that runs from the beak almost to the line of geniculation. The surface is ornamented with fine even costae and concentric rugae, similar to the outside.

The pedicle valve is strongly and evenly convex from beak to anterior margin, with steep slopes from the broad flat umbo to the posterolateral margins. The beak is large, round, and projects over

the hingeline with such convexity that much of the inflated umbo is posterior to the hingeline. The ears are small, curved, and sharply separated from the steep umbonal slopes. When preserved, at least two small spines occur along the cardinal margin. A curved row of spines runs from the ear along the base of the umbonal slope and may be on a narrow, elevated ridge. A narrow, shallow sinus begins on the umbo and runs to the anterior margin. The surface is ornamented with fine, regular, rounded costae, of which there are 10 to 13 per centimeter on the anterior slope. The posterior third of the shell has concentric rugae, diminishing in prominence anteriorly, which form little nodes where they cross the costae. Large, scattered spine bases up to one mm in diameter arise from the costae which may then thicken and bifurcate. These spine bases vary in abundance from shell to shell and usually number about six. The costae increase mainly by bifurcation rather than by intercalation.

Discussion--This species closely resembles A. hermosana, but that species has coarser costae, smaller spines, and an umbo which does not usually project so far over the hingeline. A. portlockianus is also quite similar, but has larger and more strongly curved ears, coarser costae, and is less rounded transversely.

Material and occurrence--This species was reported from Lower Pennsylvanian rocks by Girty in the following states: Colorado, Nebraska,

Kansas, and Tennessee. The species was found in Desmoinesian rocks in New Mexico by Gehrig.

Several specimens were collected from units 27 and 42 of section I, and units 24, 27, and 40 of section II, spanning the Derryan-Desmoinesian boundary.

Antiquatonia hermosana (Girty)

Plate V, no. 8-11

Productus semireticulatus var. hermosanus Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 358-359, pl. 2, figs. 1-4

Dictyoclostus hermosanus (Girty) Muir-Wood, 1930, Ann. Mag. Nat. Hist., vol. 5, ser. 10, no. 25, p. 100-108.

Antiquatonia hermosana (Girty) Miloradovich, 1945, Acad. Sci. USSR Bull., Biol. Ser., no. 4, p. 485-500 (in Russian with English summary).

Description--The shells are of medium to large size, wider than long, with the greatest width at the hingeline and the greatest thickness just anterior to it. Measurements of two specimens are:

Specimen	1	2
Length (mm)	35	33
Width (mm)	40	35
Thickness (mm)	20	19

None of the specimens collected exhibited the brachial valve.

The pedicle valve is strongly and regularly convex from the beak to the anterior margin, and has steep lateral slopes. The umbo is broad, with a narrow, shallow sinus originating on it and continuing to the anterior margin. The beak is large and blunt, and projects strongly over the hingeline. The ears are small, curved, and sharply separated from the umbonal slopes. The surface of the valve is covered with strong, regular, rarely bifurcating costae of which there are about 8 to 10 per centimeter on the anterior slope. The posterior third of the valve is covered with strong concentric rugae that form small nodes where they intersect the costae. These rugae die out anteriorly, but can still be detected at midlength. A curved row of large spine bases begins on the ears and runs anteriorly along the base of the umbonal slope, elevated on a ridge in some specimens. A few scattered, small to medium size spine bases arise from costae which may converge just posterior to the bases. Anterior to the spine base, the costae that converged form one large costa.

Discussion--This species closely resembles A. coloradoensis, but has much coarser costae and smaller spines. The latter species usually has a more inflated umbo which projects farther beyond the hingeline.

Material and occurrence--This species seems to range through rocks of Morrowan to Missourian age in Colorado (Girty,1903, p. 359), and has been found in the Desmoinesian of New Mexico.

A few specimens were collected from unit 38 section I, and unit 43, section II, of Desmoinesian age. Numerous fragments of the genus Antiquatonia are found throughout the section, but poor preservation makes specific identification impossible.

Family ECHINOCONCHIDAE

Genus ECHINOCONCHUS Weller 1914

Echinoconchus aff. E. angustus Easton

Plate V, no. 12

Echinoconchus angustus Easton, 1962, U. S. Geol. Survey Prof. Paper 348, p. 47-48, pl. 5, figs. 25, 26.

Description--The shell is small, slightly longer than wide, with the greatest width anterior to midlength. The dimensions of one specimen are:

Specimen	1
Length (mm)	23
Width (mm)	20

No brachial valves were found.

The pedicle valve is strongly convex from beak to umbo, and moderately convex from the umbo to the anterior margin. The umbo is broad, becoming narrower toward the beak and projecting posteriorly over the hingeline. The umbonal slopes are steep and the posterolateral margins are broadly rounded. An indistinct sinus originates high on the umbo and becomes more distinct anteriorly.

The ornamentation consists of concentric bands with parallel spine rows. No costae were observed. The spines are of two distinct sizes. Large spines project out of the back slopes of the concentric bands at approximately right angles to the valve surface, and smaller, flat-lying spines occur in one or sometimes two rows along the anterior edge of the bands. On the lower anterior slope there are 3 or 4 of these bands in one centimeter, but they become much more crowded toward the posterior of the valve.

Discussion--This species resembles E. genevievensis, but has a more prominent sinus and a shorter hingeline than this Mississippian species.

Material and occurrence--This species has been reported from the Heath and Cameron Formations of Chester or Morrowan age, in central Montana (Easton, 1962, p. 48).

Three poorly preserved specimens were collected from unit 18 of section II, of Derryan age.

Echinoconchus semipunctatus (Shepard)

Plate V, no. 13

Productus semipunctatus Shepard, 1838, American Jour. Sci., vol. 34 p. 153, fig. 9.

Pustula semipunctata (Shepard) Girty, 1915, Missouri Bur. Geol. and Mines, 2nd ser., vol. 13, p. 349.

Echinoconchus semipunctatus (Shepard) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 205-207, pl. 24, fig. 6; pl. 25, figs. 1-3b.

Description--The shell is large, subtriangular in outline, and slightly longer than wide. The greatest width is anterior to the midlength and the greatest thickness is posterior to the midlength. Measurements of one specimen are:

Specimen	1
Length (mm)	60
Width (mm)	55
Thickness (mm)	27

On both specimens collected the brachial valve could not be freed from the enclosing limestone.

The pedicle valve is strongly convex from beak to umbo with a gently convex anterior slope. The umbo is narrow and strongly curved over the hingeline, with a sharp beak that is curled so tightly that it almost

touches the brachial valve. A narrow, moderately deep sinus originates about one centimeter in front of the beak and continues to the anterior margin where it may become obsolete.

The surface of the pedicle valve is covered with broad, concentric bands which have gentle back slopes. On these back slopes there are 2 or 3 irregular, transverse rows of spines, which are rather fine and lie flat against the shell. Four or five of these bands occupy each centimeter along the anterior slope, but they become more crowded towards the posterior of the valve.

Discussion--The specimens were poorly preserved, and the width of the hingeline could not be determined, as the ears and brachial valves were concealed.

The only other species with which this might be confused are E. moorei and E. semipunctatus var. knighti. The latter species is smaller, has a less pronounced sinus, a less strongly convex umbo, and the blunt beak is less incurved. E. moorei has a suboval outline, is smaller, and has 3 or 4 rows of finer, more numerous spines on each concentric band than E. semipunctatus.

Material and occurrence--This species is known to range from Derryan to Missourian in the midwestern United States.

Two specimens were found in unit 28 of section II. This unit is covered, but approximately 40 feet above the base of the unit, one

outcrop to the west of the measured section contained some fossils. This unit is Derryan in age.

Family LINOPRODUCTIDAE

Genus LINOPRODUCTUS Chao, 1927

Linoproductus aff. L. platyumbonus Dunbar and Condra

Plate VI, no. 1-4

Linoproductus platyumbonus Dunbar and Condra, 1932, Nebraska Geol. Survey, Bull. 5, 2nd ser., p. 254-255, pl. 31, figs. 1-5.

Description--The shell is of medium to large size, longer than wide, with the greatest width at the hingeline. Dimensions of one specimen are:

Specimen	1
Length (mm)	30
Width (mm)	30
Thickness (mm)	14

The brachial valve is gently concave over the visceral disk then sharply geniculated. The ears are flat, conforming to the ears of the pedicle valve. The ornamentation was destroyed, except for low rugae on the ears.

The pedicle valve is strongly convex from beak to umbo and gently convex to the anterior, where the trail is broken off. The umbo is broad,

with steep lateral slopes, and projects beyond the hingeline, narrowing rapidly to form the blunt, incurved beak. The ears are relatively flat, with distinct rugae which die out on the umbonal slopes. The umbo shows a very faint, broad sinus which disappears on the anterior slope. The entire surface of the valve is covered with fine, even, rounded, radial costae. About a dozen erect spine bases are scattered over the anterior portion of the valve.

Discussion--This species is characterized by the flat umbo, faint sinus, and scarcity of spines. All specimens lack the trail and part of the anterior of the pedicle valve so that the fold described by Dunbar and Condra (1932, p. 254-255) was not preserved. Also, the ears are weathered and the width of the hingeline could not be determined.

This species resembles L. magnispinus but lacks the heavy row of spines on the anterior slope.

Material and occurrence--This species is confined to the lower Missourian of the midwestern United States (Dunbar and Condra,1932, p. 255), but has been reported from the Derryan and Desmoinesian of Mew Mexico (Gehrig, 1958, p. 21).

Specimens were collected from unit 27 of section I, and units 27, 40, and 68 of section II, spanning the Derryan-Desmoinesian boundary.

Family MARGINIFERIDAE

Genus DESMOINESIA Hoare, 1960

Desmoinesia muricatina (Norwood and Pratten)

Plate VI, no. 11-15

Productus muricatus Norwood and Pratten (non P. muricatus Phillips), 1854, Philadelphia Acad. Nat. Sci. Jour., vol. 3, 2nd ser., p. 14, pl. 1, figs. 8a-e.

Marginifera muricata (Norwood and Pratten) Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 373, pl. 5, figs. 5-5b, 6-6b.

Marginifera muricatina (Norwood and Pratten) Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2nd ser., p. 222-224, pl. 35 figs. 1-10.

Desmoinesia muricatina (Norwood and Pratten) Hoare, 1960, Jour. Paleont., vol. 34, no. 2, p. 226-227, pl. 33, figs. 8-13.

Rudinia muricatina (Norwood and Pratten) Muir-Wood and Cooper, 1960, Geol. Soc. America Mem. 81, p. 228-229. (Rudinia is a junior objective synonym of Desmoinesia Hoare).

Description--The shell is small, subrectangular in outline, wider than long, with the greatest width approximately at midlength. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	13	11	11
Width (mm)	17	16.5	16
Thickness (mm)	Not determined due to poor preservation.		

The brachial valve is gently concave over the visceral area, and geniculated at the anterior margin. The ears are small and flat, with well defined rugae. The surface of the valve has faint rugae and costae, giving it a reticulate appearance.

The pedicle valve is regularly and strongly convex from the beak to the anterior margin. The umbo is broad, with steep posterolateral slopes. The ears are small and slightly arched and the blunt beak barely projects over the hingeline. A faint median sinus appears on the umbo of many specimens, and continues to the anterior margin where it is shallow and indistinct.

The ornamentation on the pedicle valve consists of coarse, irregular costae, some of which bifurcate. There are 6 or 7 of these costae in 5 mm on the anterior slope. The posterior third of the valve has concentric rugae, strong on the ears and less distinct on the umbo, which give a reticulate appearance. There is a row of spine bases along the posterior margin of each ear, and another row curving along the base of the umbonal slopes. The entire surface of the valve is liberally sprinkled with these spine bases.

Discussion--This species resembles D. nana, but has a greater ratio of width to length, coarser costae, and more numerous spines. Retaria lasallensis resembles this species but is larger, has a strongly geniculated pedicle valve, a long trail, and a smaller length to width ratio.

Material and occurrence--This species is confined to the Desmoinesian of the midwestern United States and has been reported from the Desmoinesian and Missourian of Colorado (Girty, 1903, p. 375).

Several specimens were found in unit 43 of section II, of Desmoinesian age.

Genus RETARIA Muir-Wood and Cooper 1960

Retaria lasallensis (Worthen)

Plate VI, no. 5-10

Productus lasallensis Worthen, 1873, Illinois Geol. Survey, vol. 5, p. 569, pl. 25, fig. 9.

Marginifera lasallensis (Worthen) Girty, 1903, U. S. Geol. Survey Prof. Paper 16, p. 372, pl. 5, figs. 4, 4a.

Retaria lasallensis (Worthen) Muir-Wood and Cooper, 1960, Geol. Soc. America Mem. 81, p. 231.

Description--The shell is subquadrate in outline, a little wider than long, with the greatest width either at the hingeline or at midlength. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	15	17	14
Width (mm)	17.5	17	16
Thickness (mm)	8	8	8

The brachial valve is slightly concave over the visceral area and strongly geniculated anteriorly. The ears are flat and slightly higher than the rest of the valve. The surface is covered with low, regular costae, concentric rugae, and scattered small spine bases. The beak is small and depressed.

The pedicle valve is strongly geniculate, with a moderately convex visceral disk that tends to project over the hingeline. The umbo is low, the beak is prominent and blunt, and the lateral slopes are steep. Anterior to the line of geniculation the curvature is moderate and the trail is long. A well defined, rounded sinus begins on the umbo and extends to the anterior margin. The ears are small.

The surface of the pedicle valve is covered with fine, even costae, about 12 to 15 of which occupy one centimeter. On the visceral disk the costae are less prominent and the concentric rugae stand out. Small, very slender, erect spines are common on the surface of the shell.

The ears tend to have a row of coarser spines along the hingeline and a row running along the base of the umbonal slopes. In some specimens these tend to be scattered, not forming actual lines.

Discussion--This species resembles Desmoinesia muricatina, but that species is less convex, not geniculated on the pedicle valve, and has a shorter trail. There are also important differences in the internal structure of the brachial valve, but no interiors were observed in either species.

Material and occurrence--This species is known to range through the Missourian of the midwestern United States and through the Desmoinesian and Missourian of the western United States.

Several specimens were found in units 18, 40, and 43 of section II, of Derryan and Desmoinesian age.

Superfamily STROPHOMENACEA

Family CHONETIDAE

Genus CHONETES Fischer de Waldheim 1837

Chonetes granulifer Owen

Plate VI, no. 16-19

Chonetes granulifer Owen, 1853, Geol. Report Wisconsin, Iowa, and Minnesota, p. 583, pl. 5, figs. 12a-d.

Description--The shell is of medium size, widest at the hingeline, and a little more than half as long as wide. The outline is subquadrate, although the cardinal extremities may be mucronate. Measurements of three specimens are:

Specimen	1	2	3
Length (mm)	9.5	8	8.5
Width (mm)	16	14	13.5
Thickness (mm)	3	2.5	3

The brachial valve is gently concave over the visceral area, except for the low, indistinct fold. This is probably a feature of compression, since the fold is most distinct at the anterior margin. The beak is very small, and from this depends the cardinal process which is covered with a small, convex chilidium. The exposed posterior face of this chilidium is marked by four sharp, diverging ridges from the beak, each pair embracing one of the muscles. The interarea is extremely narrow, tapering to the cardinal margins. The surface of the valve is covered with fine, even costae, about 5 of which occupy 1 mm.

The pedicle valve is gently convex longitudinally, with gentle posterolateral slopes. A broad, poorly defined, rounded sinus begins on the umbo and continues to the anterior margin where it slightly depresses the line of commissure. In a few specimens this sinus is lacking. The beak is small but conspicuous, with a narrow interarea sloping back

under it. The triangular delthyrium is broader than high, with a vestigial deltidium filling the apex and giving a rounded lip to the delthyrium. The opening is usually filled with the cardinal process of the brachial valve. Along the posterior margin of the valve 8 or 9 small spine bases point inward on each side of the beak. The shell substance is translucent in some specimens and the spine bases penetrate the shell substance to the interior of the valve. The surface is covered with fine, regular costae, about 5 of which occur in 1 mm.

Discussion--This species has many varieties, distinguished on the basis of ornamentation and shell shape. C. granulifer var. armatus, has 6 costae per mm which are so subdued as to be almost indistinguishable. This variety is also narrower, more strongly curved, and smaller than the typical C. granulifer. C. granulifer var. transversalis is much broader, with more mucronate cardinal extremities.

Material and occurrence--This species ranges throughout the Pennsylvanian in outcrops over most of the United States.

Several specimens were collected from units 12, 18, 27, 34, and 43 of section II, spanning the Derryan-Desmoinesian boundary.

Family ORTHOTETIDAE

Genus ORTHOTETES Fischer 1850

Subgenus DERBYIA Waagen 1884

Orthotetes (Derbyia) crassa (Meek and Hayden)

Plate VII, no. 1-4

Orthisina crassa Meek and Hayden, 1858, Philadelphia Acad. Nat. Sci. Proc., vol. 10, p. 261.

Derbyia crassa (Meek and Hayden) Waagen, 1884, Palaeontologia Indica, ser. 13, vol. 1, p. 592.

For full synonymy see Girty, 1915, U. S. Geol. Survey Bull. 544, p. 54.

Orthotetes crassa (Meek and Hayden) Sokolskaya, 1954, Trudy Paleo. Inst. Acad. Nauk, S.S.S.R., vol. 51, p. 1-187, pls. 1-18.

Orthotetes (Derbyia) crassa (Meek and Hayden) Easton, 1962, U. S. Geol. Survey Prof. Paper 348, p. 42.

Description--This species is extremely variable in shell form and ornamentation, and is of medium to small size. In smaller specimens the shell is wider than long, with a relatively short hingeline. Later growth takes place mostly on the anterior as shown by growth lines, so that older, more mature specimens are almost as long as wide. Measurements of several specimens are:

Specimen	1	2	3	4
Length (mm)	29	27	20.5	20
Width (mm)	31	30	23	23
Thickness (mm)	8	9	9	8

The brachial valve is moderately convex, with the greatest thickness just posterior to the midlength. The beak is small and inconspicuous, and the cardinal area is linear and very narrow.

The pedicle valve is nearly flat, highest at the beak and sloping toward the anterior and posterolateral margins where it is slightly convex. The pedicle beak is low, with a triangular interarea about one-third as high as wide sloping under it. The area is usually flat or gently concave. The delthyrium is rather broad, and covered by a strongly convex deltidium.

The surfaces of both valves are covered with fine, rounded, regular costae, which increase by bifurcation and intercalation. There are 2 or 3 of these costae per mm at the anterior margin. Concentric rugae and growth lines are common on many individuals and rare on others.

Discussion--There are no other species with which this is likely to be confused.

The exact placement of the species is imperfectly understood, since Sokolskaya (1954) redescribed O. radiata Fischer and placed the

genus Derbyia Waagen in synonymy with Orthotetes Fischer. The internal characteristics of both genera are imperfectly known.

Material and occurrence--This species is known to range from Desmoinesian through Virgilian in the midwestern and western United States.

Several specimens were found in units 12, 18, 27, 43, and 68 of section II, spanning the Derryan-Desmoinesian boundary.

Phylum COELENTERATA

Class ANTHOZOA

Order RUGOSA

Family LOPHOPHYLLIDIIDAE

Genus LOPHOPHYLLIDIUM Grabau, 1928

Lophophyllidium idonium Moore and Jeffords

Plate VII, no. 5-10

Lophophyllidium idonium Moore and Jeffords, 1945, Univ. of Texas Pub. 4401, p. 96-99, text-figs. 25-28.

Description--The straight to slightly curved corallites are small and steeply trochoid. The epitheca has narrow but distinct septal grooves and interseptal ridges, is less than one mm thick, and shows faint transverse rugae and growth lines. A pointed columella projects above the floor of the calyx. The dimensions of three partially recovered specimens are:

Specimen	1	2	3
Length (mm)	25	20	13
Width (base of calyx) (mm)	14	16	8
Thickness of theca (mm)	0.4	0.3	0.3

At the base of the calyx there are 28 to 33 major septa, with an average septal ratio of 2.4 (the septal ratio is obtained by dividing the corallite width in mm by the number of major septa at that point), as explained by Rowett and Sutherland (1964, p. 16). The septal ratio decreases uniformly toward the apex of the corallite. The major septa are markedly rhopaloid, extend to the columella (to which they may be cemented), and are cemented together in quadrants by stereoplasm. The quadrants are sharply delineated by the cardinal and counter septa and two alar pseudofossulae. The cardinal septum is short and set in a distinct fossula. The counter septum is elongated and the distal end is thickened to form the axial column, which is laterally compressed and contains no radial elements. Minor septa were not observed. The alar pseudofossulae are narrow but distinct. In the early ephebic stage the cardinal septum becomes longer, approximately equal in length to the major septa, with a much narrower fossula. Tabulae are present, although they can not be seen in the apical region due to filling by skeletal material. Axially the tabulae are steeply inclined upward and dissepiments are absent.

Discussion--These specimens agree closely with the species description given by Moore and Jeffords (1945, p. 96-99) and emended by Rowett and Southerland (1964, p. 26-28). The latter authors pointed out the increased length of the cardinal septum proximally and reaffirmed

the lack of radial elements in the columella. Although the specimens collected show 2 to 5 more septa in mature regions than the original species, the septal ratios agree closely. The extra septa are attributed to the slightly larger corallite size.

This species can be distinguished from most other Lophophyllidium species, including those herein described, by the presence of distinct alar pseudofossulae. The species may be distinguished from L. distinctum by its rhopaloid septa, and from L. confertum by its higher septal ratio and less cylindrical shape. L. idonium differs from L. minutum in its greater size, larger number of tabulae, and lack of marked curvature in the proximal stages of the corallite.

Material and occurrence--This species was first described from the Wapanucka Formation of Oklahoma and the Marble Falls Limestone of Texas, to which it was believed to be restricted. The age of these corals in the aforementioned areas was Morrowan.

Three specimens were collected from units 42 and 43 of section II. The units are Lower Desmoinesian in age.

Lophophyllidium aff. L. ignotum Moore and Jeffords

Plate VII, no. 11-14

Lophophyllidium ignotum Moore and Jeffords, 1945, Univ. of Texas Pub. 4401, p. 108, text-figs. 36, 57, 58.

Description--The straight or slightly curved corallite is trochoid and widens rapidly near the top. The epitheca is thick and shows distinct but low septal grooves and interseptal ridges. Irregular concentric rugae, as well as growth lines are present but inconspicuous. The laterally compressed columella projects above the base of the calyx. Measurements of one specimen are:

Specimen	1
Length (mm)	27
Width (base of calyx) (mm)	21
Thickness of theca (mm)	1

At the base of the calyx there are 35 thick, somewhat rhopaloid major septa, which do not quite reach the axial column. The septa are subequal in length and no minor septa were observed. The septal ratio decreases slowly in the ephebic stage, with a ratio of 2.5 at a diameter of 12 mm and a ratio of 1.7 at the base of the calyx. Approximately 5 mm below the base of the calyx the septa reach the axial column and are cemented together and to the column by stereoplasm. The cardinal septum is short and set in a conspicuous fossula which narrows axially. The elongate counter septum is swollen at the distal end into a laterally compressed columella located in the axial region. Faint radial elements may be seen in this structure, which remains thin throughout the length of the corallite. A few widely spaced tabulae slope steeply upward to

the axis, and no dissepiments are present. In the early ephebic stage of the corallite at a diameter of 7 mm, the septal ratio is 3.8 and the dilated septa fill the corallite. The cardinal septum is equal in length to the other major septa and still set in a fossula. The epitheca, throughout the corallite, consists of an outer wall about 0.5 mm thick and a thin inner stereozone about 0.5 mm thick.

Discussion--This species is very close to L. ignotum, but differs in the lack of distinct radial elements in a large, round columella. The stereozone of this species is thinner than in the typical L. ignotum, the corallite is larger, and has slightly higher septal ratios in the proximal portion. More specimens must be found and sectioned before this species can definately be assigned to L. ignotum.

This species resembles L. extumidum, but has fewer tabulae, no alar pseudofossulae, and lacks distinct radial elements in the columella. Most other Lophophyllidium species including the ones described in this paper lack the distinctive stereozone of L. ignotum.

Material and occurrence--This species has been found in the Wapanucka Formation in the Ouachita area of Oklahoma, to which it was believed to be restricted. The age of the Wapanucka Formation is Morrowan.

One specimen was collected from unit 42 of section II, and is Lower Desmoinesian in age.

Lophophyllidium sp. A

Plate VII, no. 15-16

Description--The conical corallite is slightly curved, large, with a moderately thin epitheca which shows narrow septal grooves and wider interseptal ridges. Growth lines and concentric rugae are absent. The laterally compressed columella projects above the base of the deep calyx. Measurements of a complete specimen are:

Specimen	1
Length (mm)	40
Width (top of calyx) (mm)	28
Width (base of calyx) (mm)	21
Thickness of theca (mm)	0.7

At the base of the calyx there are 38 major septa (septal ratio 1.8) of three distinct sizes, alternating with short minor septa. The counter septum is elongate and attached to the laterally compressed axial columella which shows a median septum continuous with the counter septum, but no radial elements. The cardinal septum is short and set in a distinct cardinal fossula which narrows axially. In the counter quadrants major septa are of two distinct lengths and markedly rhopaloid. The long major septa reach almost to the axial column and alternate with shorter septa. In the cardinal quadrants thinner, non-rhopaloid septa about 5 mm long alternate with two larger rhopaloid sets of septa. The

alar pseudofossulae are indistinct. At a diameter of 8 mm there are 31 major septa (septal ratio 2.9), slightly rhopaloid, subequal in length and cemented together at their distal ends with stereoplasm. The cardinal septum is set in a distinct fossula and is slightly shorter than the other major septa. The counter septum is elongated and swollen at the distal end to form the columella. The septa are all thickened with skeletal deposits leaving only small openings between the septa. Alar pseudofossulae are indistinct, and minor septa are obsolete. No tabulae or dissepiments were observed.

Discussion--The lack of radial elements in the columella would place this species in the genus Stereostylus Jeffords, 1947. However, Rowett and Sutherland (1964, p. 25), consider Stereostylus a junior synonym of Lophophyllidium for the following reasons. The distinction made between the genera is that the former has more internal skeletal deposits, a thicker epitheca, and a larger columella with distinct radial structures. These features all seem to vary, even within a single species (Rowett and Sutherland, 1964), making it impossible to distinguish between the two genera consistently. Other authors, however, accept the new genus as valid (Ross and Ross, 1962); (Hill, 1956). Too few specimens were examined by the writer to support either concept, so for convenience Stereostylus will not be used in this paper.

Material and occurrence--One specimen was found in unit 68, section II, of Desmoinesian age.

Family CYATHOPSIDAE

Genus PSEUDOZAPHRENTOIDES Stuckenburg, 1904

Pseudozaphrentoides torquius (Owen)

Plate VIII, no. 1-6

Cyathophyllum torquium Owen, 1852, Geol. Rept. Wisconsin, Iowa, and Minnesota, tab. 4, fig. 2.

Campophyllum torquium (Owen) Swallow, 1855, Missouri Geol. Survey, First and Second Ann. Repts., Appendix B, p. 216.

Caninia torquia (Owen) Easton, 1944, Jour. Paleont., vol. 18, no. 1, p. 125-128, pl. 22, figs. 2-7; contains complete synonomy to date, p. 125-126.

Pseudozaphrentoides torquius (Owen) Moore and Jeffords, 1945, Univ. of Texas Pub. 4401, p. 149.

Description--The large, curved, corallite is conical-cylindrical with a broad, deep, flat bottomed calyx. The theca is weathered away but still shows traces of concentric rugae. Measurements of 2 broken specimens are:

Specimen	1	2
Length (mm)	90	40 (broken)
Width (top of calyx) (mm)	44	--
Width (base of calyx) (mm)	36	36

At the base of the calyx there are 45-46 major septa, reaching about two thirds the radius of the corallite in length. The major septa are thin and irregular in the dissepimentarium, thickening and becoming attenuate in the tabularium. Minor septa are short, not attaining more than half the width of the dissepimentarium. The cardinal septum is short and set in a conspicuous fossula formed by the downwarping of the tabulae and an outbending of the thickened inner wall of the dissepimentarium. In the cardinal quadrants 20 to 22 of the septa are strongly dilated in contrast to those in the counter quadrants. The counter septum is the same length as other major septa and indistinguishable from them. The dissepimentarium is broad, about one third the radius of the corallite, with large and moderately regular dissepiments appearing both subparallel and herringbone in transverse section. In longitudinal section the dissepiments are variable in size and slope steeply upward and outward toward the theca. Where the major septa are dilated in the cardinal quadrants, a distinct inner wall is formed. This wall is not present in the counter quadrants. Tabulae are thin, numerous, complete or inosculating, and

slope upward from the edge of the dissepimentarium, then flatten or are slightly domed axially. No columnar structure is present.

Discussion--This is the same species described by Easton (1944, p. 125-128) as sectioned and studied from Meek's plesiotypes. Meek (1872) collected the plesiotypes from the upper coal measures at Rock Bluff and Cedar Bluff, Nebraska.

P. torquius resembles P. spatiosus closely, but the latter species has a lower width to length ratio, is generally smaller, and has more regular dissepiments in longitudinal and transverse section. P. spatiosus has a distinct thickened inner wall of the dissepimentarium all the way around the corallite. P. lepidus lacks a distinct septa-free tabularium, P. nitellus has three distinct zones in transverse section, and P. ordinatus has a thin dissepimentarium with an indistinct cardinal fossula and more regular arrangement of dissepiments and tabulae than P. torquius.

Pseudozaphrentoides is seperated from Caninia on the basis of the wide dissepimentarium which the generotype of Caninia lacks. A complete discussion of this taxonomic problem may be found in Moore and Jeffords (1945, p. 143-147). Hill (1956, p. 298) considers Pseudozaphrentoides a junior synonym of Caninia. Sutherland (1958), Ross and Ross (1962), and Rowett and Suthurland (1964) recognize the genus. The distinction between the genera seems sufficiently valid to this writer to be recognized.

Material and occurrence--This species has a wide stratigraphic and geographic range in Pennsylvanian rocks of the United States.

One specimen was collected from unit 40 and one from unit 70, section II, of Desmoinesian age.

Pseudozaphrentoides sp. A

Plate VIII, no. 7-8

Description--The large, curved corallite is conical-cylindrical with a wide, deep, flat bottomed calyx. The depth of the calyx exceeds 16 mm and the septa slope upward from the edge of the tabularium to the margin of the calyx. The theca is weathered away. Measurements of two specimens are:

Specimen	1	2
Length (mm)	61	75 (broken)
Width (top of calyx) (mm)	37	--
Width (base of calyx) (mm)	34	22 (middle?-late? ephebic stage)

At the base of the calyx there are 49 major septa, about one half the radius of the corallite. The septa are thin and irregular in the dissepimental zone, but thicken at the edge of the tabularium and then taper distally. Minor septa are very short, less than 2 mm long. The cardinal septum is moderately long and set in a distinct fossula formed by downbending of tabulae and curving of adjacent septa around the front

of the cardinal septum. On each side of the cardinal septum 8 to 10 septa are strongly dilated in contrast to the septa of the counter quadrants. The cardinal fossula is located on the convex side of both corallites. The dissepimentarium width is less than one half the radius of the corallite at the base of the calyx, becoming thinner proximally. The dissepiments are irregular, giving a herringbone impression in transverse section. In longitudinal section they are irregular in size and shape and slope steeply upward and outward toward the theca. An inner wall is formed by the thickening of the septa and skeletal addition to the last formed dissepiments, but is less distinct in the counter quadrants. In longitudinal section the tabularium is wide and septa free, the tabulae are numerous, complete or inosculating, and flat or slightly domed in the axial region. The tabulae slope upward from the edge of the dissepimentarium. No columnar structure is present. At a diameter of 11 mm there are 28 to 30 septa, reaching three fourths the radius of the corallite, with a short cardinal septum set in a distinct fossula. Minor septa are absent, the dissepimentarium is very thin, with one or at most two layers of herringbone dissepiments. On each side of the cardinal septum there are 6 or 7 dilated septa.

Discussion--This species resembles P. spatiosus but has a longer cardinal septum, less closely spaced tabulae, a thinner dissepimentarium with more irregular dissepiments, and an indistinct inner wall.

P. ordinatus resembles this species also, especially in the immature region, but has a shorter cardinal septum and a thicker dissepimentarium with more regular dissepiments. P. torquius has a much wider dissepimentarium, a short cardinal septum, and longer major and minor septa.

Material and occurrence--Two specimens were found in unit 70, section II, of Desmoinesian age.

Genus VESICULOPHYLLUM Easton, 1944

Vesiculophyllum sedaliense (White)

Plate IX, no. 1-4

Chonophyllum sedaliense White, 1880, Contr. Invertebrate Paleontology, no. 8, p. 157, pl. 39, fig. 3a. Extract from U. S. Geol. Survey 12th Ann. Rept. (1878).

Vesiculophyllum sedaliense (White) Easton, 1944, Illinois State Geol. Survey Rept. of Inv. no. 97, p. 52-53, pl. 5, figs. 5-9, pl. 17, fig. 12. This paper contains a complete synonymy as of 1944.

Description--The corallites are conical in the early stage and cylindrical in later stages. The specimens have been weathered before burial, as the epitheca and outer parts of the dissepimentarium are gone, especially in the later stages. The calyx is deep, approximately 15 mm, with septa sloping gently upward forming a conical calyx except near

the top where the sides are straight. Measurements of two broken specimens with the apical ends missing are:

Specimen	1	2
Length (mm)	90	75
Width (base of calyx) (mm)	22	28

At the base of the calyx there are 50 to 55 long, sinuous, slightly dilated major septa, subequal in length and reaching almost to the axis of the corallite. Minor septa are short, never projecting beyond the dissepimentarium. The cardinal septum is slightly shorter than the other septa, set in an inconspicuous fossula formed by the bending of lateral septa around the front of the cardinal septum. The dissepimentarium is wide, possibly as much as half the radius of the corallite although half of this is weathered away on most of the corallite. The dissepiments are subparallel in transverse section. In longitudinal section they are elongate, stretching up the inside of the corallite, and laterally compressed. The tabulae are thin, complete or incomplete, sloping steeply toward the apex from the dissepimentarium to the axis. The numerous intersections of the tabulae and septa make them appear more incomplete than is the actual case. In the earlier stages the dissepimentarium thins to less than one fourth the corallite radius, the cardinal fossula disappears, the cardinal septum increases in length, and minor septa remain short. Major

septa become slightly longer, still sinuous and dilated, and reaching the axial region where they are not united.

Discussion--This species resembles V. incrassatum but has a narrower dissepimentarium, longer major septa, and shorter minor septa. The major septa are more dilated, especially in the cardinal quadrants. V. sutherlandi is also similar, but the septa in the cardinal quadrants are thicker, being more dilated in the tabularium, and V. sutherlandi has a much narrower tabularium. V. sp. A has rhopaloid major septa, which are much less sinuous.

Material and occurrence--This species is not known to range above Early Osagian in age. In the Mississippi Valley area it is found in Upper Kinderhookian and Lower Osagian rocks. In the Grand Canyon it is found with a typically Osagian fauna (Easton and Gutschick, 1953).

Two specimens were collected at the base of section I, in the top 2 feet of Escabrosa Limestone underlying the basal dolomite member of the Naco Formation. This indicates an Early Osagian or Late Kinderhookian age for the Escabrosa Limestone.

Vesiculophyllum sp. A

Plate IX, no. 5; Plate X, no. 1-2

Description--The corallite is conical in young stages, and cylindrical in mature stages similar to V. sedaliense. The calyx is deep and the theca

and outer dissepiments are weathered away, probably before burial. Measurements of one broken specimen with the apical end missing are:

Specimen	1
Length (mm)	100
Width (base of calyx) (mm)	24

At the base of the calyx there are 47 dilated major septa that are rhopaloid at the extreme axial ends. The septa are long, but do not reach the axis, slightly sinuous and subequal in length. Minor septa are half the length of the major septa, projecting 2 to 5 mm out of the wide dissepimental zone. The cardinal septum is slightly shorter than other major septa and set in an indistinct fossula formed by the adjacent septa bending around in front of the cardinal septum. In transverse section the dissepiments are concentric, and in longitudinal section they are only slightly depressed, almost vertical along the walls of the corallite. The thin tabulae slope steeply toward the apex of the corallite, are incomplete and irregular. In the early portion of the ephebic stage the septa are still dilated but not sinuous, and rhopaloid at the outer edges. The septa do not reach the axial region and the dissepimentarium is less than one fourth the corallite radius.

Discussion--This species does not resemble any other species of Vesiculophyllum. The rhopaloid non-sinuous nature of the septa combined

with the open space free of septa in the axial region of the corallite are sufficient to distinguish it from other species.

Material and occurrence--One specimen was found in the upper two feet of the Escabrosa Limestone at the base of section I, associated with V. sedaliense of Late Kinderhookian or Early Osagian age.

Order TABULATA

Family CHAETETIDAE

Genus CHAETETES Fischer, 1829

Chaetetes eximius Moore and Jeffords

Plate X, no. 3-4

Chaetetes milleporaceus Edwards and Haime, 1851; for discussion of synonymy see Moore and Jeffords, 1944, Univ. of Texas Bull. 4401, p. 191.

Chaetetes eximius Moore and Jeffords, 1944, Univ. of Texas Bull. 4401, p. 191-193, text-figs. 207-208.

Description--The coralla are sub-spherical, a little wider than high, and large. They also occur in irregular shaped masses up to two feet in diameter which appear to have been transported and abraded after death.

In transverse section the corallites measure 0.4 to 0.5 mm in diameter, with thick walls, 0.08 mm, that show some beading. The corallites form a honycomb pattern of 5 or 6 sided polygons, varying in shape but of approximately equal size. Pseudosepta may be seen in some corallites. In longitudinal section the corallites contain closely and rather evenly spaced tabulae. These tabulae are very thin and do not always occur at the same level in adjacent tubes. There are 4 or 5 tabulae per mm in most of the corallites.

Discussion--Chaetetes milleporaceus is not now recognizable (Moore and Jeffords, 1945) since the species was not illustrated and no specimens can be found agreeing with the original description. C. eximius differs from C. favosus in having much more crowded tabulae.

Material and occurrence--This species was originally described from the Hale Formation in Oklahoma and the Marble Falls Limestone of Texas, both of Morrowan age. The species has been tentatively reported from the Derryan and Desmoinesian Series of the Madera Formation in Colorado (Tischler, 1963). The species has been found in Arizona, in the Black Prince Limestone of Morrowan age (Nations, 1963).

Several specimens were collected from a band about two feet thick in unit 14, section II and unit 10, section I, of Derryan age. Two specimens were also found in unit 48, section II, of Desmoinesian age.

Family AULOPORIDAE

Genus MULTITHECOPORA Yoh, 1927

Multithecopora sp. A

Plate X, no. 5-6; Plate XI, no. 1-2

Description--The corallum is badly weathered and partly silicified with only the lower two inches remaining. The immature corallites are reptant, incrusting forign objects to form a base. They expand by lateral increase, with the mature portion of the corallum becoming fasiculate with subparallel corallites which are cylindrical, small, 1.6 to 2.3 mm in diameter, and generally very thick walled, 0. 23 to 0.7 mm. In transverse section there are 10 to 20 corallites per 100 sq. mm. Connecting tubules are small, approximately 1 mm in diameter and 1 to 3 mm long. The distance between corallites ranges from 0 to 3 mm.

Internally, septa are lacking, spines are rare and extremely variable, and tabulae are also lacking. The thick wall is formed by concentric layers of sclerenchyme added internally. The central open tube is located at the axis of the corallite, and parent corallites are connected to immature corallites by a similar tube. The central tube ranges from 0.4 to 0.7 mm in diameter.

Discussion--This species resembles M. hypatiae in size and density of corallites, but lacks the internal tabulae. This lack of

tabulae sets the species apart from Asiatic species also. The coral is typically Asiatic (Wilson, 1963), with only two other reports of its occurrence in North America. M. paucitabulata is reported from the lower Marble Falls Limestone (Morrowan) of Texas (Moore and Jeffords, 1945), and M. hypatiae from the Ely Limestone (Pennsylvanian) of Nevada.

Material and occurrence--Only one specimen was collected, in association with Chaetetes eximius in unit 48, section II, of Desmoinesian age.

Genus SYRINGOPORA Goldfuss, 1826

Syringopora sp. A

Plate XI, no. 3-6

Description--Fragments of two coralla about 6 inches on a side were retrieved, weathering from a limestone ledge in small blocks. In transverse section the corallites range from 3 to 3.4 mm in diameter, with a density of 5 to 6 corallites per 100 sq. mm. The walls are rather thick, from 0.2 to 0.28 mm. Septal spines are present, in rows, but are irregular in size and abundance in the corallites. Lateral processes (connecting tubes) are widely spaced and the spacing of the corallites is regular.

Good longitudinal sections are difficult to get because of the irregular corallite growth pattern. Tabulae are numerous, sloping steeply

toward the apical end and joined along their inner edges to form a hollow central tube about one fourth the diameter of the corallite. The central tube is not exactly in the center of the corallite but is always close to it, and appears to be completely free from horizontal tabulae.

Discussion--This species may be distinguished from S. sercularia by its slightly larger corallites with thinner walls and lack of flat or concave tabulae in the central tube. S. rudyi has slightly larger corallites with thinner walls without septal spines. S. magnussoni is similar to this species both in corallite diameter and spacing but the growth of the corallites is irregular, and they tend to grow in isolated clumps within the corallum. The walls of S. magnussoni are thick as in this species but the corallites join by anastomosing rather than by lateral processes.

Material and occurrence--Two specimens were found in the upper two feet of the Escabrosa Limestone, at the base of section I. The species is Late Kinderhookian or Early Osagian age in this area.

Syringopora sp. indet.

Plate XI, no. 7-8

Description--One specimen was found, with the upper two inches preserved. The corallite diameter ranges from 1.8 to 2.1 mm and 6 to 9 corallites occur per 100 sq. mm. The walls range from .09 to .18 mm

thick, with the average falling between .12 and .16 mm. The specimen is silicified and internal features are poorly preserved. Spines do not appear to be present and tabulae are fairly numerous. The position and structure of an axial tube could not be determined.

Discussion--The presence of the tabulae in the corallites indicates that it belongs to the genus Syringopora, but not enough detail was available to make careful species comparisons. The gross features of the corallites, such as diameter, wall thickness and frequency resemble S. dingmanae or S. harveyi.

Material and occurrence--One specimen was collected from the top of the Escabrosa Limestone at the base of section I, and is Late Kinderhookian or Early Osagian in age.

Plate I

All magnifications x2 except numbers 2 through 9.

Plate I

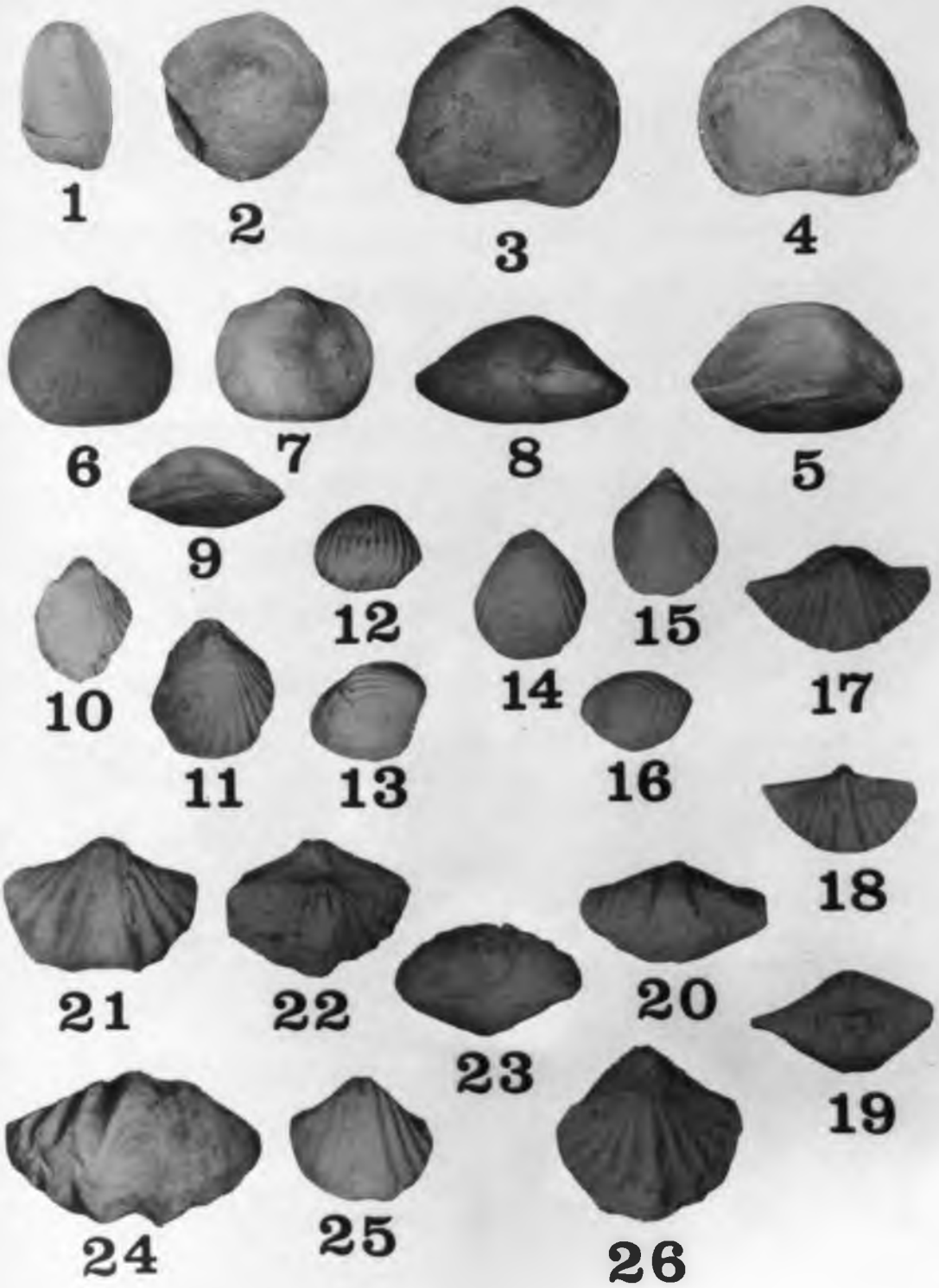

Plate II

All magnifications x1. Page

1-5 Composita argentea (Shepard); pedicle and brachial views of one individual, anterior view of a second specimen, and side and posterior views of a third individual, unit 12, section II, W-17..... 50

6-9 Composita derrya Gehrig; brachial (6) and side (8) views of one individual, pedicle (7) and anterior(9) views of a different specimen; (6,8) from unit 37, section I, W-19; (7,9) from unit 13, section II, W-20..... 52

10-16 Composita malaya Gehrig; pedicle and brachial views of one specimen, anterior, posterior and side views of a second individual, and anterior and posterior views of a third individual; (15,16) are from unit 13, section II, W-22, (10-14) are from unit 43, section II, W-21..... 54

17-20 Composita ovata Mather; pedicle, brachial, and posterior view of one individual, anterior view of a second specimen, unit 13, section II, W-25..... 55

20-26 Composita subtilita (Hall); pedicle (21), brachial (22), and anterior (25) views of one individual, anterior (23) and side (26) views of a second specimen, and posterior (24) view of a third individual, unit 27, section II, W-30..... 57

Plate II

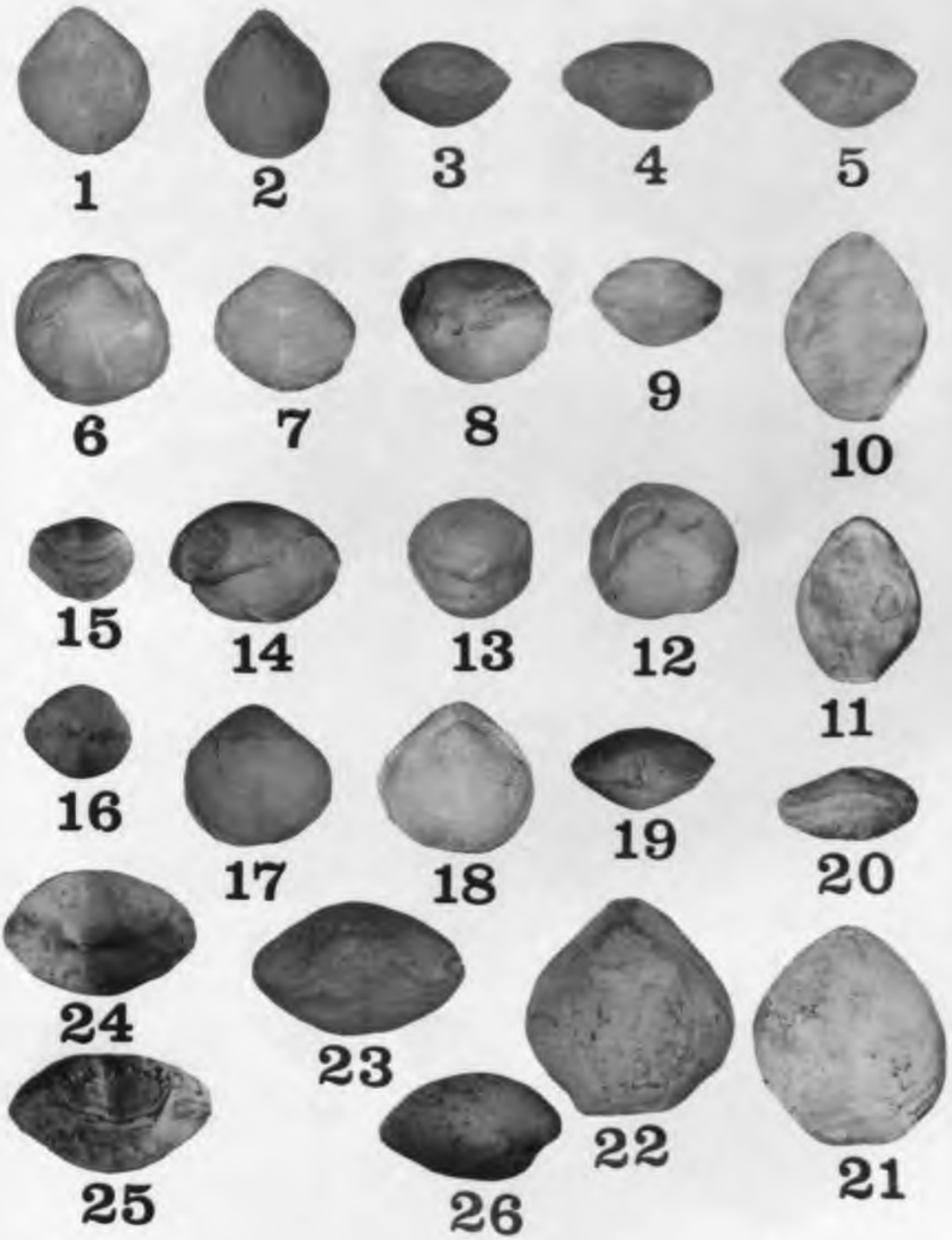

Plate III

All magnifications x1. Page

1-4 Neospirifer cameratus (Morton); pedicle, brachial, and posterior views of one specimen, anterior (4) view of a second individual; (1-3) from unit 27, section II, W-32, (4) from unit 40, section II, W-33..... 59

5-6 Neospirifer goreii (Mather); pedicle view of one specimen, brachial view of another individual, unit 43, section II, W-36..... 61

7-10 Phricodothyris perplexa (McChesney); pedicle (7), anterior (9), and side (10) views of one individual, brachial (8) view of a second specimen; (8) is from unit 38, section I, W-38, (7,9,10) is from unit 43, section II, W-39..... 63

11 Spirifer occiduus Sadlick; pedicle view, unit 43, section II, W-40..... 66

Plate III

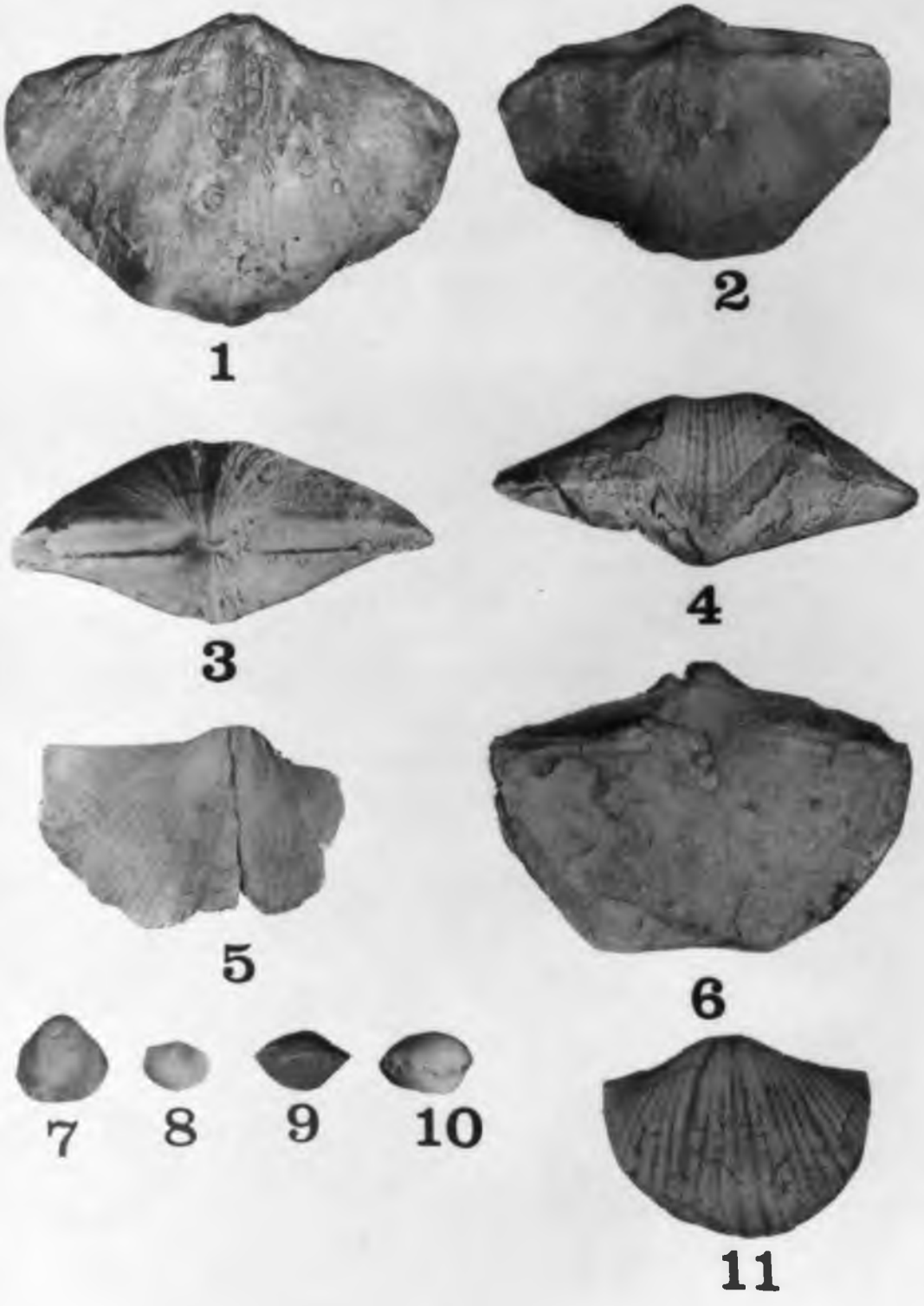

Plate IV

All magnifications x1. Page

1-5 Spirifer occiduus Sadlick; pedicle (1), brachial (2), and posterior (4) views of one specimen, side view (3) of a second individual, anterior (5) view of a third specimen, unit 43, section II, W-40..... 66

6-10 Spirifer opimus Hall; pedicle (6), brachial (7) views of one specimen, side (8), posterior (9), and anterior (10) views of a different individual; (6,7) from unit 43, section II, W-46, (8-10) from unit 27, section I, W-47..... 69

11-16 Spirifer rockymontanus Marcou; pedicle (11), brachial (13), posterior (15), and anterior (16), views of one individual, side (14) view of a second individual, and pedicle (12) view of a third specimen; (12) from unit 27, section I, W-48, all others from unit 43, section II, W-49..... 71

17-18 Juresania nebrascensis (Owen); pedicle and brachial views of one specimen from unit 27, section II, W-51..... 73

Plate IV

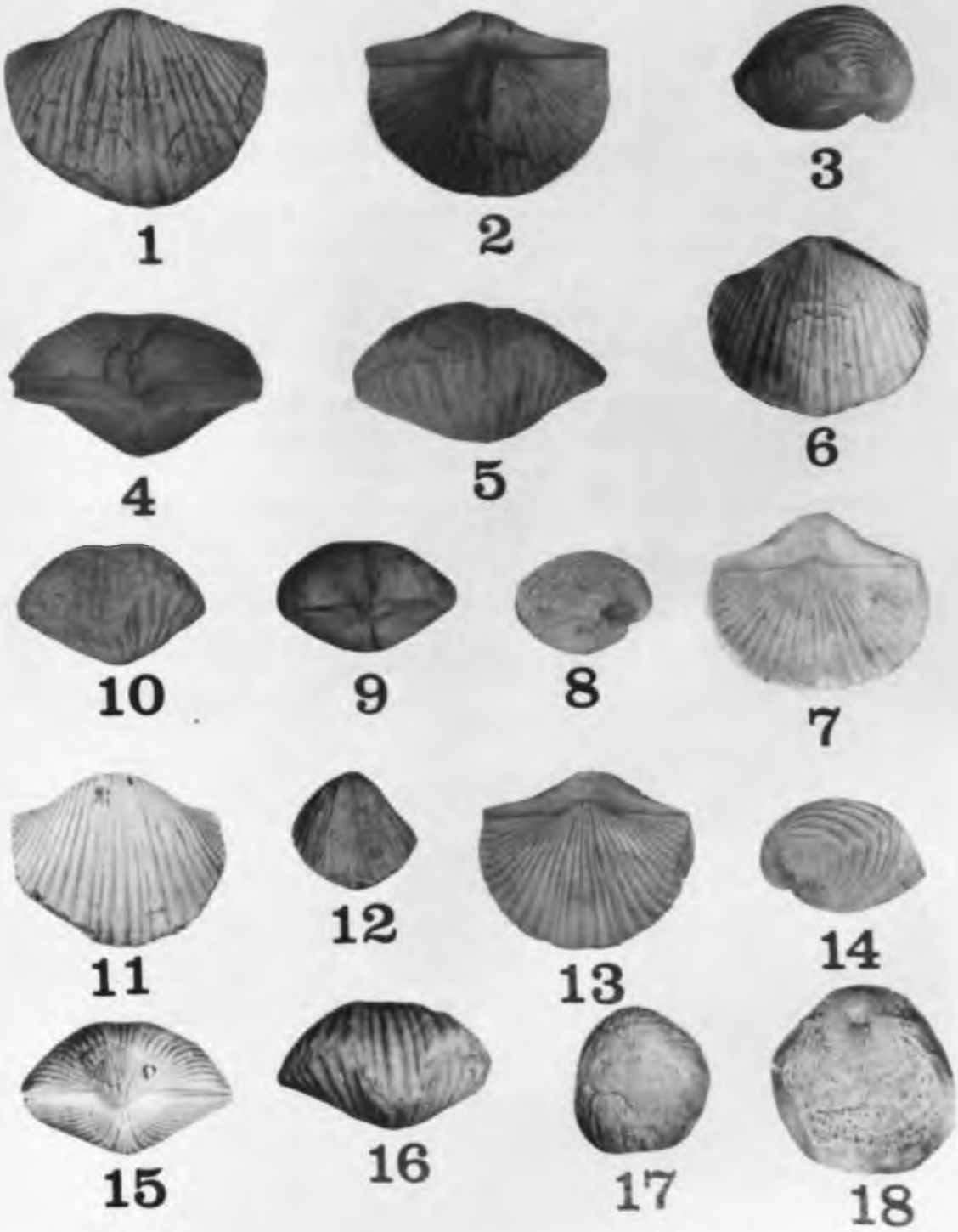

Plate V

All magnifications x1. Page

1-2 Juresania nebrascensis (Owen); side and posterior views of one individual, unit 27, section II, W-51..... 73

3-7 Antiquatonia coloradoensis (Girty); pedicle (3) view of one specimen, brachial (4) view of a second specimen, side (5), posterior (7) views of a third specimen, and anterior (6) view of a fourth individual; (4) from unit 27, section II, W-56, (4,5,7) from unit 27, section I, W-57, (6) from unit 24, section II, W-55..... 75

8-11 Antiquatonia hermosana (Girty); pedicle (8), side (9), and anterior (11) of one individual, posterior (10) of a different specimen, unit 43, section II, W-61..... 78

12 Echinoconchus aff. E. angustus Easton; pedicle view, unit 18, section II, W-68..... 80

13 Echinoconchus semipunctatus (Shepard); pedicle view, unit 28, section II, W-64..... 82

Plate V

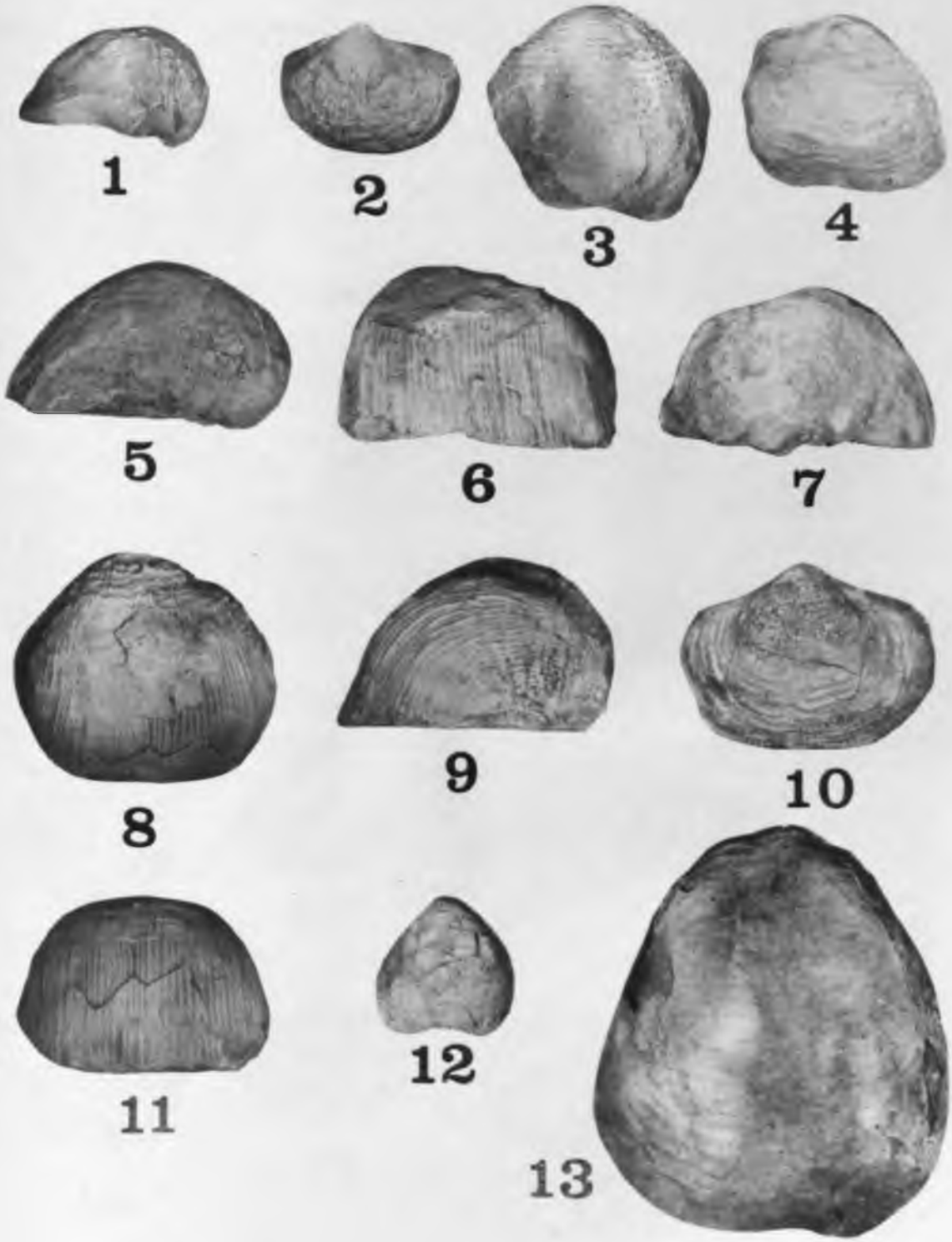

Plate VI

All magnifications x1
except 5-8 and 11-19, which are x2

Page

1-4 Linoproductus aff. L. platyumbonus Dunbar and Condra; pedicle and side views of one individual, anterior and posterior views of a different specimen, (1,2) from unit 27, section II, W-70, (3,4) from unit 40, section II, W-72 84

5-10 Retaria lasallensis (Worthen); pedicle (5) x2 and anterior (9) x1 views of one individual, brachial (6) x2 and posterior (10) x1 views of a second specimen, brachial (7) x2 and side (8) x2 views of a third individual, unit 27, section II, W-75 88

11-15 Desmoinesia muricatina (Norwood and Pratten); pedicle view, pedicle view, side view, posterior view, and brachial view, each view of a different specimen, unit 43, section II, W-80 86

16-19 Chonetes granulifer Owen; pedicle (16, 17, 18) views of three different specimens x2, brachial view (19) of a fourth individual x2, unit 27, section II, W-84 90

Plate VI

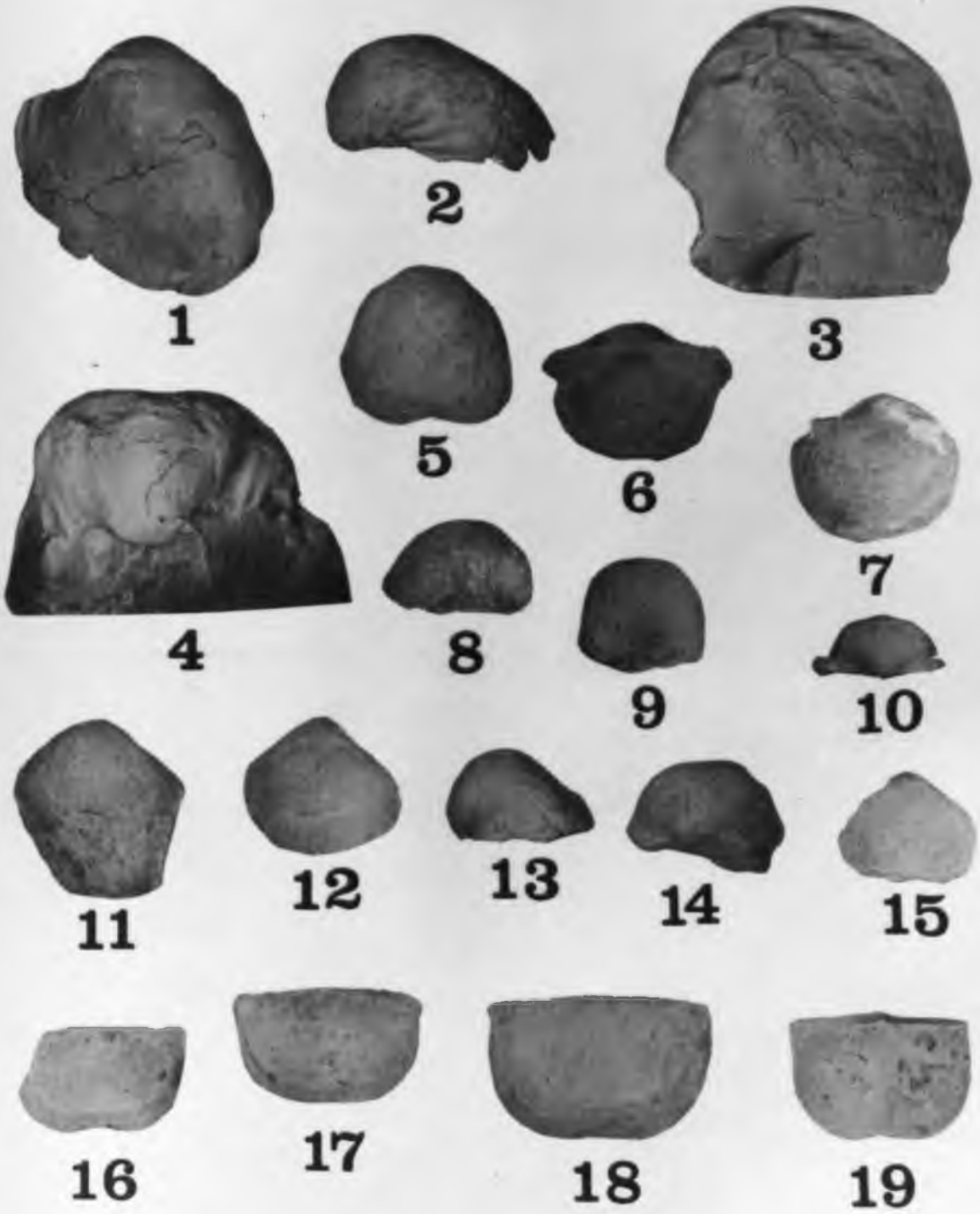

Plate VII

All magnifications x2
except 1-4 which are x1

Page

1-4 Orthotetes (Derbyia) crassa (Meek and Hayden); two pedicle and two brachial views, each view of a different specimen, unit 43, section II, W-90..... 93

5-10 Lophophyllidium idonium Moore and Jeffords; transverse sections of specimen W-100, beginning at the base of the calyx (5), and ranging down to the immature, proximal part of the corallite (8); transverse sections of second specimen W-101, near base of calyx (9), and near center of corallite (10), unit 42, section II..... 96

11-14 Lophophyllidium aff. L. ignotum Moore and Jeffords; transverse sections beginning at the base of the calyx (11) and ranging down to the immature, proximal part of the corallite (14), unit 42, section II, W-103..... 98

15-16 Lophophyllidium sp. A; transverse section near middle of corallite (15), and longitudinal section near middle of corallite (16), unit 68, section II, W-104..... 101

Plate VII

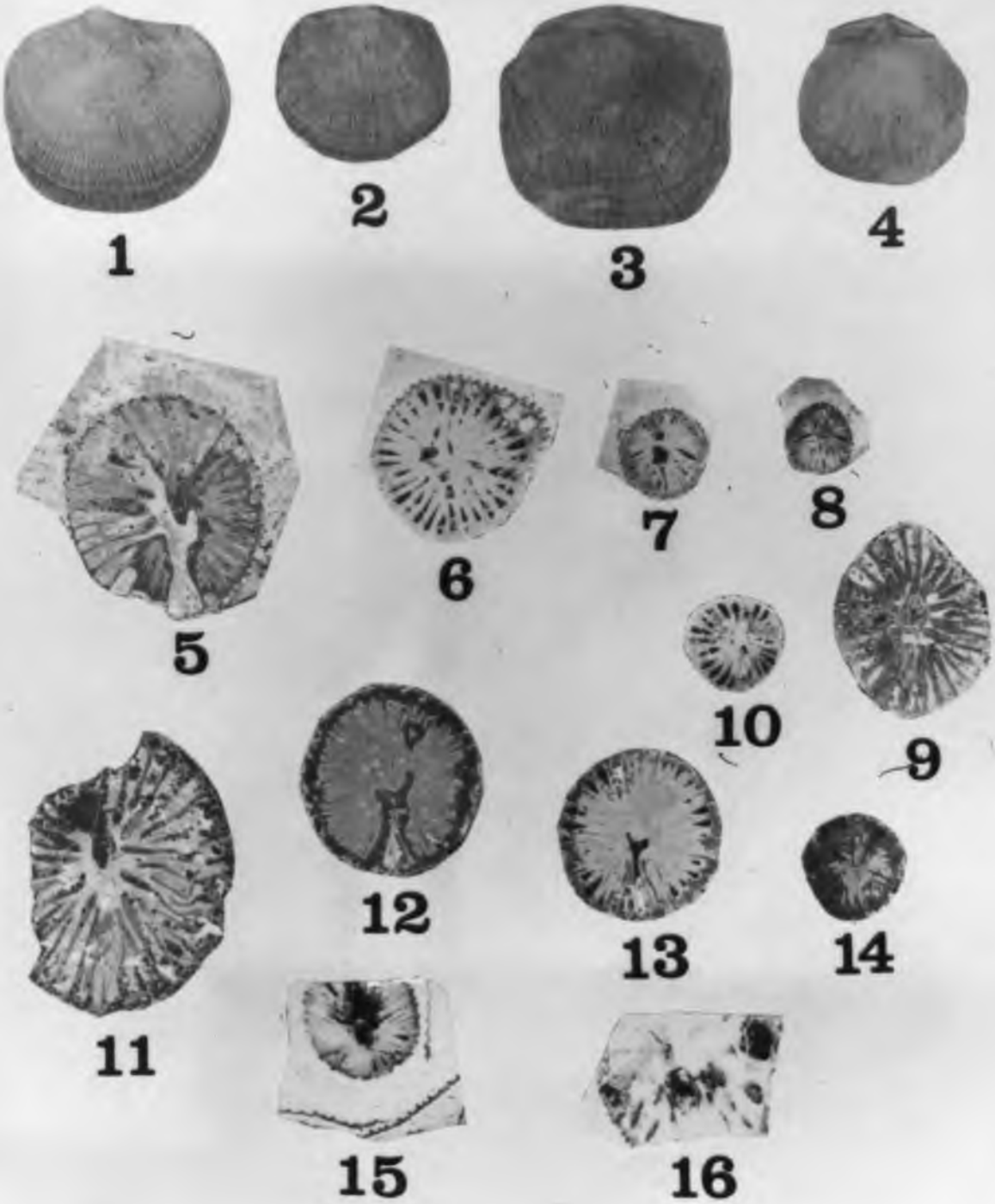

Plate VIII

All magnifications x1
except 4-7 which are x2

Page

1-3 Pseudozaphrentoides torquius (Owen); external view of one corallite from unit 40, section II, W-107; transverse section just below base of calyx (2) and longitudinal section through calyx (3) of a second specimen, unit 70, section II, W-108..... 103

4-8 Pseudozaphrentoides sp. A; transverse sections beginning at the base of the calyx (4) and continuing to the early ephebic stage (6), longitudinal section (7) between transverse sections 4 and 5, and external view of calyx (8), unit 70, section II, W-110..... 106

Plate VIII

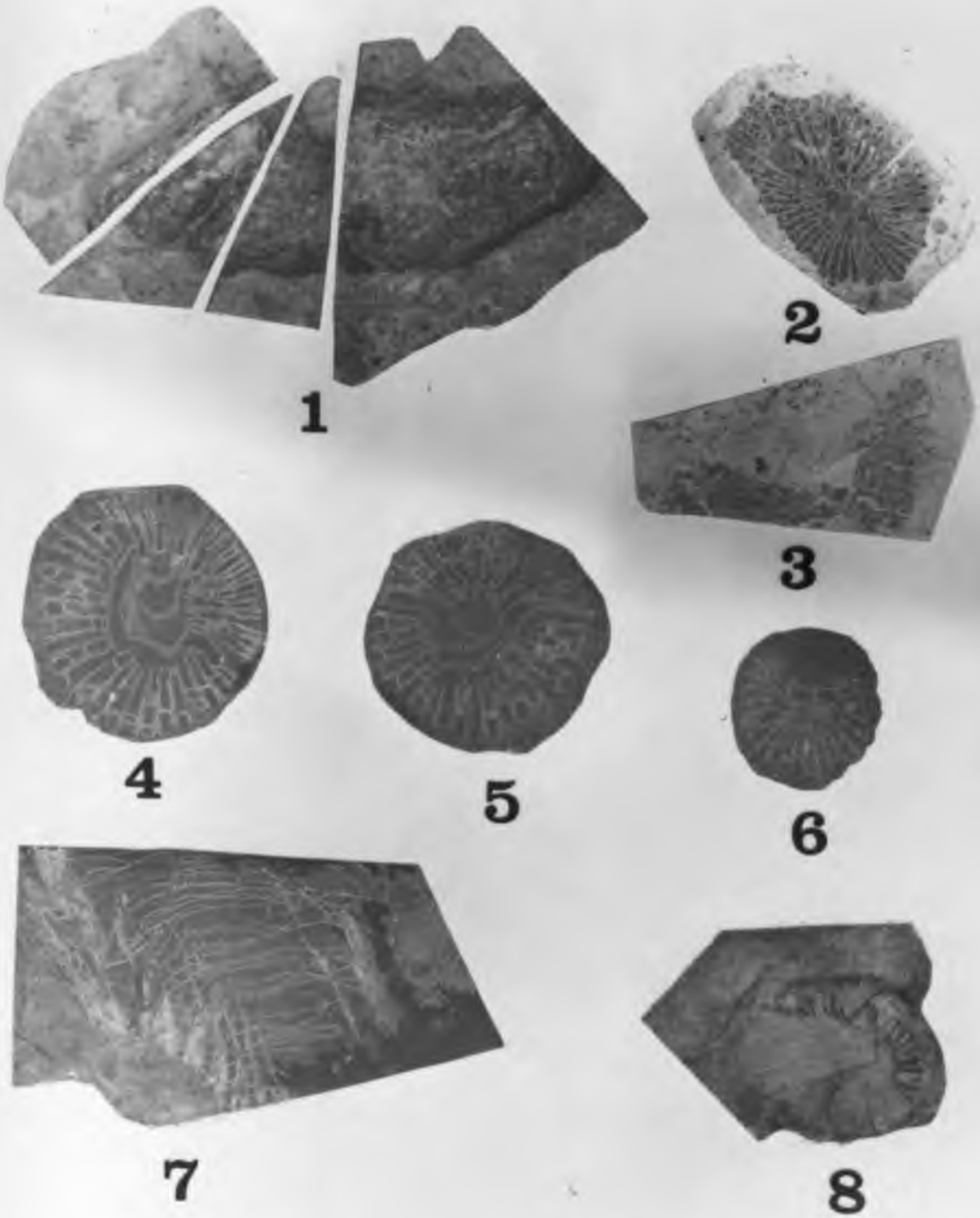

Plate IX

All magnifications x2.

		Page
1-4	Vesiculophyllum sedaliense (White); transverse section near middle of corallite (1), transverse section one inch below first section (3), and longitudinal section between transverse sections (2), of specimen W-114; longitudinal section just below calyx (4) of a second specimen, W-115, Escabrosa Limestone.....	108
5	Vesiculophyllum sp. A; longitudinal section near center of corallite, from Escabrosa Limestone, W-116.....	110

Plate IX

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Plate X

All magnifications x2
except 3, which is x1.

Page

1-2 Vesiculophyllum sp. A; transverse sections in late ephebic stage (1) and early ephebic stage (2), Escabrosa Limestone, W-116..... 110

3-4 Chaetetes eximius Moore and Jeffords; external view of one part of the rounded corallum (3), x1, section through corallum which is longitudinal near the top and transverse near the bottom, from unit 48, section II, W-121..... 112

5-6 Multithecopora sp. A; transverse sections near the base of the corallum, unit 48, section II, W-125..... 114

Plate X

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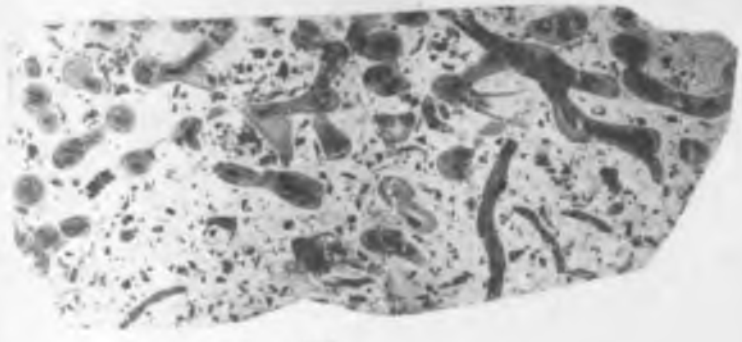

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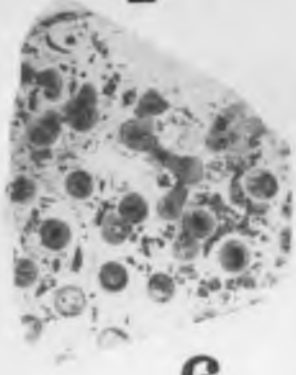

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Plate XI

All magnifications x2
except 3, which is x1.

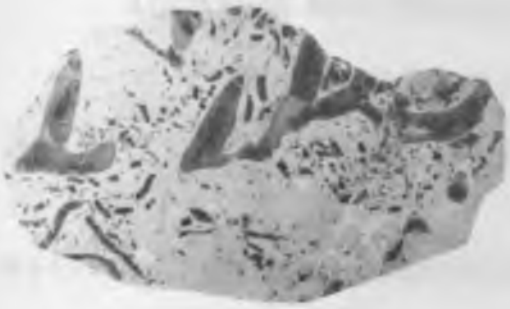
Page

1-2 Multithecopora sp. A; longitudinal sections through the base of the corallum, unit 48, section II, W-125..... 114

3-6 Syringopora sp. A; external view of corallum (3), x1, transverse section near top of corallum (4), and longitudinal sections of individual corallites (5,6), Escabrosa Limestone, W-126..... 115

7-8 Syringopora sp. indet.; transverse sections near middle of corallum, Escabrosa Limestone, W-128..... 116

Plate XI



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APPENDIX I

LOCATION AND DESCRIPTION OF SURFACE SECTIONS OF THE NACO FORMATION (PENNSYLVANIAN) NEAR WINKELMAN, ARIZONA

Section 1: composite section measured in the W1/2NW1/4 sec. 12, T. 5 S., R. 15 E. The bottom half of the section was measured from the top of the Escabrosa Limestone to the base of a feldspar-mica porphyry sill. The top half is offset about 950 feet to the north where the top of the sill crosses an old quarry road, then continues northeast to the top of the ridge (Figure 4).

Upper Limestone member:

Upper contact; eroded dip slope at top of ridge.

Unit No.		Thickness in feet
55	Concealed: appears to be calcareous siltstone, brownish black (5YR 3/1), weathering pale yellowish brown (10YR 7/2) to pale red (10R 6/2).....	15 1/2

Unit No.		Thickness in feet
54	Biosparite: medium dark gray (N4), weathering medium to medium dark gray (N4-N5); thin bedded; locally becomes a Composita biosparite; fossil replacement by moderate reddish orange and brown (10R 4/6-6/6) chert; elongate micrite intraclasts, 1 to 6 inches long, medium gray (N5) weathering very light gray (N8) occur near the top.....	3 1/2
53	Concealed: basal part banded siltstone, medium dark gray (N4), weathering light gray (N7); higher, the siltstone weathers pale red (5R 6/2) and grayish orange pink (5YR 7/2); chert bands and nodules locally present, grayish black (N2) to moderate reddish orange and brown (10R 4/6-6/6).....	8
52	Biosparite: medium dark gray (N4), weathering medium to medium dark gray (N4-N5); thin bedded.....	2

Unit No.		Thickness in feet
51	Siltstone: medium to medium dark gray (N4-5), weathering pinkish gray (5YR 8/1) to very light red (5R 7/6); thick bedded; chert nodules locally present.....	4
50	Biosparite: medium dark gray (N4), weathering light gray (N7) with a silty layer near the middle weathering moderate reddish brown (10R 4/6) and containing chert nodules of the same color; thick bedded.....	6 1/2
49	Calcareous siltstone: medium gray (N5), weathering orange pink (10YR 7/4) near base, very light gray (N8) near top; thick bedded; beds locally intraclastic, lumps of upper material included in the tan lower beds.....	6
48	Biosparite: silty, intraclastic, medium gray (N5), weathering medium to medium dark gray (N4-5); intraclasts, especially	

Unit No.		Thickness in feet
	near base are common and resemble the overlying siltstone; chert nodules locally present, weathering moderate reddish orange to brown (10R 4/6-6/6).....	4 1/2
47	Alternating thick- to thin-bedded silty fusulinid biomicrite and biosparite: biomicrite is grayish black (N2), weathering yellowish gray (5Y 8/1); biosparite is dusky red (5R 4/4), weathering grayish pink (5R 8/2) to moderate orange pink (10R 7/4); moderate reddish orange to brown (10R 4/6-6/6) chert nodules locally abundant.....	9 1/2
46	Fusulinid biosparite: medium dark gray (N4), weathering medium gray (N5) and strongly replaced by dark gray (N3) chert; thin bedded.....	2
45	Biomicrite: silty, medium gray (N5), weathering pinkish gray (5YR 8/1) and	

Unit No.		Thickness in feet
	biosparite: silty, brownish gray (5YR 5/1), weathering medium gray (N4); thick bedded becoming thin bedded and nodular near the top; chert nodules, weathering moderate reddish orange to brown (10R 4/6-6/6), are abundant.....	7
44	Alternating biomicrite, brownish gray (5YR 5/1), weathering very light gray (N8), nodular, and biosparite, medium to medium dark gray (N4-5), weathering medium to very light gray (5-8); thin bedded; chert similar to underlying unit, one thick band near the top is dark gray (N3) to moderate reddish brown (10R 4/6).....	6
43	Biomicrite: medium dark gray (N4), weathering very light gray (N8) near base; upper half has a mottled surface, medium gray (N5) in light to very light gray (N7-8); thin to thick bedded; chert nodules and fossils are light	

Unit No.		Thickness in feet
	brown (5YR 5/6) to moderate reddish brown (10R 4/6).....	4 1/2
42	Biosparite: dark gray to medium dark gray (N3-4), weathering medium light gray (N6) in pinkish gray (5YR 8/1); alternating thin- to thick-bedded; some beds silty; basal 3 feet is strongly intraclastic (intraclasts up to 6 inches long); contains Antiquatonia coloradoensis and corals; higher, the biosparite is silty, grayish red (5R 4/2), weathering pale red (10R 6/2) to grayish orange (10YR 7/4); top two feet is medium dark gray (N4), weathering very light gray (N8); nodules and bands of dark gray (N3) to pale reddish brown (10R 5/4) chert scattered throughout unit.....	8
41	Feldspar-mica porphyry sill.....	5
40	Biosparite: dark gray (N3) weathering light olive gray (5Y 6/1); thin- to thick-	

Unit No.		Thickness in feet
	bedded; some beds containing admixtures of micrite; thin lenses of biomicrite present, dark gray (N3) weathering light to very light gray (N7-8); abundant chert nodules and bands, dark reddish brown (10R 3/4) to moderate reddish brown (10R 4/6); near top, one continuous band, black (N1) to very dusky red (10R 2/2).....	6
39	Biomicrite: silty, dolomitic, grayish red (5R 4/2), weathering moderate pink (5R 7/4) to moderate orange pink (10YR 7/4), containing micrite intraclasts, grayish black to dark gray (N2-3), weathering light gray to very light gray (N7-8); top two feet becomes brownish black (5YR 3/1), weathering pinkish gray (5YR 8/1) to grayish pink (5R 8/2); thick bedded.....	5
38	Biomicrite: silty, pale brown (5YR 4/2), weathering grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4); thin	

Unit No.		Thickness in feet
	bedded; very fossiliferous, brachiopod, crinoid and bryozoan fragments forming a fossil hash; Phricodothyris perplexa, Antiquatonia hermosana, with Composita sp.....	11
37	Biosparite: brownish gray (5YR 5/1) to dark gray (N3), weathering olive gray (5Y 5/1-6/1); chert replaced fossils locally; lower 11 feet is very thick bedded; Composita derrya near base; top 5 feet contains light gray (N7) micrite intraclasts, thin and nodular biomicrite beds up to 6 inches thick, medium dark gray (N4), weathering very light gray (N8); thin- to thick-bedded.....	16
36	Siltstone: with biosparite nodules and lenses, dark gray (N3) in grayish brown (5YR 3/2), weathering very light gray (N7) to light olive gray (5Y 6/1) in dark reddish brown (10R 3/4) to pale red (10R 6/2); thick bedded; siltstone locally replaced	

Unit No.		Thickness in feet
	by chert; a 1-3 foot bed of silty biosparite occurs 6 feet above the base, dark gray (N3), weathering medium gray (N5), and contains lenses and stringers of siltstone partially replaced by chert nodules, light brownish gray (5YR 7/1) to light olive gray (5Y 6/1), that weathers pale reddish brown (10R 5/4). This is the prominent red band that can be seen throughout the area.....	21
35	Biosparite: strongly intraclastic, medium gray (N5) intraclasts weathering very light gray (N5-8) in a medium light gray (N6) biosparite which weathers light gray (N7); thick bedded; surface replacement of fossils by chert.....	6 1/3
34	Siltstone with nodular biomicrite and biosparite: medium dark gray (N4) biomicrite in grayish brown (5YR 3/2) siltstone, weathering light to very light gray (N7-8)	

Unit No.		Thickness in feet
	in the grayish orange pink (5YR 7/2) siltstone matrix; very fossiliferous with brachiopod, crinoid, and bryozoan fragments.....	11 1/2
33	Alternating biomicrite and biosparite with nodular fusulinid biomicrite partings: dark to medium dark gray (N3-4), weathering light to very light gray (N7-8); thin bedded; moderate reddish brown to orange (10R 4/6) to (10R 6/6) chert nodules abundant.....	6
32	Biosparite: intraclastic, brownish gray (5YR 5/1), weathering mottled medium gray (N5) in pinkish gray (5YR 8/1); thick bedded; intraclasts not always visable on fresh fracture; moderate orange pink (10R 7/4) to moderate reddish brown (10R 4/6) chert nodules range up to 1 foot in length.....	5

Unit No.		Thickness in feet
31	Concealed: appears to be thin bedded or nodular biosparite and biomicrite.....	7
30	Biosparite: intraclastic in basal 6 inches, subrounded to subangular limestone fragments, poorly sorted, of varying lithologic aspect (mainly biosparite), in a biosparite matrix; the overlying 2 feet is brownish gray (5YR 5/1), weathering medium to light gray (N5-7); thin bedded; the top 2 feet is medium gray (N5), weathering medium to light gray (N5-7); thin bedded, with brachiopod fragments; the upper 4 feet contains chert-replaced fossils and nodules, moderate reddish brown to orange (10R 4/6-6/6).....	4 1/2
29	Biosparite: nodular near base, mottled medium dark gray (N4) to brownish gray (5YR 4/1), weathering medium light to light gray (N6-7); the upper 4 feet is medium dark gray (N4), weathering mottled medium light gray (N6) and light	

Unit No.		Thickness in feet
	Light olive gray (5Y 6/1); thin bedded; chert-replaced coral, crinoid, and brachiopod fragments.....	6 1/2
28	Biosparite: light brownish gray (5YR 7/1), weathering light olive gray (5Y 6/1); small, very light gray (N8) micrite intraclasts; thin- to thick-bedded; brachiopods and fusulinids locally abundant; moderate reddish brown to orange (10YR 4/6-6/6) chert nodules and chert-replaced brachiopods locally.....	6
27	Interbedded shale, thin- to thick-bedded nodular biomicrites and biosparites, partly concealed: shales are blackish red (5R 2/2); five feet above the base nodular biomicrites and fusulinid biomicrites are medium dark gray (N4), weathering light gray (N7) to pinkish gray (5YR 8/1); biomicrite nodules are medium dark gray (N4), weathering medium to light gray (N5-7);	

Unit No.		Thickness in feet
	poorly preserved brachiopods, bryozoans and crinoid fragments abundant; brachiopods include Linoproductus aff. L. platyumbonus, Spirifer rockymontanus, and S. occiduus, and Antiquatonia coloradoensis.....	15
26	Interbedded thin shales and thin- to thick-bedded biosparite and biomicrite: shales are grayish red (5R 4/2); limestones are silty, mottled light brownish gray (5YR 7/1) in (5YR 6/1), weathering mottled, very light gray (N8) in dusky brown (5YR 2/2); fossil fragments locally replaced by chert which weathers moderate reddish brown to orange (10R 4/6-6/6).....	10
25	Biosparite: medium dark gray (N4) to brownish gray (5YR 5/1), weathering very light gray (N8) to pale red (10R 6/2), locally nodular in the top 2 to 3 feet; Thin- to thick-bedded; chert occurs as nodules up to 6 inches long, and as	

Unit No.		Thickness in feet
	replacement of fossil fragments, light gray (N7) becoming pale reddish brown (10R 5/4) to moderate reddish orange (10R 6/6) near the top.....	6 1/2
24	Alternating thin shales, nodular and thin-bedded biomicrites and sparry biomicrites: shales weather grayish red (5R 4/2); nodular limestones are medium dark to medium light gray (N4-6), weathering medium to very light gray (N6-8), in a clay-silt matrix resembling soil, pale red (10R 6/2).....	9
23	Fusulinid biomicrite: light olive to greenish gray (5Y-5GY 6/1), weathering very light gray (N8) with grayish red (5R 4/2) shale near the base; top 1 1/2 feet are medium light gray (N6) biosparite weathering very light gray (N8); thin bedded; abundant small brachiopod, crinoid, and bryozoan fragments.....	3

Unit No.		Thickness in feet
22	Biomicrite: basal 1 to 3 feet is baked by underlying sill, a limy shale, blackish red (5R 2/2) to light brownish gray (5YR 6/1), with micrite nodules and lenses, medium light gray (N6), weathering light to very light gray (N7-8); the upper 2 1/2 feet is silty biomicrite, mottled, light brownish gray (5YR 6/1) in olive gray (5Y 5/1) and grayish red (5R 4/2), which weathers a mottled color, medium light gray (N6) in light olive gray (5Y 6/1) and greenish gray (5GY 6/1).....	5 1/2
21	Feldspar-mica porphyry sill: variable in thickness.....	5 1/2
20	Concealed: approximately 5 feet of calcareous sediments to base of sill.....	5
19	Mainly concealed: alternating thin bedded sparry biomicrite, brownish gray (5YR 5/1), weathering white (N9), and micritic	

Unit No.		Thickness in feet
	biosparite, light gray (N7) to brownish gray (5YR 5/1), weathering light olive gray (5Y 6/1).....	5
18	Biosparite, with some micrite: brownish gray (5YR 5/1), weathering light to very light gray (N7-8); thin- to thick-bedded, partly covered; poorly preserved fossils include Antiquatonia, Composita, and Spirifer; four feet above base is a 1 foot thick chert band, moderate reddish brown (10R 4/6), chert nodules of same color scattered to top of unit; top 3 feet is thin bedded, nodular, containing some micrite.....	10
17	Biosparite and biomicrite: near base, thin bedded biosparite containing admixtures of micrite, brownish gray (5YR 5/1), weathering light olive gray (5Y 6/1); grades upward into thin bedded biomicrite and nodular biomicrite, medium gray (N5), weathering very light	

Unit No.		Thickness in feet
	gray (N9); top 1 1/2 feet is finely crystalline dolomite, grayish red (5R 4/2) weathering reddish orange (10R 7/6).....	5
16	Biosparite: light brownish gray (5YR 6/1), weathering light olive gray (5Y 6/1); thick bedded; basal 1 foot contains some micrite; 4 feet above base a small disconformity is locally present, above which is sparry biomicrite, brownish gray (5YR 5/1), weathering grayish orange pink (10R 8/2), and locally containing dusky red (5R 3/4) to moderate reddish brown (10R 4/6) chert nodules, about 1 foot thick.....	9 1/2
15	Biosparite: brownish gray (5YR 5/1), weathering light olive gray (5Y 6/1); thick bedded; contains some micrite.....	4 1/2
14	Biosparite and biomicrite: near base, thin-bedded micritic biosparite, pinkish gray (5YR 8/1), weathering mottled white (N9)	

Unit No.		Thickness in feet
	in medium dark gray (N4); poorly preserved brachiopods include Composita subtilita; top 2 1/2 feet is thin-bedded nodular biomicrite, very pale brown (10YR 6/2), weathering very light gray (N8) to white (N9).....	4
13	Biosparite: light brownish gray (5YR 6/1), weathering medium to medium dark gray (N4-5) near base, contains some micrite; thin bedded; top 2 to 3 feet is a fossiliferous oosparite with thin brachiopod shell bands, 1/2 to 1/4 inch thick; oolites weather white (N9) in medium gray (N5) background.....	5
12	Fossiliferous oosparite: pale red (5R 6/2), weathering light gray (N7); thin bedded; contains micrite intraclasts weathering very light gray (N8); top 2 feet is sparry biomicrite: thin bedded; fossils include Spirifer occiduus, S. opimus, Antiquatonia sp., and Composita sp.; preservation poor.....	5 1/2

Unit No.		Thickness in feet
11	Biosparite and biomicrite: basal 2 feet is thick bedded micritic biosparite, light brownish gray (5YR 6/1), weathering mottled very light gray (N8) in medium gray (N5); upper 8 feet is thick- to very thick-bedded sparry biomicrite: brownish gray (5YR 5/1), weathering light to very light gray (N7-8); two feet above the base is a 2 foot zone showing laminated bedding; chert, pale reddish brown (10R 5/4) to light gray (N7) occurs throughout unit, especially abundant near top.....	10
10	Biomicrite: basal 2 to 3 feet is nodular, brownish gray (5YR 5/1), weathering white (N9) to very light gray (N8) in a grayish pink (5R 8/2) limy shale matrix; remainder of unit laminated, same color as below, with nodules and lenses of chert, pale reddish brown (10R 5/4) to pale red (10R 6/2); chert appears to have hardened	

Unit No.		Thickness in feet
	before the calcium carbonate because micrite laminae bend and conform to nodules; six feet above base a 2 1/2 foot zone of Chaetetes eximius occurs; the Chaetetes colonies are up to 6 inches in diameter and weather medium gray (N5).....	10 1/2
9	Biosparite: medium dark gray (N4), weathering olive gray (5Y 5/1); thick bedded; moderate reddish brown (10R 4/6) to grayish pink (5R 8/2), chert nodules locally present throughout unit; top 6 inches is biomicrite with intraclasts of biosparite resembling the lower part of the unit.....	7
8	Biomicrite: pale red (10R 6/2), weathering very light gray (N8) to pinkish gray (5YR 8/1) near base; thin bedded; contains some sparite; top 2 feet is interbedded shaly, nodular biomicrite and thin bedded biosparite, brownish gray (5YR 5/1), weathering olive gray (5Y 5/1).....	4

Unit No.		Thickness in feet
7	Feldspar-mica porphyry sill.....	32
	Total thickness of Upper Limestone member exclusive of sills..... 332' 10"	
	Lower Dolomite member:	
6	Dolomite: brownish gray (5YR 4/1), weathering pale red (10R 6/2), finely crystalline, thick bedded; lense-shaped pale reddish brown (10R 5/4) to grayish black (N2) chert nodules up to 1 foot long near base: contains some calcite; top half thin bedded, pale brown (5YR 3/1), weathering pale yellowish brown (10R 6/2); partly concealed; numerous fossil fragments and calcite grains in varying stages of dolomitization; top 3 feet moderate yellowish orange (10YR 5/4), weathering dark yellowish orange (10YR 6/6).....	12
5	Dolomite: finely crystalline, becoming calcareous upwards; thin bedded; bottom 9 1/2 feet is medium dark gray (N4)	

Unit No.		Thickness in feet
	weathering grayish orange (10YR 7/4); contains lenses of fossil fragments and calcite grains near top; near base of unit average dolomite crystal diameter is .01 mm, increasing to .04 to .08 mm higher; next 5 feet has intercalated beds of brownish gray (5YR 4/1), weathering dark yellowish orange (10YR 6/6); top 5 feet is similar except lower part is brownish gray (5YR 5/1), weathering grayish orange pink (5YR 7/2-8/2), with small grayish orange pink (10R 8/2) to very light gray (N8) chert nodules up to 2 inches in diameter; upper beds calcareous; calcite is seen to be concentrated between dolomite crystals in thin section.....	19 1/2
4	Dolomite: interbedded medium dark gray (N4) and brownish gray (5YR 4/1) weathering moderate orange pink (10R 7/4) and moderate yellowish brown (10YR 5/4); thin- to thick-bedded; finely crystalline; two	

Unit No.		Thickness in feet
	zones of chert nodules 1 to 2 feet thick containing pinkish gray (5YR 8/1) nodules up to two inches in diameter occur 8 and 12 feet above the base; upper beds are interbedded dark gray (N3), weathering grayish orange (10YR 7/4), and brownish gray (5YR 5/1), weathering olive gray (5Y 4/1); 5 1/2 feet below top is a thin coarsely crystalline biosparite, brownish black (5YR 2/1), weathering dark olive gray (5Y 3/1), containing no dolomite: the dolomite crystals in this unit average .04 mm in diameter, larger crystals replacing ghost fossil fragments. Calcite is rare and restricted to between crystal faces. Locally chert contains dolomite rhombohedrons and ghost fossil fragments.....	18
3	Dolomite: brownish gray (5YR 5/1), weathering olive gray (5Y 5/1) near the bottom; thin bedded; finely crystalline;	

Unit No.		Thickness in feet
	lenses of sparry calcite grains and partially dolomitized chert fossil fragments, grayish red (10R 4/2-6/2); higher beds are medium dark gray (N4), weathering very pale orange (10YR 8/2) to moderate orange pink (5YR 8/4), containing lenses of fossil fragments and calcite grains replaced by moderate brown (5YR 4/4) to dark reddish brown (10R 3/4) chert; between lenses of fossil fragments and calcite grains, dolomite is finely crystalline, average diameter .05 mm, with ghost crinoid columnals and irregular grains replaced with larger crystals, average diameter .09 mm; calcite, where present, restricted to interspaces between dolomite crystal faces.....	8
2	Dolomite: medium gray (N5) weathering very pale orange (10YR 8/2) near base, becoming brownish gray (5YR 5/1), weathering grayish orange (10YR 7/4) interbedded with medium	

Unit No.		Thickness in feet
	gray (N5), weathering pinkish gray (5YR 8/1) near top; thin bedded; finely crystalline; throughout unit are thin lenses and stringers of sparry calcite crystals and partially silicified fossil fragments weathering medium dark gray (N4); chert bands, grayish red (10R 4/2) to pale reddish brown (10R 5/4), locally present; dolomite grains average .04 mm in diameter but reach .07 mm when replacing sparry calcite crystals and rounded fossil fragments; arrangement and preservation suggest that these fragments were eroded from the underlying Escabrosa Limestone; included rounded pebbles of Escabrosa biosparite are found.....	9 1/2
1	Dolomite: mainly concealed; brownish gray (5YR 5/1), weathering grayish orange (10YR 7/4) near base; thin bedded; finely crystalline; material contains weathered sparry calcite crystals and moderate red	

Unit No.		Thickness in feet
	(5R 5/4) to grayish red (10R 4/2) chert nodules	5
	Total thickness of Lower Dolomite member exclusive of sills	72'
	Total thickness of Naco section	404' 10"

Lower contact: the basal dolomite member of the Naco Formation rests unconformably on the Mississippian Escabrosa Limestone. The Escabrosa is a biosparite, medium gray (N5), weathering medium dark gray (N4), showing up to two feet of relief under the dolomite member. Fossils are scarce but include Vesiculophyllum sedaliense, V. sp. A, Syringopora sp. A, and S. sp. indet.

Section II: a composite section measured in a NNE direction on the north side of the Gila River Pass. The base of the section is located in the SW 1/4SW 1/4 sec. 7, T. 5 S., R. 16 E. The top is located in the SE 1/4SE 1/4 sec. 12, T. 5 S., R. 15 E. The base of each portion of the section is located on the Winkelman-Globe highway (Figure 4).

Upper Limestone member:

Upper contact: erosion surface at top of pass.

Unit No.		Thickness in feet
71	Biosparite: intraclastic; intraclasts range up to 2 inches in diameter, are medium dark gray (N4), weathering light gray (N7) in a medium gray (N5) matrix which weathers light olive gray (10YR 6/2); thin bedded	3
70	Biosparite: medium gray (N5), weathering very light gray (N8) to y ellowish gray (5Y 8/1); thin bedded; corals are common including Pseudozaphrentoides torquius and P. sp. A	8
69	Biomicrite: dolomitic, partly covered, very similar to underlying unit, but weathering grayish to yellowish orange (10YR 7/4-7/6); thin bedded	6
68	Biomicrite: dolomitic; interbedded medium gray (N5) and pale yellowish brown (10YR 6/2), weathering very pale orange	

Unit No.		Thickness in feet
	(10YR 8/2) and grayish orange (10YR 7/4); thin- to very thin-bedded; abundant fauna includes Composita argentea, Spirifer occiduus, Orthotetes (Derbyia) crassa, Linoproductus aff. L. platyumbonus, Neospirifer cameratus, and the coral Lophophyllidium sp. A.....	15
67	Biosparite: medium gray (N5), weathering very light gray (N8); thick bedded; contains some micrite.....	3 1/2
66	Biosparite: intraclastic, with micrite intraclasts, medium light gray (N6) weathering light olive gray (5Y 6/1); thick bedded; chert nodules weathering moderate reddish brown (10R 4/6) abundant in the upper 3 feet.....	8
65	Biosparite: light brownish gray (5YR 5/1), weathering very light gray (N8) to pinkish gray (5YR 8/1), grading up into biomicrite	

Unit No.		Thickness in feet
	containing some sparite, light brownish gray (5YR 5/1), weathering grayish orange pink (5YR 7/2); thin bedded; chert nodules and lenses weathering moderate orange pink (10R 7/4) to moderate reddish brown (10R 4/6) are abundant, especially in the lower 3 feet.....	6
64	Biosparite: medium light to light gray (N6-7), weathering yellowish gray (5Y 8/1); thin bedded, coarsely crystalline, partly covered.....	5
63	Biomicrite: medium gray (N5), weathering light to very light gray (N7-8); thick bedded; chert nodules weathering moderate reddish brown (10R 4/6) abundant.....	6
62	Biomicrite: medium to medium light gray (N5-6), weathering very light gray (N8) to greenish gray (5GY 6/1); basal 1 foot very light gray (N8), thin bedded; rest of unit	

Unit No.		Thickness in feet
	very thick bedded, containing some sparite; chert nodules and lenses weathering pale to dark reddish brown (10R 5/4-3/4) abundant, especially near top: fauna includes Hustedia mormoni.....	11
61	Biosparite: medium gray (N5), weathering medium light gray (N6) to light olive gray (5Y 6/1); thick bedded; near middle of unit a 6 inch bed of biomicrite with large fossil fragments weathering medium light gray (N6) in a light to very light gray (N7-8) background; abundant chert nodules weathering medium dark gray (N4) to brownish gray (5YR 4/1).....	5
60	Dolomite: calcareous, siliceous, thin and Irregular bedding; dark to medium dark gray (N3-4), weathering pinkish to yellowish gray (5YR 8/1-5Y 8/1); thin lenses of small fossil fragments, poorly sorted, occur.....	3 1/2

Unit No.		Thickness in feet
59	Biomicrite: medium gray (N5), weathering light olive gray (5Y 6/1); thick bedded, contains some sparite.....	4
58	Biosparite: medium gray (N5), weathering medium to medium dark gray (N4-5); thick- to very thick-bedded; top half of unit contains elongate intraclasts (up to 6 inches long), brownish gray (5YR 5/1), weathering very light gray (N8).....	10
57	Biosparite: medium gray (N5), weathering light to medium light gray (N6-7); thick bedded; near middle of unit is a 6 inch to 1 foot thick band of silty, intraclastic, micrite, grayish red (10R 4/2), weathering grayish orange pink (5YR 7/2).....	4
56	Biomicrite and biosparite: the lower 7 feet is fusulinid biomicrite near base, medium gray (N5), weathering light to very light gray (N7-8); strongly intra-	

Unit No.		Thickness in feet
	clastic biosparite higher, medium gray (N5), weathering light to medium light gray (N6-7); intraclasts appear similar to material from bottom of unit; thick bedded; upper 4 feet of unit is laminated biosparite grading up into thin bedded, intraclastic, fusulinid biosparite; medium dark gray (N4), weathering light brownish gray (5YR 7/1), with some micrite.....	11
55	Biosparite: light brownish gray (5YR 6/1), weathering light olive gray (5Y 5/1); thick bedded, contains some micrite; chert bands weathering dark gray (N3) to pale yellowish brown (10YR 6/2) occur.....	3 1/2
54	Biomicrite: pale red purple (5RP 7/2), weathering light to very light gray (N7-8); thick bedded, some sparite; numerous coral and brachiopod fragments,	

Unit No.		Thickness in feet
	including Composita, replaced by chert weathering moderate reddish brown (10R 4/6).....	2
53	Concealed.....	5 1/2
52	Biosparite: medium gray (N5), weathering light gray (N7) to pinkish gray (5YR 8/1), with micrite intraclasts, grayish red (5R 4/2), weathering light gray (N7); intraclasts well rounded, contain fusulinids; thick bedded.....	5 1/2
51	Biomicrite: medium gray (N5), weathering light gray (N7), with sparite intraclasts, grayish red (5R 4/2), weathering light gray (N7); thick bedded.....	6
50	Biomicrite: medium gray (N5), weathering light gray (N7), with biomicrite intraclasts weathering very light gray (N8) near base; thick bedded.....	5

Unit No.		Thickness in feet
49	Biomicrite and biosparite: biomicrite with some sparite grades upward into biosparite, medium light to light gray (N6-7), weathering olive gray (5Y 5/1); thick bedded; chert nodules and lenses weathering dark gray (N3) to grayish red (10R 4/2) abundant near top.....	9 1/2
48	Biosparite: dark gray (N3), weathers light olive gray (5Y 5/1-6/1); thick bedded, contains some micrite; corals common, including Chaetetes eximius and Multithecopora sp. A, partially replaced by chert; chert nodules also present, weathering moderate reddish brown (10R 4/6).....	2
47	Biomicrite: mainly concealed; silty, with small siltstone intraclasts; pale red (5R 6/2), weathering moderate orange pink (10R 7/4).....	5 1/2

Unit No.		Thickness in feet
46	Biosparite: strongly intraclastic; medium dark to medium gray (N4-5), weathering medium to medium light gray (N5-6); thin bedded.....	1
45	Dolomite and dolomitic sparite: lower 5 feet calcareous, finely crystalline dolomite, dark gray (N3) to brownish gray (5YR 5/1), weathering light olive gray (5Y 6/1) to grayish orange pink (5YR 7/2); thick bedded; upper 7 feet is dolomitic sparite, brownish gray (5YR 4/1), weathering olive gray (5Y 5/1), with intraclasts of the underlying material; thick bedded.....	12
44	Concealed.....	11
43	Biosparite: medium dark gray to medium gray (N4-5), weathering olive gray (5Y 5/1); thick bedded; medium dark gray (N4) intraclasts weathering very light gray (N8), up to 3 inches long; abundant fauna includes	

Unit No.		Thickness in feet
	Punctospirifer kentuckyensis, Neospirifer goreii, Spirifer rockymontanus, S. opimus, S. occiduus, Composita subtilita, C. argentea, C. malaya, Phricodothyris perplexa, Orthotetes (Derbyia) crassa, Antiquatonia hermosana, Retaria lasallensis, Desmoinesia muricatina, Chonetes granulifer, Lophophyllidium idonium, crinoid and bryozoan fragments.....	3
42	Sparry biomicrite: brownish gray (5YR 6/1), weathering light olive gray (5Y 6/1); very thick bedded; intraclasts near middle and top of unit; top 1 foot has same fauna as unit 43, plus Lophophyllidium aff. L. ignotum.....	6
41	Concealed: appears to be pink to red dolomite.....	2
40	Silty biomicrite: silty micrite nodules and lenses in limy siltstone matrix; micrite is medium dark gray (N4), weathering light	

Unit No.		Thickness in feet
	gray (N7); siltstone matrix is brownish gray (5YR 5/2), weathering grayish orange pink (5YR 7/2) to moderate reddish orange (10R 4/6); thick- to very thick-bedded; silt is medium to coarse, fair to good sorting, grains are angular to sub-rounded; this unit, with units 39 and 38 form a conspicuous red marker band throughout the area; abundant fauna includes Antiquatonia coloradoensis, Linoproductus aff. L. platyumbonus, Neospirifer cameratus, Retaria lasallensis, and the coral Pseudozaphrentoides torquius.....	15
39	Biosparite: brownish gray (5YR 5/1), weathering grayish orange pink (5YR 7/2) to very light gray (N8); thin bedded.....	1 1/2
38	Alternating laminae of silty micrite and micritic siltsone; medium dark to medium gray (N4-5), weathering pinkish to yellowish gray (5Y-5YR 8/1), quartz silt grains are	

Unit No.		Thickness in feet
	subangular to subrounded with fair to good sorting.....	5 1/2
37	Biosparite: brownish gray (5YR 5/1), weathering medium to very light gray (N5-8); thin bedded, with thin, pinkish gray (5YR 8/1) to moderate reddish brown (10R 4/6) chert bands.....	3 1/2
36	Concealed;.....	6
35	Biosparite and biomicrite: medium gray (N5) micritic biosparite, weathering light olive gray (5Y 6/1), near base; grades upward into dark gray (N3) biomicrite with micrite intraclasts, weathering moderate orange pink (5YR 8/4) in a medium light gray (N6) background; thick bedded.....	5
34	Micrite: silty, mottled, medium dark to medium gray (N4-5), weathering very light gray (N8) in a grayish orange pink (5YR 7/2) background; thin bedded; quartz silt grains	

Unit No.		Thickness in feet
	are well sorted, sub-angular to sub-rounded; fauna includes Chonetes granulifer and Spirifer occiduus.....	7 1/2
33	Interbedded sparry biomicrite and sparry fusulinid biomicrite: biomicrite is medium dark gray (N4), weathering pale red (10R 6/2); fusulinid biomicrite is brownish gray (5YR 4/1), weathering pale red (10R 7/2); fossil replacement and nodules of pale to moderate reddish brown (10R 4/6-5/4) chert; top 2 feet is biosparite, medium light gray (N6) weathering light gray (N7).....	11
32	Feldspar-mica porphyry sill.....	15
31	Biomicrite: silty, intraclastic, medium dark gray (N4), weathering mottled, grayish pink (5R 8/2) and medium gray (N5); thin bedded to nodular.....	5

Unit No.		Thickness in feet
30	Feldspar-mica porphyry sill.....	10
29	Biomicrite: pale brown (5YR 5/2), weathering grayish orange pink (5YR 7/2); contains small sparite intraclasts; thin bedded.....	3
28	Concealed: some interbedded nodular biomicrite and dark shales near base; float indicates feldspar-mica porphyry sill near middle; fauna includes Antiquatonia sp. and Echinoconchus semipunctatus.....	92
27	Interbedded shale and biomicrite: shale is dark brown (5YR 2/1), weathering dusky purple (5P 2/2); biomicrite is dusky blue (5PB 4/2), weathering grayish blue (5PB 6/2), nodular, and sparry: abundant fauna includes Antiquatonia coloradoensis, Linoproductus aff. L. platyumbonus, Juresania nebrascensis, Punctospirifer kentuckyensis, Spirifer occiduus, Neospirifer cameratus, Orthotetes (Derbyia) crassa, Chonetes granulifer,	

Unit No.		Thickness in feet
	Retaria lasallensis, Composita ovata, C. argentea, and C. subtilita.....	10
26	Limy siltstone: quartz grains well sorted, sub-rounded to rounded; pale brown (5YR 5/2), weathering mottled moderate reddish brown and orange (10R 4/6-6/6), with silty micrite intraclasts, pale brown (5YR 5/1), weathering grayish orange pink (5YR 7/2), and medium gray (N5), weathering pale yellowish brown (10YR 6/2).....	3
25	Micrite and biosparite: biosparite near base, mottled medium gray (N5) and pale yellowish orange (10YR 8/6), weathering light and very light gray (N7-8); thin bedded; near top, laminated micrite, mottled medium dark and light gray (N4-7), weathering pale yellowish brown (10YR 6/2).....	6
24	Mainly concealed: float indicates inter-bedded dark shales and nodular biomicrite;	

a small outcrop yielded Antiquatonia coloradoensis..... 14

23 Gravelly sparite: medium gray (N5), weathering medium light to light gray (N6-7); pale reddish brown (10R 4/4) chert sand and pebbles, poorly sorted, sub-angular to sub-rounded, form lenses and stringers in the sparite; thin bedded..... 2 1/2

22 Biomicrite: basal five feet sparry, medium gray (N5), weathering medium light to very light gray (N7-8), thick bedded, strongly intraclastic in top foot; contains bands of pale reddish brown (10R 5/4) chert up to one foot thick; upper six feet nodular and shaly, becoming sparry at the top; pale brown (5YR 5/1), weathering very light gray (N8) to pinkish gray (5YR 8/1)..... 11

21 Biomicrite: yellowish gray (5Y 8/1), weathering very light gray (N8) to pinkish gray (5YR 8/1); nodular to thin bedded; contains nodules of moderate reddish brown (10R 4/6)

Unit No.		Thickness in feet
	chert; at the base of this unit is a 0 to 1 foot thick bed of dolomicrite, pale reddish brown (10R 5/4), weathering moderate reddish orange (10R 6/6), with micrite intraclasts similar to above.....	5 1/2
20	Interbedded biosparite and micritic biosparite: same color as unit 21, thin bedded, overlies unit 21 with a small disconformity.....	5 1/2
19	Biomicrite and biosparite: medium gray (N5), weathering pale red (10R 7/2); sparry biomicrite near base, with micrite intraclasts, light brownish gray (5YR 6/1), weathering pale red (10R 7/2); thin- to thick-bedded; upper part of unit biosparite, one foot of sparry biomicrite at top.....	7
18	Interbedded biosparite, biomicrite and oosparite; biosparites and biomicrites are light brownish gray (5YR 6/1), weathering pale red (10R 7/2); thin- to thick-bedded;	

Unit No.		Thickness in feet
	basal foot is partly nodular oosparite, pale pink (5RP 8/2), weathering white (N9); oolites appear sporadically throughout unit; micrites locally become nodular, and fossiliferous; abundant fauna includes Juresania nebrascensis, Echinoconchus aff. E. angustus, Chonetes granulifer, Orthotetes (Derbyia) crassa, Retaria lasallensis, Spirifer opimus, S. occiduus, Composita subtilita, C. argentea, and one fish tooth.....	9 1/2
17	Oosparite and biosparite: basal 16 inches is oosparite, pale pink (5RP 8/2), weathering white (N9); the rest of the unit is biosparite, medium gray (N5), weathering grayish pink (5R 8/2) to very light gray (N8), with scattered oolites locally; thin- to thick-bedded.....	9
16	Biomicrite: sparry, light brownish gray (5YR 6/1), weathering very light gray to	

Unit No.		Thickness in feet
	white (N8-9); thin bedded to nodular; fauna includes Spirifer opimus and and pelecypod fragments.....	2
15	Sparry micrite: olive gray (5Y 5/1), weathering grayish orange pink (5YR 8/2 near base, becoming medium dark gray (N4), weathering medium light to light gray (N6-7) higher; very thick bedded; contains grayish pink (5R 8/2) chert nodules.....	11
14	Biosparite and biomicrite: basal 4 feet is laminated biomicrite, light brownish gray (5YR 6/1), weathering very light gray (N8), with pale reddish brown (10R 5/4) chert nodules and lenses; biomicrite laminae bend around and conform to shape of chert nodules, indicating that the chert hardened before the calcium carbonate; upper 6 feet is interbedded brownish gray (5YR 5/1) micritic biosparite, weathering yellowish gray (5Y 8/1), and nodular sparry, biomicrites;	

Unit No.		Thickness in feet
	biosparite thick bedded and intraclastic; four feet from the base of the unit a dense zone of Chaetetes eximius colonies occurs; colonies appear to have been transported or abraded; they weather medium to medium dark gray (N4-5) and may be partially replaced by chert.....	10
13	Biosparite: medium light gray (N6) to light brownish gray (5YR 6/1), weathering light to very light gray (N7-8); thin bedded; locally this material is intercalated with limy shales and nodular micrites; top 1 1/2 feet is a Composita biosparite; fauna includes Composita argentea, C. subtilita, C. ovata, C. malaya, C. derrya, Spirifer rockymontanus, S. occiduus, S. opimus, and Punctospirifer kentuckyensis.....	3

Unit No.		Thickness in feet
12	Biomicrite and biosparite: basal 4 feet is sparry biomicrite, medium dark gray (N4), weathering pinkish gray (5YR 8/1), thin bedded, with intercalated thin shales, moderate red (5R 4/6), weathering moderate red (5R 5/4); upper 4 feet is biosparite, moderate red (5R 4/6), weathering very light gray (N8) to pinkish gray (5YR 8/1); thick bedded; abundant fauna includes Orbiculoidea capuliformis, Lingula carbonaria, Punctospirifer kentuckyensis, Reticulariina aff. R. spinosa, R. aff. R. campestris, Composita subtilita, C. ovata, C. argentea, Orthotetes (Derbyia) crassa, Chonetes granulifer, Spirifer occiduus, S. opimus, S. rockymontanus, Hustedia mormoni, H. miseri, Schizophoria texana, S. resupinoides, echinoid spines, crinoid plates, and trilobite pygidia.....	8

Unit No.		Thickness in feet
11	Gradation zone from limy shale at base, to nodular micrite, to thin bedded biomicrite at top with brachiopod fragments; same color as unit 12.....	3
	Total thickness of Upper Limestone member exclusive of sills.....	463' 6"
	Lower Dolomite member:	
10	Shales and chert bands: interbedded dusky blue (5PB 3/2-2/2) shales and thin 1 to 2 inch thick chert bands, similar in color to unit 9, with very distorted bedding; top foot is a chert pebble conglomerate, grayish to dark grayish red (5R 4/2-3/2), weathering pale red (5R 6/2-10R 6/2); pebbles poorly sorted, sub-angular to sub-rounded, in a similar quartz sandstone matrix.....	5 1/2
9	Chert: varying color, mottled brownish gray (5YR 5/1), pale olive (10Y 6/2), and dark yellowish orange (10YR 6/6), weathering	

Unit No.		Thickness in feet
	moderate reddish brown to orange (10R 4/6-6/6) and grayish red (10R 4/2); thin bedded.....	4
8	Dolomite: finely crystalline, laminated and siliceous in top 1 to 2 feet locally; medium dark gray (N4), weathering varicolored, grayish orange (10YR 7/4), grayish red (10R 4/2), and light olive gray (5Y 6/1); thin bedded.....	5
7	Dolomite: finely crystalline; medium gray (N5), weathering moderate orange pink (10YR 7/4); thin- to very thin-bedded near base, becoming laminated 5 feet up; near top is a zone of very light gray (N8) chert nodules up to 1 inch in diameter.....	7 1/2
6	Dolomite: finely crystalline; medium dark gray (N4), weathering greenish gray (5GY 6/1); thin bedded; near top is a zone of very light gray (N8) chert nodules up to 1 inch in diameter.....	4

Unit No.		Thickness in feet
5	Dolomite: finely crystalline; mottled reddish brown (10R 4/4) and medium dark gray (N4), weathering reddish brown (10R 4/4) near base; medium dark gray (N4), weathering dark yellowish gray (5Y 6/2), higher; thin- to very thin-bedded, becoming laminated locally; scattered large, very light gray (N8) chert nodules, up to one foot in diameter, throughout unit.....	11
4	Dolomite: finely crystalline; medium dark gray (N4), weathering dusky yellow (5Y 6/4); thin bedded.....	5
3	Dolomite: finely crystalline; medium gray (N5), weathering grayish orange pink (5YR 7/2); thin bedded.....	3
2	Dolomite: finely crystalline; brownish gray (5YR 5/1), weathering light brown (5YR 5/6), grading up into medium gray (N5), weathering moderate reddish orange (10R 6/6)	

Unit No.		Thickness in feet
	to pale reddish brown (10R 5/4); very thick bedded.....	18 1/2
1	Dolomite: finely crystalline; mottled pale yellowish brown (10YR 6/2) and medium light gray (N6), weathering very pale orange (10YR 8/2), grading up into medium dark gray (N4), weathering pale brown (5YR 5/2); thin bedded.....	11 1/2

Total thickness of Lower Dolomite member exclusive of sills..... 75'

Total thickness of Naco section..... 538' 6"

Lower contact: not well exposed; basal dolomite member of the Naco Formation rests unconformably on the Mississippian Escabrosa Limestone. The Escabrosa is a biosparite, medium gray (N5), weathering medium dark gray (N4)

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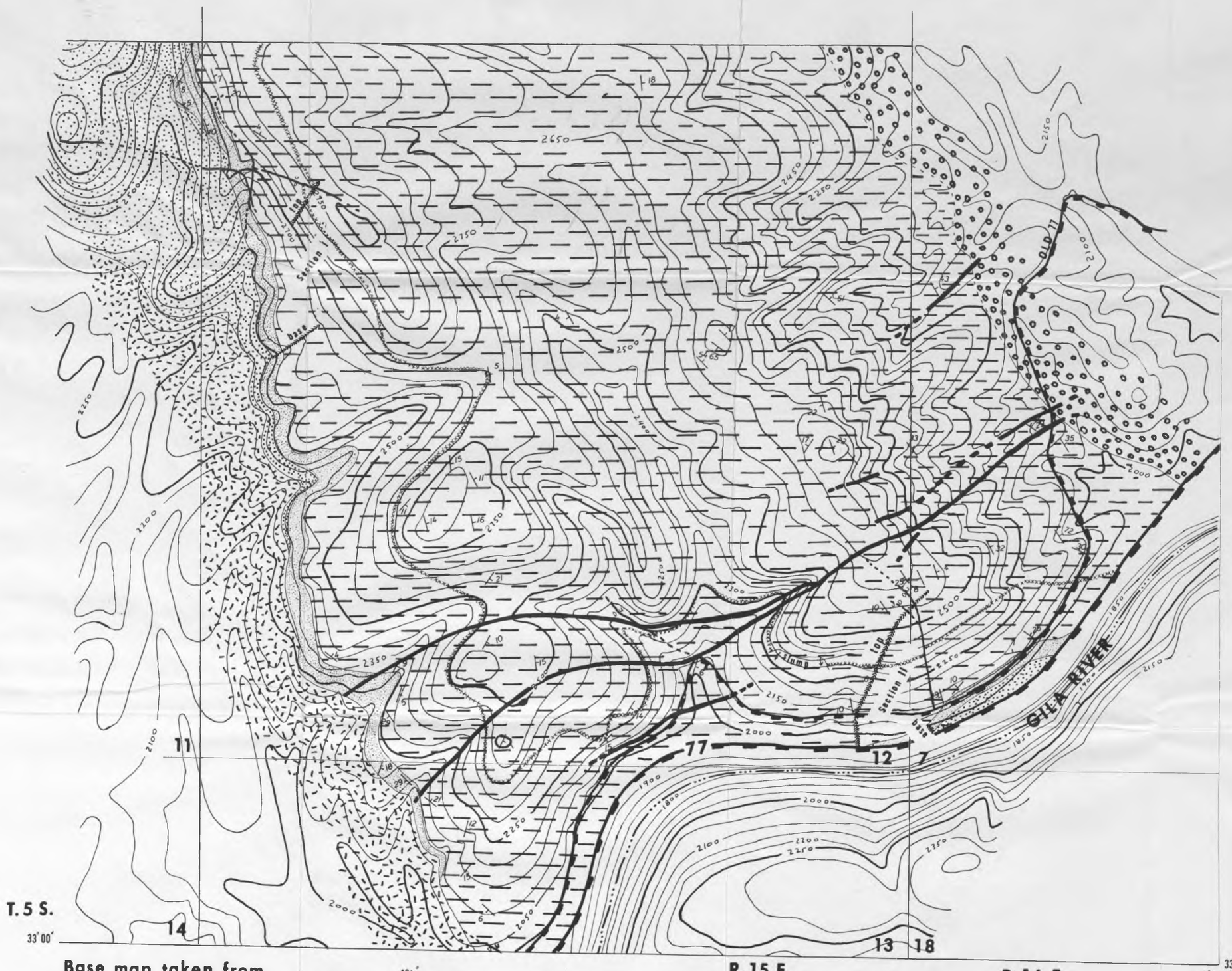
FIGURE 4 GEOLOGIC MAP OF AREA INVESTIGATED NORTH OF WINKELMAN, ARIZONA



EXPLANATION

- TERTIARY
  - Gila Conglomerate
- CRETACEOUS
  - Cretaceous volcanics
  - red, silty marker bed
  - Naco Limestone, upper limestone member
- PENNSYLVANIAN
  - Naco Limestone, lower dolomite member
- MISSISSIPPIAN
  - Escabrosa Limestone
- Measured section
- Highway
- Dike
- Fault

Base map taken from USGS Ray quadrangle, 1948

FIGURE 3
STRATIGRAPHIC SECTIONS OF THE NACO FORMATION PENNSYLVANIAN WITH FAUNAL HORIZONS IN SOUTHERN GILA COUNTY, ARIZONA

ROCK SYMBOLS

Dolomite
Limestone
Dolomitic Limestone
Silty Limestone
Oolitic Limestone
Cherty Limestone
Shaly Limestone
Calcareous Siltstone
Siltstone
Chert pebble conglomerate
Chaetetes zone
Shale
Concealed

SECTION I

Antiquatonia coloradoensis
Feldspar-mica porphyry sill 5'
Phricodothyris perplexa
Antiquatonia hermosana
Composita derrya
Linoproductus aff. L. platyumbonus
Spirifer rockymontanus
S. occiduus
Antiquatonia coloradoensis
Feldspar-mica porphyry sill 100'+
Composita subtilita
Spirifer occiduus
S. opimus
Chaetetes eximius
Feldspar-mica porphyry sill 32
Vesiculophyllum sedaliense
V. sp. A
Syringopora sp. A

Escabrosa Lim

SECTION II

Pseudozaphrentoides torquius
P. sp. A
Composita argentea
Spirifer occiduus
Orthotetes (Derbyia) crassa
Linoproductus aff. L. platyumbonus
Neospirifer cameratus
Lophophyllidium sp. A
Hustedia marmoni
Chaetetes eximius
Chonetes granulifer
Desmoinsia muricatina
Retaria lasallensis
Antiquatonia hermosana
Orthotetes (Derbyia) crassa
Phricodothyris perplexa
Composita subtilita
C. argentea, C. malaya
Spirifer occiduus, S. opimus
Spirifer rockymontanus
Neospirifer goreii
Punctospirifer kentuckyensis
Lophophyllidium idonium
Lophophyllidium idonium
L. aff. L. ignotum
Antiquatonia coloradoensis
Linoproductus aff. L. platyumbonus
Neospirifer cameratus
Retaria lasallensis
Pseudozaphrentoides torquius
Chonetes granulifer
Spirifer occiduus
15' Feldspar-mica porphyry sill
10' Feldspar-mica porphyry sill
60' gaped out
Antiquatonia coloradoensis
Linoproductus aff. L. platyumbonus
Jurasania nebrascensis
Punctospirifer kentuckyensis
Spirifer occiduus
Neospirifer cameratus
Orthotetes (Derbyia) crassa
Chonetes granulifer
Retaria lasallensis
Composita subtilita, C. ovata
C. argentea
Antiquatonia coloradoensis
Echinoconchus aff. E. angustus
Jurasania nebrascensis
Chonetes granulifer
Orthotetes (Derbyia) crassa
Retaria lasallensis
Spirifer opimus, S. occiduus
Composita subtilita, C. argentea
Spirifer opimus
Chaetetes eximius
Composita subtilita, C. argentea
C. ovata, C. malaya, C. derrya
Spirifer rockymontanus
S. occiduus, S. opimus
Punctospirifer kentuckyensis
Orbiculoidea camuliformis
Lingula carbonaria
Punctospirifer kentuckyensis
Reticulariina aff. R. spinosa
R. aff. R. campestris
Composita subtilita, C. ovata
C. argentea, Spirifer opimus
S. occiduus, S. rockymontanus
Orthotetes (Derbyia) crassa
Chonetes granulifer
Hustedia marmoni, H. miseri
Schizophoria texana, S. resupinoides

50 feet
30
20
10
0
Scale

AL REID
1965