CONODONT AND FORAMINIFER BIOSTRATIGRAPHY OF THE KELLY LIMESTONE (MISSISSIPPIAN), WEST-CENTRAL NEW MEXICO

by

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ABSTRACT

The Kelly Limestone (Mississippian) of west-central New Mexico consists of the Caloso Member and the overlying Ladron Member. The Caloso ranges in age from early Kinderhookian to early Osagean (early to late Tournaisian). The Ladron and Caloso are separated by a sharp disconformity representing a short duration during the early Osagean (late Tournaisian). The Ladron is early Osagean (late Tournaisian) to Meramecian (early middle Visean) in age. These rocks were deposited in a shallow-marine environment. The Caloso represents a nearshore environment while the Ladron was deposited in a well-agitated open shallow sea of normal marine salinity. The disconformity separating the two members indicates a rapid relative lowering of sea level in the early Osagean (late Tournaisian). The sea slowly retreated in early to middle Meramecian (middle Visean) time.

The lowermost Caloso Member limestones contain a conodont assemblage of the sulcata Zone (early Kinderhookian). The upper part of the Caloso and lowermost Ladron Member yielded conodonts which indicate an Upper typicus Zone to lower anchoralis-latus Zone (early - middle Osagean). This interval also contains foraminifers of Mamet Zones 8-9 (early - middle Osagean). The upper crinoidal grainstones of the Ladron contain conodonts of upper texanus Zone (late Osagean) along with Mamet Zone 12 foraminifers. The uppermost Ladron yielded conodonts of the Cavusgnathus Zone (early Meramecian). A new species, "Spathognathodus" n. sp., was recovered from the uppermost Caloso to lowermost Ladron interval.

These conodont and foraminifer data agree with other studies in the western interior. Furthermore, the conodont and foraminifer data from the Kelly Limestone support findings in the midcontinent which recommend adjusting foraminifer biozones to match earlier established conodont biozones in Mississippian stratotypes.

The Kelly Limestone correlates to Mississippian stratotypes in the midcontinent. The lowermost limestones in the Caloso Member correlate to the "Glen Park" formation and lower Hannibal Formation (lower Kinderhookian). The wackestone and packstone unit of the upper part of the Caloso and lower crinoidal unit of the Ladron Member correspond to the Fern Glen Formation - lower Burlington Limestone (early Osagean). The upper crinoidal unit of the Ladron correlates to the Keokuk Limestone to lowermost Warsaw - Salem Limestones (latest Osagean to earliest Meramecian). The uppermost part of the upper crinoidal unit and bryozoan-crinoidal unit correspond to the St. Louis Limestone (Meramecian).

I. INTRODUCTION

A major purpose of this study was to determine as precisely as possible the age of the Kelly Limestone of west-central New Mexico. Age determinations were based primarily on the conodont biozonations of Lane et al. (1980). Comparisons were made with the foraminifer biozonations of Mamet and Skipp (1970 and 1971) using the conodont and foraminifer data. Discrepancies were found between the conodont biozonations and the foraminifer biozonations, particularly when the biozonations were related to the Osagean-Meramecian and Tournaisian-Visean series boundaries within the Mississippian (Lower Carboniferous) System. Another major goal of this study was to test the conodont biozonations and refine them if necessary.

The Kelly Limestone was chosen because conodonts were expected to be found in this Mississippian unit, and because several well-exposed sections were known to occur in the Socorro area. Figure 1 shows the locations of the measured sections in the Coyote Hills, Magdalena Mountains, Lemitar Mountains, and Ladron Mountains. In addition, foraminifer assemblages in the Kelly had previously been reported by Armstrong (1958b and 1967), Armstrong and Holcomb (1967), and Armstrong and Mamet (1974, 1976, 1977a and 1977b).

Each section was measured and described in detail. Samples were taken for paleontologic and petrographic

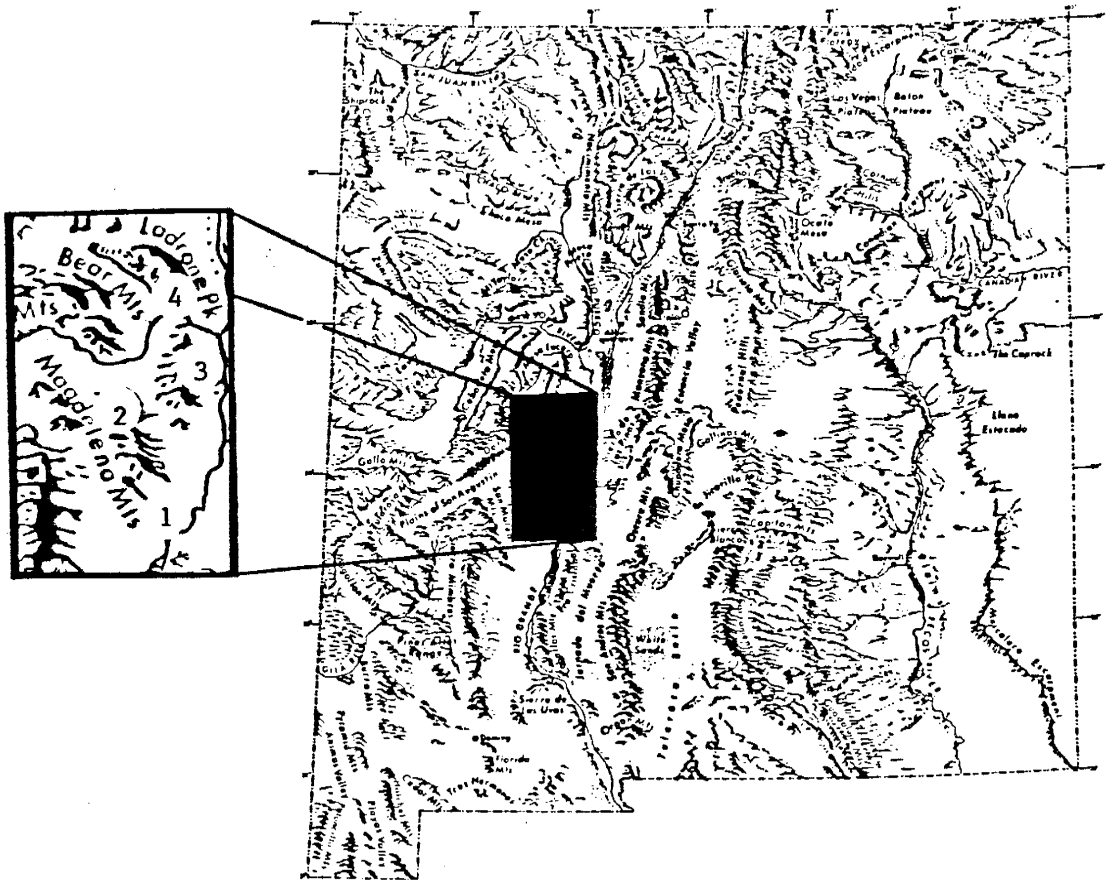


Figure 1. Reference map of New Mexico mountain ranges. Measured sections are labeled in the Coyote Hills (1), Magdalena (2), Lemitar (3), and Ladron (4) Mountains. Map is from Williams and McAllister (1979).

analysis, especially of conodont- and foraminifer-bearing intervals. Conodonts were systematically described and illustrated in order to establish their biostratigraphic position and paleoecologic distribution.

The Caloso Member of the Kelly Limestone ranges in age from early Kinderhookian to early Osagean (early to late Tournaisian). The overlying Ladron Member is separated from the Caloso by a disconformity representing time within the early Osagean (late Tournaisian). The Ladron is early Osagean (late Tournaisian) to Meramecian (early middle Visean). Mississippian rocks were deposited in a shallow-marine environment. The Caloso represents a nearshore environment while the Ladron was deposited in a well-agitated, open, shallow sea of normal marine salinity. The disconformity separating the two members indicates a rapid relative lowering of sea level of the early Osagean (late Tournaisian) sea. Another relative lowering of sea level occurred in early to middle Meramecian (middle Visean) time.

II. THE MISSISSIPPIAN SYSTEM TYPE SECTIONS

Hall (1858) published a complete classification of formations and groups which came to be known as the type Mississippian System. The name "Mississippi group" was proposed by Winchell (1869) for the Carboniferous limestones that are exposed in the Mississippi River Valley.

Williams (1891, p. 135) defined the Mississippian as the "... series of rocks, prevailingly calcareous, which occupies the interval between the Devonian system and the Coal Measures, and is typically developed in the States forming the upper part of the valley of the Mississippi River viz Missouri, Illinois, and Iowa." Chamberlin and Salisbury (1906) elevated the series to system rank. The United States Geological Survey (USGS) officially classified the Mississippian and Pennsylvanian as systems (Keroher, 1970).

Collinson et al. (1979, p. 8) stated: "The stratotype for the Mississippian extends from approximately 20 miles (32 km) north of the river town of Burlington, Iowa, southward along the river past Keokuk, Warsaw, Quincy, Kinderhook, Hannibal, Louisiana, St. Louis, Valmeyer, Prairie du Rocher, Ste. Genevieve and Chester -- more than 300 miles (483 km) with nearly continuous exposure... . The individual reference sections are mainly in the river cliffs of the Mississippi, Illinois, and Meramec Rivers and their tributaries."

The USGS and the Mississippian Subcommittee of the Committee on Stratigraphy of the National Research Council (Weller *et al*., 1948) recognize four series within the midcontinent stratotype of the Mississippian, from oldest to youngest (see Figure 2): Kinderhookian, Osagean, Meramecian and Chesterian. The Kinderhookian Series is represented by the following formations (in ascending order): Grassy Creek Shale, Saverton Shale, Louisiana Limestone, Maple Mill Shale, Chouteau Limestone, Sedalia Limestone and Gilmore City Limestone. The Osagean Series is represented by the Fern Glen Formation, Burlington Limestone and Keokuk Limestone. The Meramecian Series is represented by the Warsaw, Salem, St. Louis and Ste. Genevieve Limestones. The Chesterian Series is represented by the New Design, Hamberg and Elvira Groups. For a historical perspective on the problems concerning the boundaries of the Mississippian System, and those involving the series boundaries between the Kinderhookian-Osagean and Meramecian-Chesterian boundaries, the reader is referred to Weller *et al*. (1948, p. 97-107).

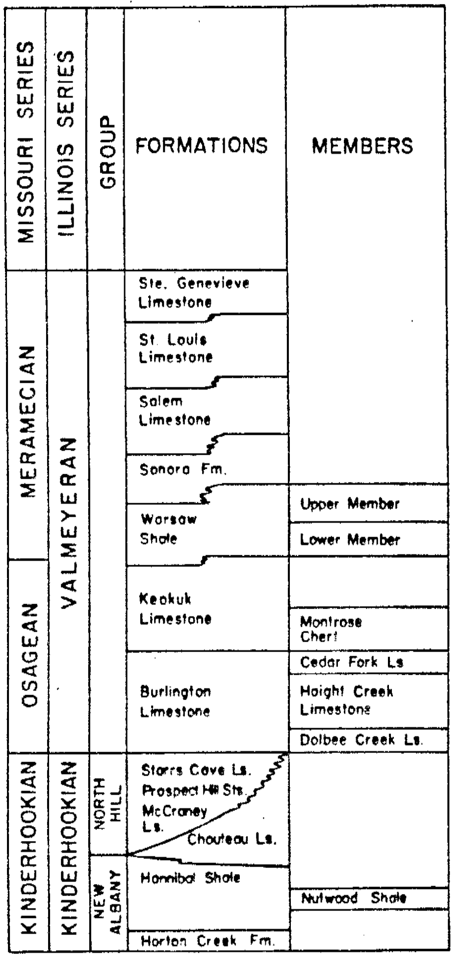
The Osagean-Meramecian Boundary

The dispute over the Osagean-Meramecian boundary was concerned principally with its placement relative to the Warsaw Limestone. Ulrich (1911), Weller and Sutton (1940), and Laudon (in Weller *et al*., 1948) believed a clear stratigraphic break occurred at the Keokuk Limestone -

Figure 2. Stratigraphic chart illustrating Mississippi Valley type formations for the Lower Carboniferous (Mississippian) from Collinson *et al*. (1979).

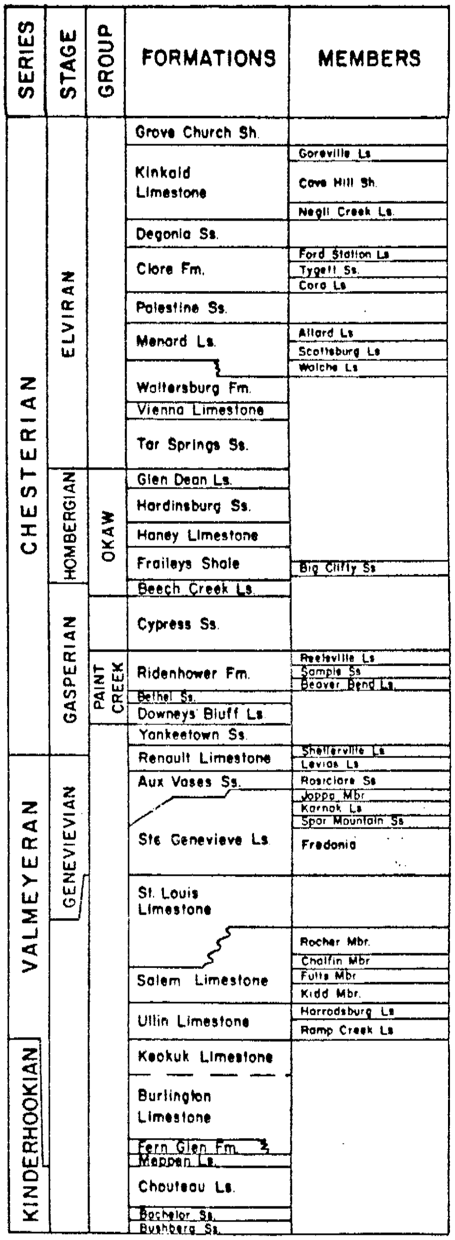
MISSISSIPPIAN STRATIGRAPHIC UNITS

NORTHWESTERN ILLINOIS, NORTHEASTERN MISSOURI



MISSOURI SERIES	ILLINOIS SERIES	GROUP	FORMATIONS	MEMBERS
MERAMECIAN	VALMEYERAN		Ste. Genevieve Limestone	
			St. Louis Limestone	
			Salem Limestone	
			Sonora Fm.	
			Warsaw Shale	Upper Member
				Lower Member
OSAGEAN			Keokuk Limestone	
				Montrose Chert
			Burlington Limestone	Cedar Fork Ls
				Haight Creek Limestone
				Dolbee Creek Ls.
KINDERHOOKIAN	KINDERHOOKIAN	NORTH HILL	Starrs Cove Ls. Prospect Hill Sts. McCraney Ls. Chouteau Ls.	
		NEW ALBANY	Hannibal Shale	
				Nutwood Shale
			Horton Creek Fm.	

SOUTHWESTERN ILLINOIS, EAST CENTRAL MISSOURI



SERIES	STAGE	GROUP	FORMATIONS	MEMBERS
CHESTERIAN	ELVIRAN		Grove Church Sh.	
			Kinkaid Limestone	Goreville Ls
				Cave Hill Sh.
				Negli Creek Ls.
			Degonia Ss.	
			Clore Fm.	Ford Station Ls
				Tygett Ss.
				Cora Ls
			Palestine Ss.	
			Menard Ls.	Allard Ls
				Scottsburg Ls
				Walche Ls
			Waltersburg Fm.	
			Vienna Limestone	
			Tar Springs Ss.	
	HOMBERGIAN	OKAW	Glen Dean Ls.	
			Hardinsburg Ss.	
			Haney Limestone	
			Fraileys Shale	Big Clifty Ss
			Beech Creek Ls.	
	GASPERIAN		Cypress Ss.	
		PAINT CREEK	Ridenhower Fm.	Reelsville Ls
				Sample Ss
				Beaver Bend Ls.
			Bethel Ss.	
			Downeys Bluff Ls.	
			Yankeetown Ss.	
VALMEYERAN	GENEVIEVIAN		Renault Limestone	Shetlerville Ls
				Levias Ls
			Aux Vases Ss.	Rosiclare Ss
			Ste Genevieve Ls.	Joppa Mbr
				Karnak Ls
				Spar Mountain Ss
				Fredonia
			St. Louis Limestone	
			Salem Limestone	Rocher Mbr.
				Chalfin Mbr
				Fults Mbr
				Kidd Mbr.
			Ullin Limestone	Harrodsburg Ls
				Ramp Creek Ls
KINDERHOOKIAN			Keokuk Limestone	
			Burlington Limestone	
			Fern Glen Fm.	
			Meppen Ls.	
			Chouteau Ls.	
			Bachelor Ss.	
			Bushberg Ss.	

Warsaw Limestone boundary based on both lithostratigraphic and biostratigraphic criteria. However, Weller (1914), Weller (1934), and Moore (1935) found no satisfactory lithologic basis for differentiating the Keokuk from the overlying Warsaw. Weller _et_ _al_. (1948) reported that the lithostratigraphic units in the Mississippian type areas were miscorrelated, particularly the principal part of the Warsaw in southwestern Missouri and Indiana.

Weller (1908) first published the description of the Mississippian section at Meramec Highlands. Ulrich (1911) first used the term Meramecian for this Mississippian section. The Meramecian of Ulrich (1911) was incorporated into the Mississippian by Weller _et_ _al_. (1948).

Ulrich's definition of the Meramecian included the Warsaw limestones and shales occurring in the lowermost part of the Meramec Group at Meramec Highlands. Many subsequent authors interpreted "Meramec Highlands" to be an area of hills called Meramec Highlands along the Meramec River west of St. Louis. After studying the literature and researching local history, Lane and Brenckle (1977) determined that "Meramec Highlands" had actually referred to a resort and associated quarry in existence at the turn of the century. This quarry was identified as the site where Weller (1908) conducted his investigation and where Ulrich (1911) proposed the Meramec Group.

The term Osage was first applied to outcrops along the Osage River in west-central Missouri (Williams, 1891).

Williams (1891) used the term "Osage Group" to describe one of three faunal subdivisions of his Mississippian Series. He included the Keokuk and Burlington Limestones in the group. Lane and Brenckle (1981) note that the type section of the "Augusta Limestone" of Keyes (1893) in southeastern Iowa more adequately represents what Williams intended the Osage Group to embrace. Weller (1898), however, promoted the usage of Osage because of priority. After the publication by Ulrich (1911) on the Mississippian System, the name Osage gained wide acceptance throughout North America. Kaiser (1950) stated that the most complete section in the Osceola, Missouri area is at the Bullard-Hunt Quarry, west of the town. There is no formal type section for the Osage, but the Bullard-Hunt Quarry has been treated as the principal reference section (Lane and Brenckle, 1981).

The concept of the Osagean has been modified through the years. Ulrich (1911) included the Fern Glen Formation within the Osagean. The lower dolomitic limestones of the Fern Glen were renamed the Meppen Limestone (Atherton et al., 1975). Within the Osagean, Moore (1928) included his Sedalia Formation which he correlated with the Fern Glen. The upper portion of Moore's (1928) Sedalia was assigned to the Northview Shale and Pierson Limestone in the Osage (Beveridge and Clark, 1952; Spreng, 1952). In the Osceola area, these authors restricted the Sedalia to beds beneath the Northview and suggested the Kinderhookian-Osagean boundary should coincide with the Northview-Pierson contact (Lane and Brenckle, 1981).

The Tournaisian-Visean Boundary In Europe

The history of research concerning the Tournaisian-Visean boundary in the Dinant area of Belgium was outlined by Conil et al. (1969). According to these authors, the problem of placing the Tournaisian-Visean boundary in the type sections of the Dinant series is similar to that of the Osagean-Meramecian.

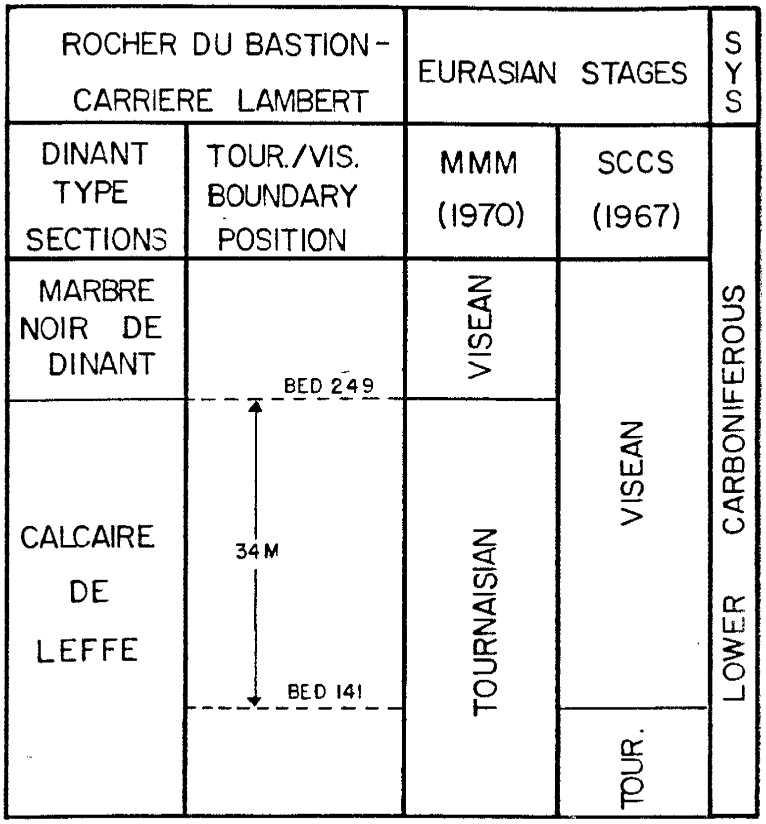
Dupont (1865) first used the term "Dinant Stratum" to describe portions of the Lower Carboniferous in the Dinant area, specifically the "carriere de marbre" near the town of Saint-Paul. His locality description, however, is too general to be used as a stratotype. Later workers have described the "marbre noir de Dinant," but none have described Dupont's original type section.

Conil and Lys (1964) first established a complete, detailed biostratigraphic zonation (based on foraminifers) to document the Tournaisian-Visean boundary within the Dinantian. They worked along the "Route de Salet," a stratigraphic reference section of the Dinant well known for its exceptional foraminifer faunas. Subsequent studies of the foraminifers by Conil (1965 and 1967), Conil and Dupont (1965), Conil and Lys (1967), and Conil et al. (1967 and 1969) have helped to refine the biostratigraphy of the Dinant stratotype.

Conodont biostratigraphers including Austin and Rhodes in Conil et al. (1969), and Groessens (1971a and 1971b) established a conodont succession in the Belgian Dinantian. Subsequent studies by Austin and Groessens (1972), Groessens (1975 and 1976), Groessens and Noel (1977), Lane and Ziegler (1983), and Paproth et al. (1983) established a detailed conodont zonation for the Tournaisian - Visean stratotype in the Dinant area of Belgium.

The Subcommission of Carboniferous Stratigraphy (SCCS) at a meeting in Sheffield, England in 1967 (v. I, p. 188), formally agreed to place the Tournaisian-Visean boundary at the base of the first bed of marbre noir in the "calcaires et marbres noir" at Dinant as identified by Conil et al. (1967), some 30 to 34 meters below the conventional base of the Marbre Noir de Dinant of the Carte Geologique de Belgique. This position was described by Conil et al. (1967 and 1969) as the base of Bed 141 in the section exposed along the trail leading from Rocher du Bastion to Carriere Lambert. This position is 34 meters below the base of the Marbre Noir de Dinant (see Figure 3). The SCCS decision was based on a proposal made by Conil, Pirlet and Lys in Conil et al. (1967) that the base of the Visean be redefined on the basis of increased biostratigraphic knowledge in the upper Tournaisian and lowest Visean beds of Belgium. Mamet et al. (1970) argued on lithostratigraphic grounds that the Tournaisian-Visean boundary remain at what they believed to be the traditional base of the Marbre Noir de Dinant.

Figure 3. Tournaisian-Visean (T-V) boundary position at Bed 141 of Belgium stratotype. MMM refers to Mamet's _et_ _al_. (1970) view of a traditional T-V boundary; SCCS is the position for the T-V boundary adopted by the Subcommission on Carboniferous Stratigraphy.

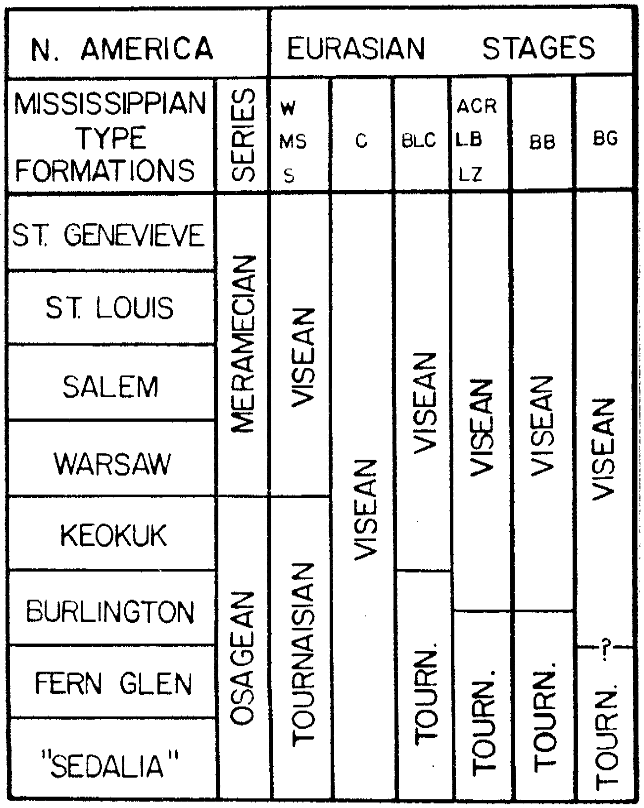

ROCHER DU BASTION - CARRIERE LAMBERT
EURASIAN STAGES
SYS
DINANT TYPE SECTIONS
TOUR./VIS. BOUNDARY POSITION
MMM (1970)
SCCS (1967)
MARBRE NOIR DE DINANT
CALCAIRE DE LEFFE
BED 249
34 M
BED 141
VISEAN
TOURNAISIAN
VISEAN
TOUR.
LOWER CARBONIFEROUS

The Tournaisian-Visean Boundary In North America

Austin *et al*. (1973) acknowledged the difficulties of recognizing the Tournaisian-Visean boundary in places other than the type area of Dinant, Belgium. A major problem is the lack of precision and agreement in the detailed description of the type area. Another difficulty concerns facies variations characteristic of these rocks in establishing a biostratigraphic framework. Further problems are generated by the effects of epeirogenic movements at the time of the Tournaisian-Visean transition. These tectonic events produced local disconformities marked by karst topography, and rapid faunal migration and replacement which may mask evolutionary changes of endemic faunas.

Weller *et al*. (1948) were among the first to point out the problems of correlating the Lower Mississippian of North America to the Lower Carboniferous of western Europe. In that work, the Mississippian Subcommittee of the Committee on Stratigraphy of the National Research Council, chaired by Weller, placed the "traditional" Tournaisian-Visean boundary in the Mississippian type section between the Keokuk Limestone and Warsaw Limestone (see Figure 4). This correlation was based on a poorly developed ammonoid zonation in the Mississippi Valley. Their decision was influenced by the facts that the United States Geological Survey and the Missouri Geological Survey recognized the overlying Warsaw as Meramecian and that there was a

Figure 4. Various authors' interpretations for the position of the Tournaisian-Visean boundary at the Mississippian Stratotype for North America. W = J. M. Weller _et al_. (1948); MS = Mamet and Skipp (1970 and 1971); S = Sando (1985); C = Collinson _et al_. (1962); BLC = Brenckle _et al_. (1974); ACR = Austin _et al_. (1973); LB = Lane and Brenckle (1977); LZ = Lane and Ziegler (1983); BB = Baxter and Brenckle (1982); BG = Brenckle and Groves (1986).



N. AMERICA		EURASIAN STAGES					
MISSISSIPPIAN TYPE FORMATIONS	SERIES	W MS S	C	BLC	ACR LB LZ	BB	BG
ST. GENEVIEVE	MERAMECIAN	VISEAN	VISEAN	VISEAN	VISEAN	VISEAN	VISEAN
ST. LOUIS							
SALEM							
WARSAW							
KEOKUK	OSAGEAN	TOURNAISIAN					
BURLINGTON				TOURN.	TOURN.	TOURN.	
FERN GLEN							? TOURN.
"SEDALIA"							

significant lithologic break between the Warsaw and underlying Keokuk.

In correlating their foraminifer microfossil zones from western Europe to North America, Mamet and Skipp (1970 and 1971) disregarded the definition of the Tournaisian-Visean Boundary Stratotype by the SCCS. Their correlation coincided with that of the Weller et al. (1948) subcommittee which placed the Tournaisian-Visean boundary between the Keokuk Limestone and Warsaw Limestone. In a previous paper (Sando et al., 1969), foraminifer zonations for Mississippian strata in the Northern Cordillera had been established, and these strata also had been correlated to the midcontinent type sections coinciding with the interpretation of the Tournaisian-Visean boundary in North America of both Weller et al. (1948) and Mamet and Skipp (1970 and 1971).

The conodont faunal succession is well documented for the Mississippian type sections of the Midcontinent. The texanus Zone has been firmly established throughout the Keokuk Limestone by Collinson et al. (1962, 1971, 1979 and 1981), Rexroad and Collinson (1965), and Brenckle et al. (1974). Collinson et al. (1962, 1971 and 1981), Thompson (1967), Thompson and Fellows (1970), and Lane et al. (1980) have shown anchoralis-latus Zone conodont faunas in the Fern Glen and Burlington Limestones (Osagean). Austin et al. (1973) correlated the 1967 Tournaisian-Visean boundary to be within the Burlington Limestone (Osagean) in the Mississippi

Valley by comparing the results of conodont studies in western Europe and North America. Brenckle et al. (1974) found conodonts in the Keokuk which correlated with Visean strata in Belgium; and therefore correlated the Tournaisian-Visean boundary to the Burlington-Keokuk contact. (See Figure 4).

In the Dinant type area in Belgium Lane and Ziegler (1983) determined that the Tournaisian-Visean boundary (as approved by the SCCS) lies within the anchoralis-latus Zone of Lane et al. (1980). This conforms to the SCCS decision concerning Bed 141 of the Marbre Noir de Dinant (Lane and Ziegler, 1983). The conodont faunas in the uppermost part of the Tournaisian in Belgium contain Scaliognathus anchoralis Morphotype 2. Its descendent, Sc. anchoralis Morphotype 3, is found near the top of the Fern Glen Limestone and in the Pierson Formation (Osagean) of the Mississippi Valley. Brenckle and Lane (1981) and Lane and Ziegler (1983) indicated that the SCCS Tournaisian-Visean boundary should occur below the appearance of Sc. anchoralis M3 at a position within the Burlington Limestone of southeastern Iowa, the upper Fern Glen of southern Illinois, and the Pierson of southwestern Missouri. This is much lower than at the top of the Keokuk Limestone by Weller et al. (1948) and Mamet and Skipp (1970 and 1971). It also is lower than the placement of the Tournaisian-Visean boundary at the Burlington-Keokuk contact as proposed by Brenckle et al. (1974). (See Figure 4.)

III. CONODONT AND FORAMINIFER BIOZONATIONS

Conodont Biozonations

During the late 1950's and the early 1960's several workers studied conodont faunas from Mississippian strata in the Mississippi Valley. This research group, centered at the Illinois State Geological Survey, produced a series of studies based on specific stratigraphic sequences. These works include: Rexroad (1957), Collinson and Scott (1958), Rexroad (1958), Rexroad and Clarke (1960), Rexroad and Jarrell (1961), Scott and Collinson (1961), Scott (1961), Rexroad and Burton (1961), Rexroad and Liebe (1962), Rexroad and Collinson (1963), Rexroad and Furnish (1964), Rexroad and Collinson (1965), Rexroad and Scott (1964), and Rexroad and Nicoll (1965).

Collinson *et al*. (1962) proposed a comprehensive zonal classification for the Mississippian of the Mississippi Valley consisting of 17 conodont assemblage zones. The zones were based on major North America conodont faunas as well as on goniatite zones of the Lower Carboniferous in Europe (Collinson *et al*., 1971). Other studies from the midcontinent and western interior by Beach (1961), Koucky *et al*. (1961), Klapper and Furnish (1962), Muller (1962a), Burton (1964 and 1965), Dunn (1965), Ethington (1965), Klapper (1966), Sandberg and Klapper (1967), Sandberg *et al*. (1967), and Webster (1969) provided Collinson *et al*. (1971) with the necessary data to establish a conodont zonation for the Mississippian of North America. These conodont zonations were correlated with those of the Avonian of Great Britain by Rhodes *et al*., (1969), the Carboniferous of Germany by Voges (1959 and 1960) and Meischner (1967), as well as with the the goniatite zonations of Europe.

Investigations by Thompson and Fellows (1970), Collinson *et al*. (1971), Jenkins (1974), Lane (1974), Pierce and Langenheim (1974), Groessens (1976) and Sandberg (1979) have established provincial conodont biozonations in the Lower Carboniferous (Mississippian). However, Lane *et al*. (1980) pointed out differences in conodont ranges from one area to another, showing that these zonations cannot be used interregionally or globally.

Six global conodont zones were established by Sandberg *et al*. (1978) for the Lower Carboniferous (Lower Mississippian, Kinderhookian; Lower Tournaisian). This global zonation was based on first occurrences of selected species of *Siphonodella*. The top of the *Siphonodella* zonation is placed at the highest occurrence of the last remaining species, *Siphonodella isosticha*. This zonation has been utilized in the Lower Carboniferous of western Europe and the United States by Carman (1987), Hayes (1985), Lane and Ormiston (1982), Stewart (1981), Varker and Sevastopulo (1985), and Belka and Groessens (1986).

The base of the *S*. *sulcata* Zone corresponds to the base of the Carboniferous on a worldwide basis, *i*.*e*. base of the Mississippian (Kinderhookian) in North America. The last occurrence of *Siphonodella* is nominally coincident (or nearly so) with the first appearance of *Gnathodus typicus* Morphotype 2 (Sandberg *et al*., 1978). The first appearance of *G. typicus* M2 marks the base of the post-*Siphonodella* conodont zonal sequence of Lane *et al*. (1980). In North America, the first appearance of *G. typicus* is useful in defining the base of the Osagean (Sandberg *et al*., 1978).

The lowermost zone, the *sulcata* Zone, is applicable to this study of the Kelly Limestone. It is defined by the first occurrence of *Siphonodella sulcata* as its lower limit, and the first occurrence of *Siphonodella duplicata* Morphotype 1 as its upper limit. Associated conodont fauna includes the following taxa: *Siphonodella praesulcata*, several species of *Protognathodus*, *Bispathodus stabilis*, *Bispathodus aculeatus aculeatus*, *Bispathodus aculeatus anteposticornis*, *Bispathodus aculeatus plumulus*, *Polygnathus communis communis*, *Polygnathus communis carina*, *Polygnathus inornatus*, *Polygnathus longiposticus*, *Patrognathus variabilis*, and several species of *Pseudopolygnathus* (Sandberg *et al*., 1978; Varker and Sevastopulo, 1985).

The lower part of the Caloso Member has been interpreted as a shallow-water, nearshore deposit by Armstrong (1955, 1958a and 1963), Armstrong and Mamet (1974, 1976 and 1977a), and Armstrong *et al*. (1980). *Siphonodella* has been found in relatively deep-water, offshore marine environments (Sandberg *et al*., 1978). No siphonodellids were recovered from the Kelly Limestone; however, conodont faunal assemblages collected from the Caloso Member were used to determine the biostratigraphic position.

Lane *et al*. (1980) synthesized data contained in above mentioned studies from Australia, North America, and western Europe to produce the preliminary global conodont zonation shown in Figure 5 and Figure 6. Previous proposed zonations were based on relative abundances and sudden cryptogenic appearances of zonal name-bearing taxa. The preliminary global conodont zonation of Lane *et al*. (1980) used first appearances of taxa to determine the base of a zone (see Figure 5), and then the determination is reinforced by subsequent evolutionary sequences. The preliminary standard global zonation begins at the top of the *isosticha*-Upper *crenulata* Zone of Sandberg *et al*. (1978). It ends with the first appearance of the genus *Cavusgnathus* (Meramecian). Baxter *et al*. (1979) determined that the first appearance of *Cavusgnathus* in North America correlates approximately to the base of Visean V3 or the first appearance of *Gnathodus bilineatus* in continental Western Europe. (See Figure 6). Lane *et al*. (1980) established, in ascending order, the following biozones: the *typicus* Zone (both upper and lower subzones), *anchoralis*-*latus* Zone, and *texanus* Zone (see Figure 5); the base of each zone marks the top of the preceding zone. This scheme has been utilized by Belka (1985), Carman (1987), Lane and Ormiston (1982), Ruppel and

Figure 5. Ranges of important Lower Carboniferous (late Kinderhookian-middle Meramecian) conodonts. (Modified from Lane *et al*., 1980, table 2, p. 121).

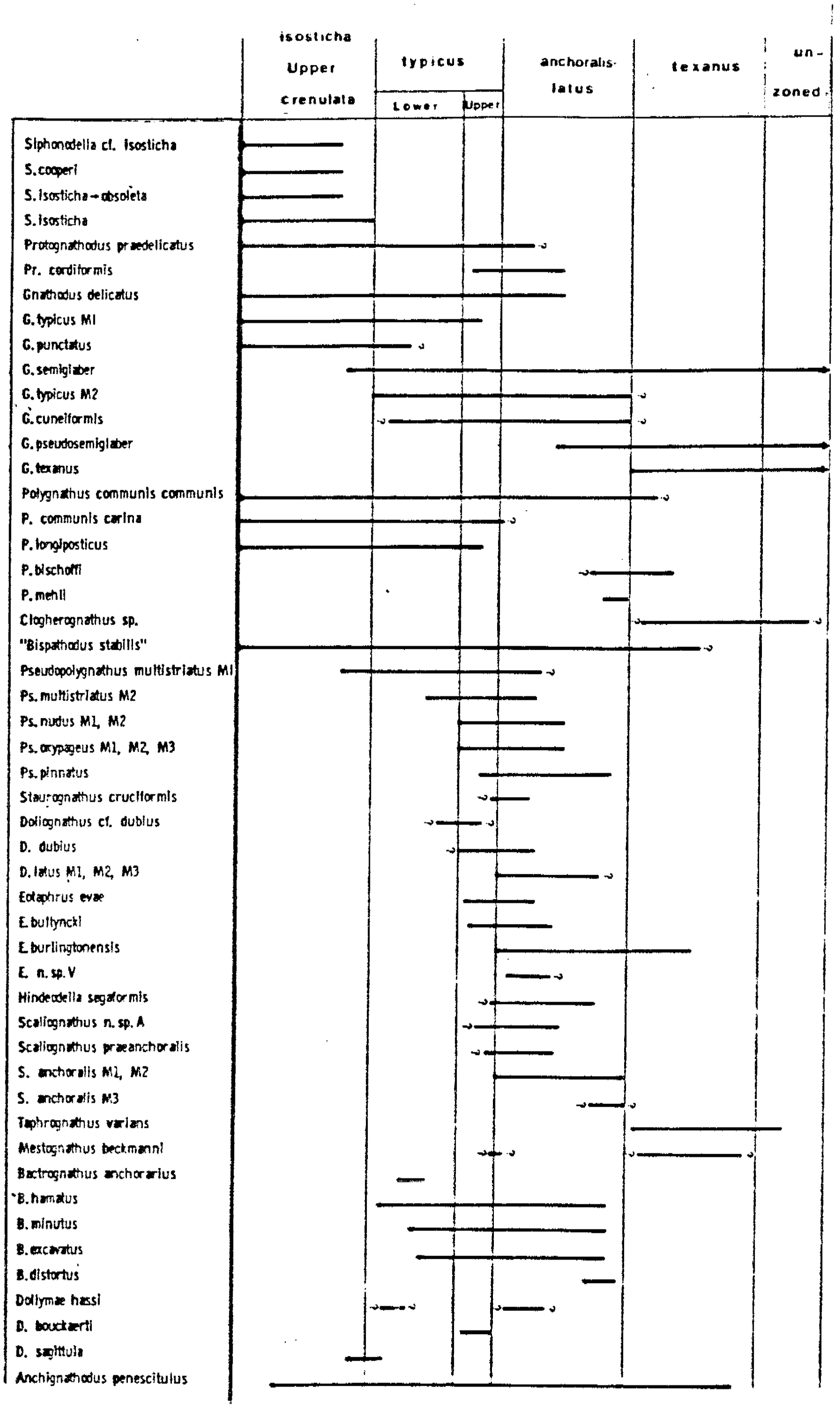

isosticha
Upper
crenulata
typicus
Lower
Upper
anchoralis-
latus
texanus
un-
zoned
Siphonodella cf. isosticha
S. cooperi
S. isosticha → obsoleta
S. isosticha
Protognathodus praedelicatus
Pr. cordiformis
Gnathodus delicatus
G. typicus M1
G. punctatus
G. semiglaber
G. typicus M2
G. cuneiformis
G. pseudosemiglaber
G. texanus
Polygnathus communis communis
P. communis carina
P. longiposticus
P. bischoffi
P. mehli
Cloghergnathus sp.
"Bispathodus stabilis"
Pseudopolygnathus multistriatus M1
Ps. multistriatus M2
Ps. nudus M1, M2
Ps. oxypageus M1, M2, M3
Ps. pinnatus
Staurognathus cruciformis
Doliognathus cf. dubius
D. dubius
D. latus M1, M2, M3
Eotaphrus evae
E. bultyncki
E. burlingtonensis
E. n. sp. V
Hindeodella segaformis
Scaliognathus n. sp. A
Scaliognathus praeanchoralis
S. anchoralis M1, M2
S. anchoralis M3
Taphrognathus varians
Mestognathus beckmanni
Bactrognathus anchorarius
B. hamatus
B. minutus
B. excavatus
B. distortus
Dollymae hassi
D. bouckaerti
D. sagittula
Anchignathodus penescitulus

Figure 6. Comparison of previous local conodont zonations with preliminary global conodont standard zones proposed. (Lane *et* *al*., 1980, Table 1, p. 118.)

PRESENT PAPER ZONES	N. AMERICA					EUROPE					AUSTRALIA
	LANE, 1974	SANDBERG IN GUTSCHICK ET AL. 1980	SANDBERG (1979)	COLLINSON ET AL. 1971	THOMPSON & FELLOWS, 1970 THOMPSON, 1967	MARKS & WENSINK, 1970	EBNER, 1977	GROESSENS, 1974	RHODES, AUSTIN & DRUCE (1970)	VOGES, 1960, BISCHOFF, 1957 (PARTIM)	JENKINS, 1974
BILINEATUS	9	UNZONED INTERVAL	UNZONED INTERVAL	G. BILINEATUS-CAVUSGN. CHARACTUS		G. COMMUTATUS COMMUTATUS	BILINEATUS		MESTOGNATHUS BECKMANNI-GN. BILINEATUS	BILINEATUS	
UNZONED INTERVAL	8	CAVUS-GNATHUS		APATO. SCALENUS-CAVUSGNATHUS		GNATHODUS TYPICUS ZONE	GNATHODUS SP. A.		APATO. GEMINUS-CAVUSGNATHUS. TAPH. VARIANS-CAVUSGN.-APATOG. CAVUS. UNICORNIS-APATOGNATHUS.	BILINEATUS-ANCHORALIS-INTERREGNUM	
TEXANUS	7	UPPER TAPHROGNATHUS VARIANS		TAPHROGN. VARIANS-APATOGNATHUS	G. TEXANUS-TAPHROGNATHUS. G. BULBOSUS.		GNATHODUS TYPICUS	MESTOGNATHUS BECKMANNI	NO CONODONTS		PATROGNATHUS ? CF. CAPRICORNIS
		LOWER TAPHROGNATHUS VARIANS	TAPHROGNATHUS VARIANS LOWER PART	GNATHODUS TEXANUS-TAPHROGNATHUS BACTROG.-TAPHROGN.	BACTRO. DISTORTUS- GN. CUNEIFORMIS.				MESTO. BECKMANNI-POL. BISCHOFFI		PS. CF. NODOMARGINATUS
ANCHORALIS-LATUS	6	"SPATHO" N. SP.	DOLIOGNATHUS LATUS	BACTROGNATHUS-POLYGNATHUS COMMUNIS	BACTROGNATHUS-PSEUDO-POLYGNATHUS MULTI-STRIATUS.	S. ANCHORALIS ZONE	ANCHORALIS	SCALIOGNATHUS ANCHORALIS	GNATHODUS ANTETEXANUS-POL. LACINATUS	ANCHORALIS	SCALIOG. ANCHORALIS
	5	DOLIOGNATHUS LATUS									
	UPP.										
UPPER TYPICUS	4 LOW.	PSEUDOPOLYGNATHUS N. SP.	GNATHODUS TYPICUS	GN. SEMIGLABER-PS. MULTISTRIATUS			UNZONED INTERVAL	POLYGN. COMMUNIS CARINUS	POL. LACINATUS-PS. CF. LONGIPOSTICUS	UNZONED INTERVAL	GNATHODUS SP. A.
LOWER TYPICUS	3	GNATHODUS TYPICUS			GN. SEMIGLABER-POL. COMMUNIS CARINUS.				POLYGN. LACINATUS		GN. SEMIGLABER
ISOSTICHA-UPPER CRENULATA	2	SIPHONODELLA ISOSTICHA-UPPER S. CRENULATA	SIPHONODELLA ISOSTICHA-UPPER S. CRENULATA	SIPHONODELLA ISOSTICHA-S. COOPERI	S. COOPERI HASSI-G. PUNCTATUS		UPPER CRENULATA	SIPHONODELLA	SP. COSTATUS COSTATUS-GN. DELICATUS.	UPPER CRENULATA	GN. PUNCTATUS
	1				GNATHODUS DELICATUS-SIPH. COOPERI COOPERI						

Lemmer (1986), and Varker and Sevastopulo (1985). The global conodont zones are briefly described below.

typicus Zone. The base of the *typicus* Zone is defined by the first occurrence of *Gnathodus typicus* Morphotype 2. Coincidentally, the first occurrence of *Gnathodus cuneiformis* is slightly later, but close to that of *G. typicus* Morphotype 2 aiding in recognizing the base of the *typicus* Zone. The *typicus* Zone is subdivided into upper and lower parts. The base of the Lower *typicus* Zone is recognized by the first occurrence of *G. typicus* Morphotype 2 (which is only well known in western and central United States) and the upper limit of the genus *Siphonodella*. The base of the Upper *typicus* Zone is defined by the first occurrences of *Pseudopolygnathus oxypageous* and *Pseudopolygnathus nudus*.

anchoralis-*latus* Zone. The lower boundary of the *anchoralis*-*latus* Zone is defined by the first occurrence of the conodonts whose names it bears, *Scaliognathus anchoralis* and *Doliognathus latus*. The *anchoralis*-*latus* Zone is identical to the *anchoralis* Zone of Bischoff (1957) and Voges (1959). *Doliognathus latus* was added to aid in recognition of this zone in shallow shelf environments.

texanus Zone. The texanus Zone has its base defined by the first appearance of Gnathodus texanus. Help in recognizing the base of the texanus Zone is provided by other taxa whose first occurrences take place close to that of G. texanus. These are Taphrognathus varians in western and central North America; Mestognathus beckmanni in Europe, Australia, and eastern North America; and Cloghergnathus spp.

The origin of Gnathodus texanus was determined to be coincident with the extinction of Scaliognathus anchoralis europensis (Lane et al. 1980; Lane and Ziegler, 1983). Thornbury (1985), however, found that the ranges of Gnathodus texanus (the zonal marker species for the texanus Zone of Lane et al., 1980) and Sc. a. europensis overlapped in Dinantian rocks of southwestern Ireland. The range of G. texanus was shown by Varker and Sevastopulo (1985, Table 6, p. 250-251) to extend from the upper part of their anchoralis Zone (anchoralis-latus Zone of Lane et al., 1980). In testing the preliminary standard conodont zonation of Lane et al. (1980), Belka and Groessens (1986) sampled for conodonts along the section called "Route de Salet" in the Molignee Valley of Belgium, a parastratotype section for the Lower Visean (Conil, 1967). At Salet, G. texanus (two specimens) occurs just below the first appearance of Sc. a. europensis (Belka and Groessens, 1986, fig. 3, p. 260). Belka and Groessens (1986) supported their finding with a detailed phylogenetic study of *G. texanus*, documenting the transition from *Gnathodus semiglaber* to *G. texanus* in this stratigraphic section. Belka and Groessens based their findings on only two specimens of *G. texanus* from the stratigraphic level in question. No other specimens of *G. texanus* were recovered between this stratigraphic position and the previously estsablished base of the *texanus* Zone in the "Route de Salet" parastratotype.

At present there are no global standard conodont stratigraphic zonations for the Lower Carboniferous above the *texanus* Zone of Lane *et al*. (1980). In North America, however, some provincial zonations apply for areas in the western United States; areas which are adjacent to west-central New Mexico. In a study of southeastern New Mexico (Sacramento Mountains) and western Texas, Lane (1974) provided a biozonation based on conodont faunas, *i*.*e*. Faunal Units (FU) 1-12. These were utilized and modified in a study of Waulsortian facies in the Sacramento Mountains by Lane and Ormiston (1982). Sandberg in Sandberg and Gutschick (1979 and 1980) and Gutschick *et al*. (1980) devised a conodont zonation for use in the Great Basin and Rocky Mountain regions. His *Taphrognathus* Zone is partly correlative to the (lower) *texanus* Zone of Lane *et al*. (1980); and his *Cavusgnathus* Zone is identical to FU 8 in Lane (1974) and the Unzoned Interval in Lane *et al*. (1980, Table 1, p. 118; Figure 6 herein). The base of FU 8 and

Sandberg's *Cavusgnathus* Zone is defined by the first appearance of the genus *Cavusgnathus* in North America. The top of FU 8 is defined by the youngest common occurrences of *Apatognathus* and *Hindeodus scitulus*. Lane and Ormiston (1982) and Lane *et al*. (1980) correlate FU 8 to the *Apatognathus scalenus*-*Cavusgnathus* Zone of Collinson *et al*. (1971). The base of FU 9 corresponds to the lower boundary of the *Gnathodus bilineatus*-*Cavusgnathus charactus* Zone of Collinson *et al*. (1971). Collinson *et al*. (1971, fig. 8, p. 384) and Dutro *et al*. (1979, fig. 88, p. 424-425) show the first occurrence of *Cavusgnathus charactus* at the horizon which defines the boundary between the *A*. *scalenus*-*Cavusgnathus* Zone and the *G*. *bilineatus*-*C*. *charactus* Zone, *i*.*e*. FU 8 and FU 9 respectively.

Foraminifer Biozonations

Establishing foraminifer biozonations for North America began with the pioneering study of Zeller (1950). He identified parts of the Mississippian sequence in its type area by means of evolutionary changes in endothyrids. Zeller (1957) published a study of 12 endothyrid zones of Mississippian age from the Cordilleran region; however, he could not extend them to faunas in the Lower Mississippian of the Mississippi Valley. Woodland (1958) recognized three zones and one subzone in the Mississippian of central Utah which were similar to those of Zeller (1950 and 1957) in the

Osage - Meramec interval. Armstrong (1958a and 1967) used endothyrid faunas to differentiate rocks of Early Mississippian age in northern and central New Mexico (Espiritu Santo Formation and the Kelly Limestone, respectively). Mamet (1962) observed how closely the Carboniferous Foraminifera of western Europe (Tournaisian, Visean, and Namurian type sections) resembled foraminiferal families observed in North America. McKay and Green (1963) recognized four main successive range zones, two concurrent range zones, and one assemblage zone in the Mississippian rocks of Alberta. They attempted to correlate them with the type Mississippian and sections in the western United States by means of endothyrid faunas. The Redwall Limestone of Arizona was studied by Skipp (1963, 1964 and 1969); she recognized six zones of endothyrids and tournayellids ranging in age from Kinderhookian to late Meramecian. Skipp et al. (1966) summarized the known distributions of tournayellids in the Mississippian of North America.

Mamet in Sando et al. (1969) presented a 14-zone foraminifer zonation for the Lower Carboniferous in the Northern Cordillera of the United States. The foraminifer zones recognized in this work were part of a 19-zone system originally established on European and Asiatic faunal successions by Mamet (1965), Mamet et al. (1965), Legrand et al. (1966), and Mamet and Reitlinger (1969). That paper formed the foundation for subsequent foraminiferal zonations for the Mississippian in North America. Subsequently, Mamet and Skipp (1970 and 1971) presented a comprehensive outline of foraminifer zonations of North America for the Mississippian. Fourteen assemblage zones were established and the standard units of the type Mississippian were correlated to their counterparts in the standard western European sections of the Lower Carboniferous (Mamet and Skipp, 1971, fig. 7, p. 1141). The foraminifer biozonation of Mamet and Skipp (1970 and 1971) is the one most widely used in the Lower Carboniferous (Mississippian) of North America. It was the major reference for the foraminifer studies of Armstrong and Mamet (1974, 1976, 1977a and 1977b), Mamet (1975), Sando *et al*. (1976), Armstrong *et al*. (1979), and Sandberg and Gutschick (1980).

The 14-zone foraminifer biozonation of Mamet and Skipp (1970 and 1971) range from late Kinderhookian through Chesterian. It is based on both phylogenetic grounds (range zones) and peak abundances (acme zones) of foraminifer taxa, with emphasis placed on the latter. These zones were compared with those previously described in Eurasia and extended to the type sections of the Lower Carboniferous of Europe.

Mamet and Skipp (1971, p. 1130) asserted that "... the sampled lithologic sections, ..., include the best-known formations of the Mississippian... . Particular attention has been paid to the type sections, wherever foraminifera [sic] bearing." Brenckle and Groves (1986), however, found no data published by Mamet and Skipp to substantiate the assignments of foraminifer zones in the Mississippi Valley type formations; the author also found no such data published by Mamet and Skipp. (See also Brenckle et al., 1988.) In addition, precise locality descriptions for these stratotypes were not reported.

Foraminifer Zones (referred to as "Mamet Zones") 8, 9, and 12 are relevant to this study of the Kelly Limestone. Important taxa in Mamet Zone 8 include: Septaglomospiranella, Septabrunsiina, Spinoseptatournayella (first appearance), Spinoendothyra (first appearance), Tuberendothyra tuberculata (acme), Palaeospiroplectammina, Brunsia, Chernyshinella, Tournayella, Latiendothyra, Earlandia, Paracaligella, Bisphaera, Parathurammina, and Calcisphaera of the group C. laevis (Mamet and Skipp, 1971).

Important taxa for Mamet Zone 9 contain the following common to abundant taxa for North America: Septaglomospiranella, Septabrunsiina, Spinoseptatournayella, Latiendothyra of the group L. parakosvensis, Spinoendothyra (acme), Spinoendothyra costifera, Spinoendothyra bellicosta, Tuberendothyra tuberculata, "Endothyra" of the group E. taedia, Eoforchia, and Tetrataxis (Mamet and Skipp, 1971). According to Mamet and Skipp (1971), the following non-coiled forms are present in North America and Eurasia in Mamet Zone 9: Earlandia, Earlandinella, Lugtonia, Paracaligella, Parathurammina, and Calcisphaera (C. pachysphaerica -- first appearance)

Mamet and Skipp (1971) list the following as the most characteristic genera in North America for Mamet Zone 12: Tournayella, Eoforschia of the group E. moelleri, Palaeotextularia of the group P. consobrina (a rare but important form), Globoendothyra, Globoendothyra baileyi (last appearance), Eoendothyranopsis of the group E. spiroides, Tetrataxis, Propermodicus, Archaediscus of the group A. krestovnikovi, Planoarchaediscus, and the algae Koninckopora (which first appears in abundance in this zone in both Eurasia and North America). Most of the noncoiled forms are also present in Mamet Zone 12.

Problems Between Conodont and Foraminifer Biozonations

Figure 7a illustrates how Mamet and Skipp (1970, 1971) assigned their microfossil zones in the type Mississippian formations. Mamet Zones 8 and 9 have been assigned to the Keokuk Limestone by Mamet and Skipp (1970 and 1971). Conodont faunas of the texanus Zone have been found in the Keokuk by Collinson et al. (1962, 1971, 1979 and 1981), Rexroad and Collinson (1965), and Brenckle et al. (1974). If Mamet Zone 8 and 9 foraminifers are reliable biostratigraphic indicators, then they should be found together with texanus Zone conodonts in Keokuk equivalents elsewhere.

A controversy arose when Brenckle et al. (1974) documented Keokuk Limestone foraminiferal assemblages no older than Mamet Zone 10 and possibly as young as Mamet Zone

Figure 7. Stratigraphic charts illustrating conodont and foraminifer biozonation schemes. 7a: Lower Mississippian in the stratotype area, Mississippi Valley. Conodont zones are after Collinson et al. (1962, 1971, 1979 and 1981), Rexroad and Collinson (1965), Brenckle et al. (1974), and Lane et al. (1980). Foraminifer zones are from Mamet and Skipp (1970 and 1971). 7b: Lower Mississippian conodont and foraminifer zonations as presented in the western cordillera by Sando et al. (1981), Sando (1985) and Sando and Bamber (1985).

N. AM. SERIES	MISSISSIPPI VALLEY		
	TYPE FORMATIONS	CONODONT ZONES	FORAMINIFER ZONES
MERAMECIAN	ST. LOUIS LS.	*Cavusgnathus*	14
			13
	SALEM LS.		12
			11
	WARSAW LS.		10
OSAGEAN	KEOKUK LS.	*texanus*	9
			8
	BURLINGTON LS.	*anchoralis-latus*	7
	FERN GLEN FM.	U. *typicus*	pre-7
	MEPPEN FM.	L. *typicus*	
KINDER.		*Siphonodella*	

7a

WESTERN CORDILLERA		N. AM. SERIES
FORAMINIFER ZONES	CONODONT ZONES	
14	*T. varians*	MERAMECIAN
13		
12	*texanus*	
11		
10		
9	*anchoralis-latus*	OSAGEAN
8	U. *typicus*	
7	L. *typicus*	
pre-7	*Siphonodella*	KINDER.

7b

13 in the Mississippi Valley type sections. These age determinations are younger than Mamet Zones 8 and 9 reported by Mamet and Skipp (1971). Subsequent studies have shown similar results including Brenckle and Groves (1986), Brenckle and Lane (1981), Brenckle *et al*. (1982), Dutro *et al*. (1979), Paproth (1969), and Sando *et al*. (1976). Some biostratigraphic studies have agreed with Mamet and Skipp (1970 and 1971) when utilizing foraminifers along with other taxa: Dutro (1979), Gutschick *et al*. (1980), Sandberg and Gutschick (1980), Sando (1985), and Sando *et al*. (1981).

Figure 7b (redrawn after Sando *et al*., 1981; Sando, 1985; Sando and Bamber, 1985) shows that in the western cordillera, foraminifers of Mamet Zones 8 and 9 occur with conodonts of the Upper *typicus* and *anchoralis*-*latus* Zones, below the *texanus* Zone. Brenckle and Groves (1986, p. 567) present one explanation for these differences:

> "The changes in conodont ranges may in some measure be influenced by the occurrence of Mamet Zones 9-10 and basal Zone 10 foraminifers with *Taphrognathus varians* in the Cordillera as reported by Sandberg and Gutschick (1980). According to these authors, *T. varians* first occurs in the Keokuk Limestone, thus relating parts of zone 9 and 10 to the late Osagean. Actually this conodont is first reported from the upper Burlington Limestone (Collinson *et al*., 1971), which would be a more logical position for these Mamet zones..."

Evidence consisting of detailed foraminifer data from the Keokuk Limestone and Humboldt Oolite of Iowa was published by Brenckle *et al*. (1974 and 1982), Brenckle and Lane (1981), and Brenckle and Groves (1986). They suggest that the discrepancies between conodont and foraminifer zonations would be resolved by adjusting foraminiferal zones to previously established conodont ranges (see Figure 8 and Figure 9).

Brenckle and Marshall (1979) and Brenckle *et al*. (1982) reported the presence of *Koninckopora*, *Skippella*, *Globoendothyra*, *Epistacheoides*, *Fourstonella*, and *Eoendothyranopsis* in the "Foram Bed" of the upper Keokuk Limestone. The "Foram Bed" would have previously been considered "Meramecian" because it contains this fauna. The concurrence of *Eoendothyranopsis scitula* and *Eoendothyranopsis spiroides* represented a short time span within the middle Meramecian (late Salem Limestone - early St. Louis Limestone or Mamet Zone 12-13 boundary). The extension of this concurrent range zone into the Osagean makes a Visean age (1967 SCCS revision) more likely for the Keokuk (See Figure 8 herein and Brenckle *et al*., 1982, "Inferred Mamet Zones," fig. 3, p. 50). Figure 9 shows conodont zones alongside the adjusted zones of Baxter and Brenckle (1982) for the Mississippian type formations in the Mississippi Valley.

According to Austin *et al*. (1973), microfossils have proven to be the most precise and reliable biostratigraphic data used in the determination of the Tournaisian-Visean boundary stratotype in Dinant, Belgium. The difficulties in using macrofossils to define this boundary was demonstrated by Conil *et al*. (1967 and 1971) and Paproth *et al*. (1983).

Figure 8. Stratigraphic chart after Baxter and Brenckle (1982) illustrating adjustment of Mamet foraminifer zones for the Mississippi Valley type formations of the Lower Mississippian. M&S = Mamet and Skipp (1970 and 1971); B&B = Baxter and Brenckle (1982).

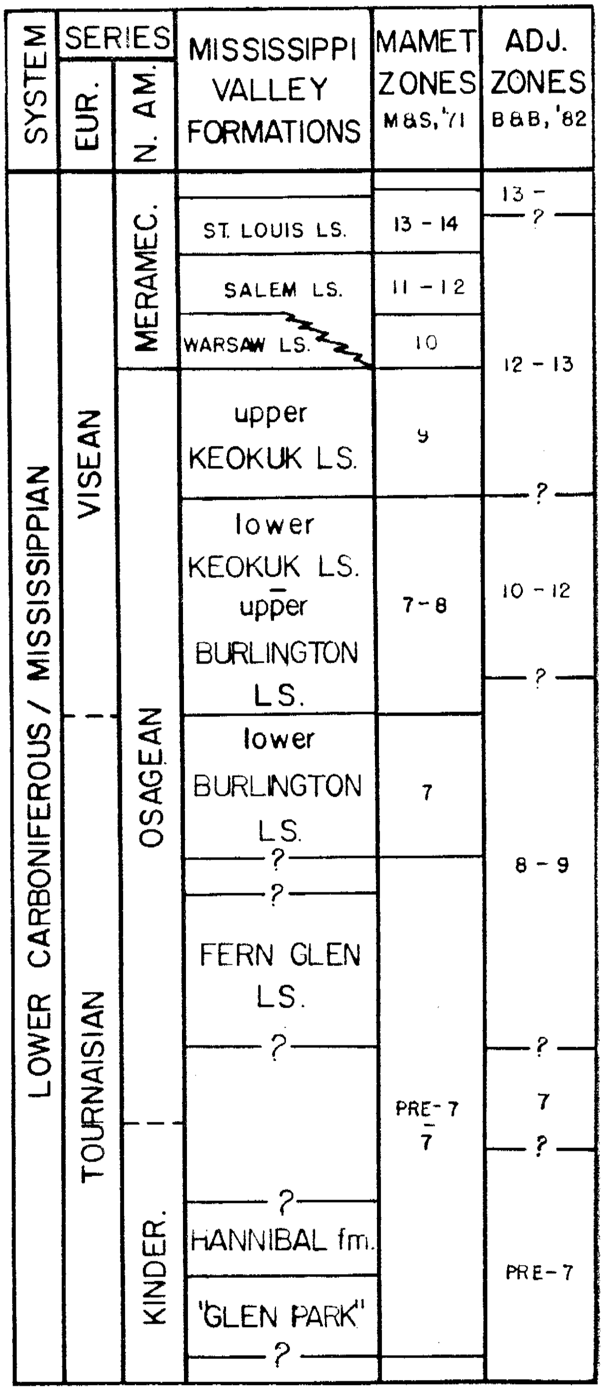

SYSTEM
SERIES
EUR.
N. AM.
MISSISSIPPI VALLEY FORMATIONS
MAMET ZONES M&S,'71
ADJ. ZONES B&B,'82
LOWER CARBONIFEROUS / MISSISSIPPIAN
VISEAN
TOURNAISIAN
MERAMEC.
OSAGEAN
KINDER.
ST. LOUIS LS.
SALEM LS.
WARSAW LS.
upper KEOKUK LS.
lower KEOKUK LS. upper BURLINGTON LS.
lower BURLINGTON LS.
FERN GLEN LS.
HANNIBAL fm.
"GLEN PARK"
?
13 - 14
11 - 12
10
9
7 - 8
7
PRE-7 - 7
13 -
12 - 13
10 - 12
8 - 9
7
PRE-7

Figure 9. Stratigraphic chart illustrating conodont zones and adjusted zones of Baxter and Brenckle (1982) for the Mississippi Valley type formations of the Lower Mississippian.

N. AM. SERIES	MISSISSIPPI VALLEY		
	TYPE FORMATIONS	CONODONT ZONES	ADJ. ZONES
MERAMECIAN	ST. LOUIS LS.	*Cavusgnathus*	13 - ? 12 - 13
	SALEM LS.		
	WARSAW LS.		
OSAGEAN	KEOKUK LS.	*texanus*	? 10 - 12
	BURLINGTON LS.	*anchoralis-latus*	? 8 - 9
	FERN GLEN FM.	*U. typicus*	
	MEPPEN FM.	*L. typicus*	? pre-7 - 7
KINDER.		*Siphonodella*	

Early conodont biostratigraphers (Austin and Rhodes in Conil *et al*., 1969; Groessens, 1971a and 1971b) produced a conodont succession in the Belgian Dinantian. Subsequent conodont studies by Austin and Groessens (1972), Groessens (1975 and 1976), Groessens and Noel (1977), Lane and Ziegler, (1983), and Paproth *et al*. (1983) established a detailed conodont zonation for the Tournaisian-Visean stratotype.

The base of the Visean at Dinant coincides with the first appearance of *Mestognathus beckmanni* and *Gnathodus* cf. *G. homopunctatus* (the base of the *M. beckmanni* zone of Groessens, 1975). Lane *et al*. (1980), however, show a gap in the range of *M. beckmanni* through most of the *anchoralis-latus* Zone (Figure 5, p. 24-25). Lane and Ziegler (1983) point out the occurrence of *M. beckmanni* with *Scaliognathus anchoralis* at the Yvoir section of Groessens (1975) indicating the extension of the range of *M. beckmanni* down to the middle *anchoralis-latus* Zone. Lane *et al*. (1980) show the base of the *M. beckmanni* zone of Groessens (1975) corresponding approximately to the base of their *texanus* Zone (Figure 6, p. 26-27).

Mestognathus beckmanni is not present in the upper Mississippi Valley type sections probably due to the variation in lithology, *i.e*. environmental controls, between the North American Mississippian stratotypes and the Dinantian stratotypes (Austin *et al*., 1973). The conodont faunas at the top of the Tournaisian in Belgium contain

Scaliognathus anchoralis Morphotype 2. Its descendent, *Sc. anchoralis* Morphotype 3, is found near the uppermost Fern Glen Limestone and in the Pierson Formation of the Mississippi Valley. Brenckle and Lane (1981), and Lane and Ziegler (1983) indicated that the Tournaisian-Visean boundary should occur below the appearance of *Sc. anchoralis* M3 at a position within the Burlington Limestone of southeastern Iowa, the upper Fern Glen of southern Illinois, and the Pierson of southwestern Missouri.

In the foraminifer biozonation of Mamet and Skipp (1970 and 1971), emphasis is placed on acme zones rather than on range zones. The use of acme zones is vulnerable to influences of depositional environments in which organisms lived. This was pointed out by Sando *et al*. (1969, P. E17), Brenckle *et al*. (1974), and Armstrong and Mamet (1976 and 1977a). Mamet and Skipp also address this problem (1971, p. 1143-1144 and fig. 10). The factors governing the abundance of any organism in time and place are those ecological conditions which allow the organism to take full advantage of its reproductive capabilities. In other words, under the right conditions organisms produce the maximum number of offspring. Acme zones, therefore, may tend to shift in both time and space, depending on local environmental conditions. The Lower Carboniferous is known for its variation of facies from the Dinant type area to Avon Gorge in Britain to the upper Mississippi Valley to the western Cordillera of North America (Austin *et al*., 1973).

Mamet and Skipp (1971) reported that the Tournayellidae exhibit acme zones in North America that lag one Mamet Zone behind those in Eurasia, *i.e.* acme zones are one zone younger in North America. This may be the result of placing the Tournaisian-Visean boundary at the base of the Marbre Noir de Dinant. Consequentially any biozonation schemes using the base of the Marbre Noir de Dinant as the Tournaisian-Visean boundary in lieu of the decision of the SCCS should appear to be younger than schemes adhering to that decision.

The discovery of a tuberculate foraminifer assemblage in the Humboldt Oolite of Iowa by Brenckle and Groves (1986) allows foraminiferal correlations between western North America and the midcontinent. Such an assemblage had hitherto been unknown east of the Transcontinental Arch. Supported by evidence from other fossil groups (conodonts and brachiopods) a youngest age of early Osagean is suggested for the Humboldt. The Humboldt foraminifer fauna itself, therefore, cannot be considered to be any younger than this. Brenckle and Groves (1986, fig. 6, p.570) correlate their "Zone of Tuberculate Foraminifers" (ZTF) with Mamet Zones 8-9, thus reassigning these zones to the early Osagean. This correlation of the ZTF with Mamet Zones 8-9 also agrees with the "adjusted zones" (Figure 8 and Figure 9 herein) of Baxter and Brenckle (1982). The top of the ZTF corresponds approximately to the SCCS Tournaisian-Visean boundary based on *Eoparastaffela* and

Eoendothyranopsis faunas (which first occur at the base of the Visean in Europe) occurring immediately above the ZTF.

IV. THE MISSISSIPPIAN OF WEST-CENTRAL NEW MEXICO

The name Kelly Limestone refers to Mississippian strata exposed in fault-block mountains along the western margins of the Rio Grande Rift Valley in Socorro County, west-central New Mexico. Its original type area is in the Kelly Mining District in the Magdalena Mountains. It is named after the nearby ghost town of Kelly, New Mexico.

The Kelly Limestone consists of about 35 m (115 ft) of thick bedded, medium to coarsely grained crystalline limestone. Its lowermost units contain clastic mudstones, arenites, and conglomerates. The "silver pipe," an argillaceous dolomitic mudstone, named for its association with ore shoots, is a conspicuous 2 m (6 ft) unit in the middle of the Kelly. The lower member, the Caloso Member, consists of lime mudstones, packstones, wackestones, and crystalline limestones. The overlying Ladron Member is mostly crinoidal grainstones.

The southernmost outcrops are located in the Coyote Hills, the low-lying southern extension of the Chupadera Mountains, about 17 miles (27 km) south of Socorro, New Mexico. To the north, outcrops of the Kelly extend along the crest of the northern Magdalena Mountains for about four miles (6.4 km), from North Peak (Tip Top Mountain) to North Baldy. Six miles (9.7 km) north of Socorro in the Canoncito de Puertocito del Lemitar (Corkscrew Canyon) of the Lemitar Mountains, the Kelly crops out along a north-south band for approximately one mile (1.6 km) in the eastern foothills of the Lemitars. Eighteen miles (29 km) north of Socorro is another outcrop of the Kelly located in the southern Ladron Mountains just west of Cerro de Colorado. There the Kelly is exposed along Arroyo Caloso for about four miles (6.4 km) in a band trending north-south from Rio Salado to the northern end of Cerro de Colorado (just south of Ladron Peak). The northernmost exposure of the Kelly is north of Ladron Peak at the mouth of Canon del Norte where a thin outcrop of the Caloso Member occurs. It is not included in this report. For more information about the geographic location and access of these outcrops, please refer to Appendix I: Stratigraphic Sections, p. 228.

The Kelly Limestone was deposited in a major, regional, marine transgression in the Lower Mississippian, when epicontinental seas extended to the central and northern parts of New Mexico (Armstrong et al., 1980). The fauna of the Kelly Limestone is composed mostly of echinoderms, brachiopods, and corals. Armstrong interpreted the environment of deposition as an open-marine shelf.

The Caloso Member unconformably overlies Precambrian igneous and metamorphic rocks. A sharp disconformity representing a relatively short duration, separates the Caloso from the Ladron Member (Armstrong and Mamet, 1974). The Ladron is unconformably overlain by clastic rocks of the Sandia Formation (Pennsylvanian).

Previous Work

The name "Graphic - Kelly" limestone was first applied to the ore-bearing rocks in the Magdalena Mining District by Herrick (1904). The name was taken from two principal mines in the area. Keyes (1904a and 1904b) correlated elements of the microfauna in these units to the Lower Carboniferous rocks of Colorado and the Mississippi Valley. Gordon (1907) renamed this unit the Kelly Limestone after the town near the major outcrop. Gordon (1907 and 1910) tentatively classified the Kelly Limestone as Mississippian because of its lithologic and paleontologic similarities to the Lake Valley Limestone of southern New Mexico.

Gordon (1907) and Darton (1917) reported the earlier (1905) discoveries of Lee in which limestone, units similar to the Kelly Limestone, were found in the southern Sierra Ladrones (Ladron Mountains). Fossil collections made by Lee were determined by G. H. Girty to be of early Mississippian age. However, Girty suggested these fossils were not typical of Lake Valley faunas, but that they may be contemporaneous with or younger than the Lake Valley. Darton (1928, p. 136) referred to the Kelly Limestone as "Lake Valley limestone" based on this and lithologic considerations.

Lasky (1932), Loughlin and Koschmann (1942), and Jicha (1954) give excellent accounts of the history and descriptions of the ores of the Kelly/Magdalena Mining District. Loughlin and Koschmann (1942) and Blakestad

(1978) discussed geology and ore deposits of the mining district. Both works contain excellent geologic maps.

Loughlin and Koschmann (1942) noted the scarcity of identifiable fossils in the Kelly Limestone. Collections were taken from the lowermost and uppermost parts of the Kelly. Again Girty made the identifications and the interpretations (Loughlin and Koschmann, 1942, p. 16):

> The faunas as represented by these small lots are markedly unlike, thus suggesting a marked difference in age, ... neither of these faunas is closely related to that of the Lake Valley limestone, which they might be expected to resemble. Indeed, from our present inadequate knowledge, the faunas of the Kelly limestone is [are] rather strikingly different from the fauna of the Lake Valley limestone, though it [they] is [are] not necessarily of a different geologic age.

Laudon and Bowsher (1949) also observed the scarcity of fossils in the Kelly Limestone. They studied fragmental, poorly preserved fossils *in situ* in the upper part of the Kelly, and inconclusively considered them to be Osagean in age. However, Laudon and Bowsher (1949, fig. 2, p. 9) correlated the Kelly with the Fern Glen - Burlington of southwestern Missouri. They designated a unit in the Mimbres Range as the the Kelly Limestone and recommended that a detailed study be made of the relationship with the Lake Valley Formation. Jicha (1954) redesignated the Kelly Limestone of Laudon and Bowsher (1949) in the Mimbres Range as the Tierra Blanca Member of the Lake Valley.

Noble (1950) and Kelley and Silver (1952) proposed the name Caloso Formation for the complete Mississippian section in the southern Ladron Mountains. The name was taken from Arroyo Caloso where it crops out. Noble (1950) collected fossils from the lowermost part of the unit, and S. A. Northrop identified the fossils as Kinderhookian forms. This age assignment was older than Osagean as determined by Laudon and Bowsher (1949). Noble (1950) and Kelley and Silver (1952) pointed out the lithologic similarities between their Caloso and the Kelly Limestone in the Magdalena Mountains, and the lithologic differences with the Lake Valley Formation.

In his study of the Mississippian of west-central New Mexico, Armstrong (1955 and 1958a) recognized the Caloso Formation as a lower unit of sandstones, shales and dense gray limestones; and the Kelly Formation as an overlying unit of crinoidal limestones. He assigned the Caloso an early Kinderhookian age based on the brachiopods _Dielasma chouteauensis_ Weller and _Spirifer centronatus_ Winchell. He assigned the Kelly a late Osagean - early Meramecian age based on brachiopods and blastoids. Armstrong (1962) reassigned the Caloso to the early Osagean based on the brachiopod _Beecheria_ cf. _B_. _chouteauensis_ Weller. He also indicated a lithostratigraphic correlation of the Kelly and the A member of the Keating Formation (Escabrosa Group of southwest New Mexico, and southeastern Arizona) based on abundant crinoids. Armstrong (1967) and Armstrong and Mamet (1974) shifted the age assignment of the Caloso to late Osagean based on endothyrid foraminiferal faunas (Mamet Zone

8). They assigned the Kelly to the latest Osagean based on similar evidence (Mamet Zone 9).

Armstrong and Mamet (1976) redefined the Kelly Limestone as consisting of two members, the lower Caloso Member, and an overlying crinoidal unit, the Ladron Member. The name Kelly Limestone was restricted to west-central New Mexico in the Lemitar, Magdalena and Ladron Mountains, and the Coyote Hills of Socorro County. The locality of the type section of the Ladron Member is along the crest of the Magdalena Mountains (specifically: NE1/4 SW1/4 sec. 31, T. 2 S., R. 3 W.). The type section for the Caloso Member is in Arroyo Caloso of the southeastern Ladron Mountains (specifically: E1/3 sec. 30, T. 2 N., R. 2 W.) along which the Mississippian section is exposed.

Armstrong and Mamet (1976 and 1977a) found foraminifers in thin sections of the Kelly Limestone. Those in the Caloso Member were determined to be in Mamet Zone 8 (upper Osagean/traditional upper Tournaisian). Those in the Ladron Member were determined to be in Mamet Zone 9 (uppermost Osagean/traditional upper Tournaisian).

V. FIELD AND LABORATORY METHODS

Field Methods

Field investigations of the Kelly Limestone were conducted during the summers of 1985, 1986, and 1987. The early summer of 1985 was spent reconnoitering areas of interest, selecting appropriate stratigraphic sections to measure, and sampling for petrographic and biostratigraphic analyses.

Stratigraphic sections were measured using Brunton transit, measuring tape, and Jacob staff. While measuring these sections, a wide variety of rock types, particularly carbonates, were sampled for conodonts and petrographic analysis. An assortment of carbonates were sampled to ascertain which rock types would yield the best conodont faunas in terms of diversity and quantity. After processing samples for conodonts, sections were resampled for specific rock types which supported conodont faunas. Stratigraphic sections were again resampled where stratigraphic boundary problems needed to be resolved. In late summer of 1987, stratigraphic sections were resampled, specifically for foraminifers, concentrating on fossiliferous mudstones, wackestones and packstones.

Laboratory Procedures

Conodont Sample Preparation

Carbonate rock samples contaminated with mud and plant material (*e.g.* roots; lichens) were washed with a brush to remove unwanted debris. Caliche deposits were removed by hammer and chisel. After the bulk sample was dry, it was broken into pieces approximately 1.5 cu cm in size with the aid of a hydraulic rock splitter. Sample lots of 500 g each were digested in 10 percent formic acid solution. After 18-24 hours in the acid bath most carbonate rocks were completely dissolved. Samples remained in the acid bath no longer than 24 hours to prevent dissolution of conodont elements by weak acid solutions (Jeppsson *et al.*, 1985).

Insoluble residues were wet sieved through a stack of 10-, 120-, and 230-mesh (ASTM Tyler Equivalent) sieves. Particles caught in the 10-mesh sieve were placed back into an acid solution to complete digestion. Conodont elements were gleaned from 120-mesh residues. If these residues weighed more than 35 g, conodonts were concentrated using the sodium metatungstate, heavy liquid separation technique (Krukowski, 1988). Heavy mineral fractions from these separations, and 120-mesh residues weighing less than 35 g, were sorted by hand under the microscope. The 230-mesh residues were not sorted for conodonts unless they were needed to resolve taxonomic and/or stratigraphic problems.

Sample residues were sorted by stratigraphic position for each measured section. After hand picking/sorting conodonts from residues, they were sorted by taxonomy.

Foraminifer Sample Preparation

Thin sections were made from all rocks sampled for conodonts. These thin sections were inspected for foraminifer specimens. Although found with most kinds of Paleozoic marine fossils, conodonts are less frequently found in association with foraminifers. Therefore, it was necessary to collect a second sample suite specifically for foraminifer specimens. A total of nineteen samples were collected from the North Peak and Cerro de Colorado sections, near or at the type localities of the Ladron and Caloso Members, respectively.

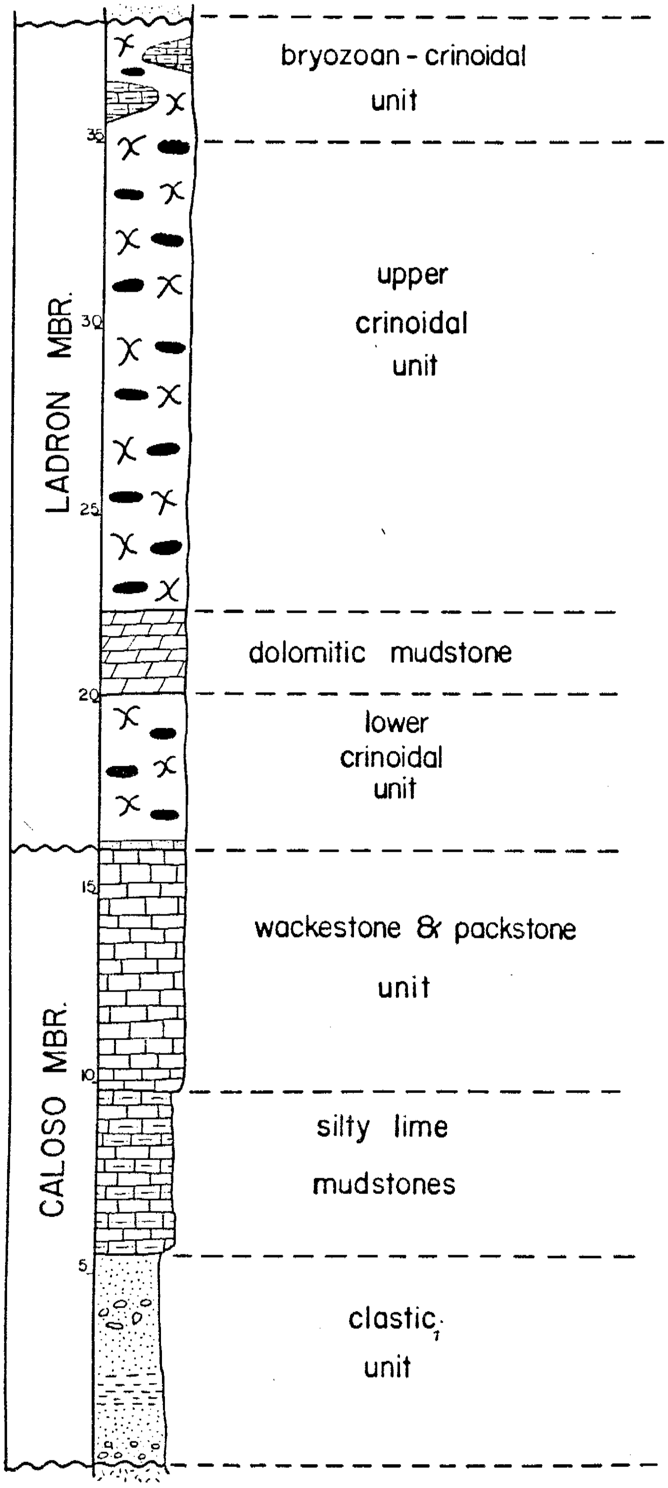
Sampling efforts were concentrated on fossiliferous lime mudstones, wackestones, and packstones because they are the most likely rock types for foraminifers (Mamet and Skipp, 1971). Micrites and arenaceous limestones, as well as clastic rocks in the lower Caloso Member, were not sampled for foraminifers. Collecting was difficult in the Ladron Member because of the preponderance of crinoidal grainstones. Fortunately, some of these units grade into crinoidal packstones. These latter rock types, along with bryozoan-rich limestones of the uppermost Ladron, were sampled for foraminifers.

VI. MEASURED STRATIGRAPHIC SECTIONS

Five Mississippian sections were measured in west-central New Mexico: Chupadera Peak in the Coyote Hills; North Peak and Chihuahua Gulch in the Magdalena Mountains; Corkscrew Canyon in the Lemitar Mountains; and Cerro de Colorado (Arroyo Caloso) in the southern Ladron Mountains. The Kelly Limestone ranges up to 34.5 m in thickness. The Caloso is thickest in the Coyote Hills (over 20 m) and thinnest at North Peak (9.5 m). The Ladron is thickest (22 m) at North Peak, and absent at Chupadera Peak. Appendix I (p. 228) gives detailed information concerning stratigraphic sections and their locations. Photographs of outcrops are included in Appendix I (p. 228).

The Caloso Member contains more terrigenous material (shales, mudstones, sandstones and conglomerates) than the Ladron Member, which contains mostly crinoidal grainstones and packstones. The Caloso Member consists of three lithologic units (Figure 10). The lowermost unit, the clastic unit, consists primarily of quartz and arkosic arenites which are normally 1-2 m thick. The middle unit is mostly silty lime mudstones. The third and uppermost unit is dominated by fossiliferous wackestones and packstones. The Ladron is composed of four lithologic units (Figure 10): a lower crinoidal unit, a dolomitic mudstone unit (silver pipe), an upper crinoidal unit, and a bryozoan-crinoidal unit (Bryozoan-_Pentremites_ _conoideus_ zone of Armstrong, 1955). (See Figure 10). Figure 11 shows

Figure 10. Composite stratigraphic column of the Kelly Limestone. Scale is in meters.


bryozoan - crinoidal unit
upper crinoidal unit
dolomitic mudstone
lower crinoidal unit
wackestone & packstone unit
silty lime mudstones
clastic unit
LADRON MBR.
CALOSO MBR.
35
30
25
20
15
10
5

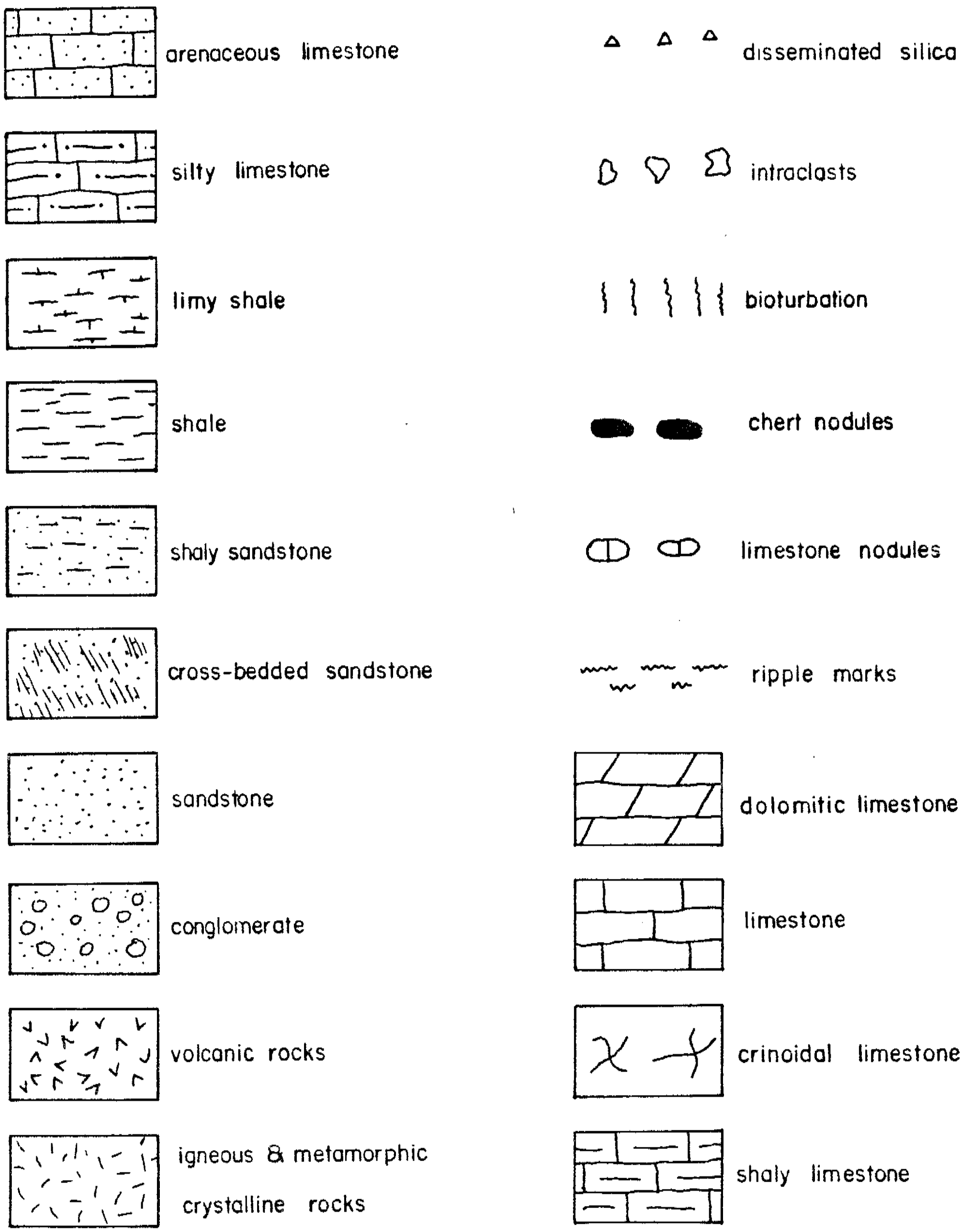


Figure 11. Lithologic symbols used in this report.

lithologic symbols used in this report. The upper and lower crinoidal units are separated by the dolomitic mudstone unit. The Caloso and Ladron are separated by an unconformity of short duration (Armstrong, 1955 and 1958b). This hiatus is marked by a sharp break in the lithologic character between the dark, fine-grained limestones of the Caloso, and the lighter, coarse-grained, crinoidal grainstones and packstones of the Ladron.

Chupadera Peak Section (Coyote Hills)

Caloso Member. In the Coyote Hills, the lower clastic unit of the Caloso Member rests nonconformably upon Precambrian granitoid plutonic rocks (Eggleston, 1982). The clastic unit consists of 2.25 m of pink, planar cross-bedded, quartz arenite; the lower 1.75 m consists of well sorted, subrounded, fine-grained sandstone, the upper 50 cm consist of medium to coarse-grained sandstone, the uppermost 10 cm consist of arkosic arenite.

Here the silty lime mudstone unit is generally brown in color. Quartz grains range up to fine sand in size, but the majority of grains are silt particles. This unit is 2.3 m thick and contains conspicuous dissolution cavities, a few of which range up to 1 m in diameter.

The upper wackestone and packstone unit of the Caloso Member is 16 m thick. The lower half consists of alternating crinoidal grainstones and packstones; the upper half consists of lime mudstones and wackestones. Crinoid columnals are coarse sand size. In places, the lime mudstones and wackestones weather into nodules. Towards the top, these limestones gradually become finely to medium crystalline; recrystallization has destroyed the depositional textures. The lower 50 cm of the wackestone and packstone unit is composed of wackestones consisting of rounded, fine to medium sand size fossil debris, similar to the uppermost Caloso in the Magdalena and Ladron Mountains sections.

The top of the Caloso Member generally is an erosional surface. Locally in this area, the Caloso is overlain nonconformably by andesitic to latitic lavas of the Spears Formation (Tertiary). Pebbles to boulders of Caloso limestone have been reworked into the rubble zone of these volcanic flows. Dissolution cavities, joints, and Tertiary volcanic stream channels cut into the top of the Caloso are filled with these volcanic rocks. Armstrong (1958b) observed Ladron Member boulders incorporated in these rubble zones as well.

Ladron Member. The Ladron Member has been removed by erosion in the Coyote Hills section.

Chihuahua Gulch Section (Magdalena Mountains)

This section is located at the head of Chihuahua Gulch along its north wall, nearly at the crest of the Magdalena Mountains. Varying degrees of silicification occur in these rocks, particularly along fractures, joints, and occasionally along bedding planes. Silicification increases progressively southward until the Kelly Limestone is almost completely silicified at North Baldy.

Caloso Member. Here the Caloso Member nonconformably overlies Precambrian basement rocks composed of quartz monzonite, granite, and greenschist. The lowermost clastic unit of the Caloso Member is composed of white to very pale green, lithic arenites which grade laterally into lithic boulder conglomerates. Lithic fragments are monzonite, quartzite, and granitic rocks. These sandstones and conglomerates are less than 1 m thick. Grains of pebble size and larger tend to be rounded, but finer intergranular sands are more angular.

The lowermost 75 cm of the silty lime mudstone unit is a fossiliferous, coarsely crystalline limestone. Fossil fragments include crinoid ossicles and brachiopod shells. The upper portion of this bed contains quartzose and felsic lithic fragments. It is from units similar to this that Loughlin and Koschmann (1942) and Armstrong (1958b) collected fossils.

Above this fossilliferous crystalline limestone, the silty lime mudstone unit is 5.5 m thick, and consists mainly of interbedded calcareous shales and lime mudstones. No fossils were observed within this interval.

The wackestone and packstone unit is 6 m thick. The lower half consists of fossiliferous wackestone and lime mudstone conglomerate. The lower fossiliferous wackestone contains unidentifiable, angular, very coarse, sand size fossil fragments. Medium to coarsely crystalline spar has replaced much of the lime mud. The overlying lime mudstone conglomerate contains boulders of arenaceous lime mudstone, and grades upward into a shaley intraclastic wackestone. The intraclasts are thinly laminated to very thinly bedded lime mudstone pebbles.

The uppermost half of the wackestone and packstone unit consists of thinly to thickly laminated, fossiliferous grainstone. Laminations are laterally continuous and display penecontemporaneous microfolding and microfaulting. Rounded fossil fragments of fine- to medium-grained sand size may be mistaken for oolites. Bedding plane surfaces from this unit contain oscillation ripple marks which are easily observed when viewed from above.

Ladron Member. The contact between the Caloso Member and Ladron Member is an abrupt and undulose erosional surface, easily recognized by a conspicuous change in rock type. The lowermost Ladron, the lower crinoidal unit, is marked by 10 cm of fossiliferous arenaceous lime mudstone which grades laterally into calcareous coarse-grained quartz arenite (well-rounded, coarse, quartz sand which may range up to 90% of grains). Fossils are conspicuous on weathered surfaces:

rugose corals, brachiopods, and shark teeth are well preserved.

The lower crinoidal unit is 2 m thick, and consists of crinoidal grainstones, generally light gray in color. Macrofossils include brachiopods, rugose corals, bryozoans, and trilobites. On weathered surfaces, fossils are obvious due to replacement by pink silica. Crinoidal grainstones may grade laterally into crinoidal packstones.

The argillaceous dolomitic mudstone unit, the silver pipe of the Magdalena Mining District, is 30 cm thick, and overlies the lower crinoidal unit. This unit is an easily recognized marker bed in the Kelly Limestone; however, Siemers (1973) and Iovenitti (1977) have reported the silver pipe to be an unreliable stratigraphic marker because they could not find it throughout the area.

The upper crinoidal unit is 4.5 m thick and consists of crinoidal grainstones. These grainstones contain conspicuous pink to white chert nodules which range up to 1 m long and 10 cm thick. The top of the Ladron Member is an erosional surface which forms the western dip slopes of the Magdalena Range.

North Peak Section (Magdalena Mountains)

The type section for the Ladron Member is a cliff face located about 1500 m south of North Peak along the crest of the Magdalena Mountains. This section provided Armstrong and Mamet (1976) with the best exposed outcrop at the time.

The North Peak site was chosen for this study because: the contact with the overlying Sandia Formation (Pennsylvanian) is present (the top of the type section is an erosional surface); the researcher has more lateral control; and the lowermost Mississippian units are exposed.

Caloso Member. The clastic unit at North Peak overlies Precambrian granitoid rocks and greenschists. The lowermost part of the clastic unit is a red, well-sorted, quartz arenite about 1 m thick. It is composed of angular, very fine sand reminiscent of the lowermost part of the clastic unit at Chupadera Peak. Directly above this sandstone are approximately 2.5 m of lime mudstone pebble conglomerates. Lime mudstone clasts range up to boulder size. Cobbles and boulders are concentrated in the middle of the unit. A few chert and quartz pebbles also occur. Olive green to light brown color clays, sands, and muds occur as matrix material, and grade laterally and vertically into one another. Above these conglomerates are 50 cm of nodular lime mudstone which pinches and swells. No fossils were found. Immediately above is another sandstone; a well-sorted, well indurated, lithic, quartz arenite whose fine to medium sand grains are rounded. Lithic fragments are particles of calcium carbonate.

The silty lime mudstone unit is 3.6 cm thick. It consists of interbedded packstones and lime mudstones; argillaceous, nodular lime mudstones predominate.

The upper wackestone and packstone unit is 4-5 m thick and consists of interbedded packstones and lime mudstones; packstones predominate. Lime mudstones may contain medium sand size quartz. Herkimer twins (about 1.5 mm long) are observed on weathered surfaces of some of the lime mudstones. Packstones contain well-sorted, calcium carbonate, medium sand; presumably composed of fossil debris. The uppermost 30 cm of this unit is rich in silica and has a pinkish gray hue. The top of the Caloso is a sharp undulating erosional surface (Figure 12).

Ladron Member. The lowermost Ladron Member, lower crinoidal unit, is recognized by conspicuous coarse-grained, well-rounded, quartz sand similar to that found in the lowermost Ladron at Chihuahua Gulch. At North Peak, however, it is an arenaceous crinoidal wackestone, 4-12 cm thick. Crinoid ossicles are the most abundant fossils, but brachiopod shell fragments and a rare rugose coral are also present. The relative amounts of fossil grains and quartz sand changes laterally, with either alternating as the predominant grain type.

The lower crinoidal unit is 4 m thick and consists of crinoidal grainstone. Occasional crinoid ossicles are replaced by pink silica, and are readily observed on weathered surfaces.

The argillaceous dolomitic mudstone unit is about 2.25 m thick. This unit is thinly to thickly laminated. The contact with the overlying upper crinoidal unit is gradual.

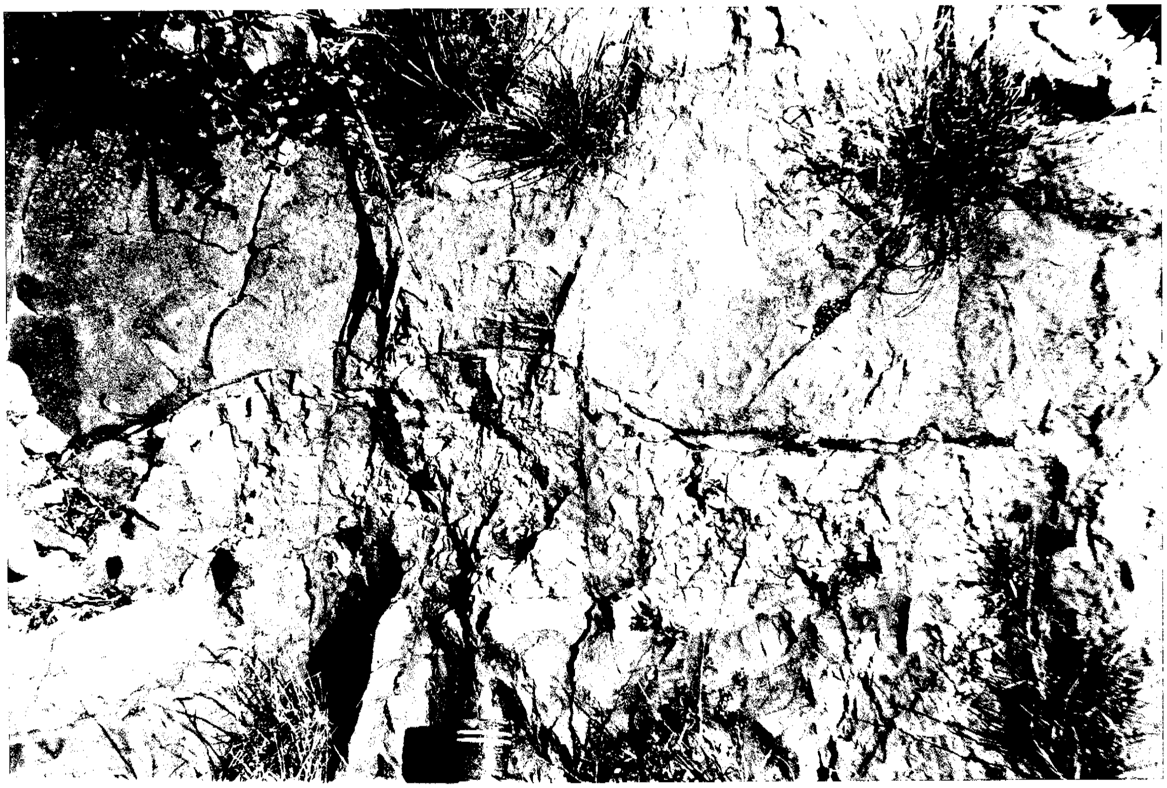


Figure 12. Contact between the Caloso Member and Ladron Member at North Peak. Contact is a sharp, undulatory surface. Note coarse sand grains and crinoidal debris in the lowermost Ladron.

In an interval of only 4-5 cm, the dolomitic mudstone grades upwards into crinoidal packstone then crinoidal grainstone. No fossils are found in the dolomitic mudstones.

The upper crinoidal unit is 14.5 m thick and consists of very light gray crinoidal grainstones. Other fossils present are brachiopods, bryozoans, rugose corals, trilobites, and gastropods. Large, white and pink, lozenge-shaped, chert nodules (1 m long and 10 cm thick) are conspicuous in this thick bedded unit (Figure 13). The uppermost 2 m of the upper crinoidal unit are darker and may be brown or orange in some places.

The bryozoan-crinoidal unit is 1.5 m thick and is generally dark. It consists of conspicuously thinner bedded, alternating crinoidal grainstones and fossiliferous wackestones. Crinoid columnals are markedly smaller, ranging from fine to medium sand size. Fenestrate bryozoans are the predominant fossils in the wackestones, and are conspicuous on bedding plane surfaces. A considerable amount of lime mud has been replaced by silica in these wackestones. Orange chert nodules are observed in the lower 30 cm of this uppermost unit.

The contact with the overlying Sandia Formation (Pennsylvanian) is abrupt and irregular. Cut-and-fill structures can be observed along this horizon. Armstrong (1958b) documented 30 ft of relief along the Mississippian-Pennsylvanian erosional surface elsewhere in the Magdalena

Figure 13. Chert nodules in the upper crinoidal unit of the Ladron Member at North Peak.

Mountains. The Sandia consists of red to purple, cross-bedded, quartz arenite.

Corkscrew Canyon Section (Lemitar Mountains)

This section is best exposed on the south wall of Corkscrew Canyon where the Kelly Limestone dips steeply to the west at 65 degrees.

Caloso Member. Here the clastic unit nonconformably overlies Precambrian metamorphic greenstones. The nonconformity can be observed on the north wall of Corkscrew Canyon. The nonconformity is abrupt and irregular. The lowermost clastic unit is 1 m thick and consists of a white to very light brown, friable, medium-grained, quartz arenite. Minor amounts of feldspar and lithic fragments are present. Grains are subangular to subrounded and well-sorted. The lower one-third of the clastic unit is a green shale with small Precambrian greenstone pebbles at its base. This quartz arenite is reminiscent of the lowermost clastic unit at Chupadera Peak and the Magdalena Mountains.

The silty lime mudstone unit is about 4 m thick, and consists of lime mudstones. The lower half consists of fossiliferous, arenaceous, lime mudstone. Quartz sand and lithic fragments are more abundant than fossil grains, which include brachiopod shells, crinoid ossicles, and fenestrate bryozoans. Gray and brown chert nodules up to 1 m long, and which are parallel to bedding, may also be observed in the lower portion of this unit. The uppermost 2 m are composed of nodular lime mudstone and fossiliferous, arenaceous, lime mudstone. Stylolites and quartz- and calcite-filled fractures are also observed in this arenaceous lime mudstone.

The next 2 m are finely to medium crystalline limestone. About 3 m of lime mudstone and intraclastic packstone overlie the crystalline limestone. Lime mudstones are thinly to thickly laminated. The intraclastic packstone occurs in the middle of this 3-meter unit. Intraclasts range up to cobble size and are thinly laminated lime mudstones. Intraclasts are randomly oriented in a lime mudstone matrix. Lime mudstones and packstones grade into nodular lime mudstones and/or silty lime mudstones, respectively. These rock types are easily weathered, and form slopes in the Caloso Member. They are easily recognized because of their brown color.

Here the wackestone and packstone unit is approximately 3 m thick, and consists of a series of alternating shales, lime mudstones, and crinoidal grainstones. Lime mudstones are thinly laminated and may grade laterally into nodular lime mudstone. The crinoidal grainstones are generally thickly bedded. Grain size ranges from medium sand to granule size; medium sand predominates in the lower portions and grades upward to granule size. In decreasing order of abundance, other fossil grains include unidentifiable fossil debris, broken brachiopod shells, and bryozoan fragments.

<u>Ladron Member</u>. The lowermost 6-12 cm of the lower crinoidal unit grade laterally into arenaceous lime mudstone, packstones, and crinoidal grainstones. Coarse, quartz sand, which is characteristic of this interval, is occasionally observed. The lower crinoidal unit is 2.5 m thick and consists of crinoidal grainstone. Other fossils include brachiopod shells, rugose corals, and bryozoans.

About 3 m of alternating shales, lime mudstones, and crinoidal grainstones overly the lower crinoidal unit. This interval is the approximate stratigraphic position of the dolomitic mudstone unit (silver pipe) of the Kelly Limestone in the Magdalena Range.

The upper crinoidal unit is 16.5 m thick, and consists of crinoidal grainstones. Crinoid columnals range from medium sand to pebble size. Other fossils found in this unit are brachiopods, rugose corals, bryozoans, gastropods, trilobites, and blastoids.

Average grain size diminishes in the bryozoan-crinoidal unit, the uppermost 4.5 m. Some crinoidal grainstones grade laterally into silty crinoidal packstones. These grainstones and packstones tend to be thinner bedded, light brown and orange, and are rich in bryozoans. Fenestrate bryozoans are particularly noticeable on bedding plane surfaces.

White, pink, and gray chert nodules occur throughout the thickness of the Ladron Member (except at the stratigraphic position of the dolomitic mudstone unit).

These are parallel to bedding, and range up to 1.5 m long and 12-15 cm thick.

The Kelly Limestone is overlain by the Sandia Formation (Pennsylvanian). Up to 1.3 m of relief is observed on the Ladron Member erosional surface. Cut-and-fill structures are present along this horizon. The lowermost part of the Sandia is a tan to brown, hematitic, medium-grained, quartz arenite.

Cerro de Colorado Section (Ladron Mountains)

This section is exposed along a series of north-south trending hogback ridges over 4 miles long, directly west of Cerro de Colorado along Arroyo Caloso. This is the type section for the Caloso Member of the Kelly Limestone.

Caloso Member. The Precambrian-Mississippian nonconformity is abrupt and irregular. Up to 1 m of relief is observed along this horizon. Precambrian rocks consist of of schists and gneisses that weather into platy slabs. The lowermost part of the clastic unit is a lithic pebble conglomerate which includes lithic fragments of underlying schists and gneisses.

The clastic unit is 5 m thick and consists of subarkosic quartz arenites and nodular arenaceous limey shales. These light brown arenites are medium-grained, and moderately sorted. Oscillation ripple marks are obvious bedding plane features. Arenites are friable. The arenaceous shales occur in an interval about 1 m thick above the arenites. Spherical nodules or concretions within the shales range up to 16 cm in diameter and are composed of arenaceous calcareous mudstone. The largest nodules are concentrated in the middle of the unit gradually decreasing in size towards the top and bottom.

Immediately above these arenites and shales is another meter of quartz arenite. This quartz arenite is very light brown (tan) to white in color and is composed of well-sorted, rounded, very fine sand. It is very friable. It resembles the lowermost quartz arenite of the clastic unit in the Lemitar Mountains.

The silty lime mudstone unit is only 50 cm thick here, and consists of mottled lime mudstone.

The wackestone and packstone unit is 5.5 m thick here, and consists of fossiliferous wackestones and packstones. Small rounded grains, unidentifiable in the field, were identified as peloids and foraminifers in thin section. Rugose corals and brachiopods are found in a 3- to 5-centimeter band about 3 m from the base of the wackestone and packstone unit. These fossils are replaced by pink silica, and protrude from weathered surfaces. The uppermost 30 cm of the wackestone and packstone unit has a pink hue and contains disseminated silica. The contact with the overlying Ladron Member is abrupt. It is an irregular to undulating erosional surface.

Ladron Member. The lower crinoidal unit and the dolomitic mudstone unit are missing from this section. Here the Ladron Member is nearly 14 m thick. The upper crinoidal unit consists mostly of crinoidal grainstones which occasionally grade into crinoidal packstones. The light gray color of the Ladron easily distinguishes it from the darker Caloso Member below. White chert nodules up to 1.5 m long and 12-15 cm thick occur throughout the Ladron. Crinoid columnals range up to pebble size. Other megafossils are found including bryozoans, brachiopods, rugose corals, gastropods and trilobites. The uppermost 2 m is the bryozoan-crinoidal unit, and is composed of alternating crinoidal grainstones and silty bryozoan crinoidal packstones. The latter is an orange to brown color. Fenestrate bryozoans are conspicuous on bedding plane surfaces. Crinoid columnals tend to be smaller in these uppermost units. The strata in the bryozoan-crinoidal unit are thinner bedded.

The Mississippian-Pennsylvanian contact is abrupt and irregular. The overlying Sandia Formation (Pennsylvanian) consists of dark brown, hematitic, quartz arenite. The top of the Ladron Member is an erosional surface with about 1 m of relief. One may observe cut-and-fill structures along the contact.

VII. PETROGRAPHY OF THE KELLY LIMESTONE

The carbonate rock classification system of Folk (1959) was used in assigning rock names to thin sections, with Dunham (1962) rock names in parentheses. In order to avoid confusion concerning the use of the term mudstone for both carbonate and terrigenous rocks, the modifier "lime" was used to distinguish carbonate mudstone of Dunham (1962) from clastic mudstones of Dott (1964). Appendix II (p. 289) tabulates petrographic (thin section) data by stratigraphic sections.

Caloso Member. Samples of the Caloso Member were collected to make thin sections at all five major outcrop areas. The largest number of samples (12) came from the Cerro de Colorado section. The Corkscrew Canyon section provided material for 8 thin sections. North Peak and Chihuahua Gulch outcrops each had 5 thin sections made from Caloso rock types. Four thin sections were cut from the Chupadera Peak section. Of all 34 thin sections examined, the majority (24) are micrites (lime mudstones); 6 are sparites (crystalline limestones); 3 are combination micrites/sparites (lime mudstones/crystalline limestones); and one is a dismicrite (bioturbated lime mudstone).

Samples FT-1 and FT-2 from the clastic unit at the North Peak section were the only arenites that were sampled for thin section analysis. These arenites were selected because of the anomalously high percentage of calcium carbonate present. They have abundant, rounded, calcium carbonate grains (intraclasts), and abundant quartz grains.

Most micrites contain varying amounts of angular, silt-sized quartz grains. Aggrading neomorphism is also a common feature. Many of these micrites contain dolomite rhombs. Some of the micrites examined display one or more of the following characteristics:

- repetitive layered structures parallel or subparallel to bedding planes;
- layers which are hummocky to gently rounded in outline (convex side up);
- alternating dark and light layers;
- inclusion of detrital (usually silt) materials as continuous layers, i.e. alternating laminations of micrite-rich sediments;
- dark micritic patches which may appear irregular or scalloped in outline;
- fenestral fabric (fenestrae are irregular in outline);
- pelletization of micrite;
- shrinkage cracks; and,
- microborings.

These features are usually of mm scale, but may range up to cm scale. Figure 14 is an example of one such thin section.

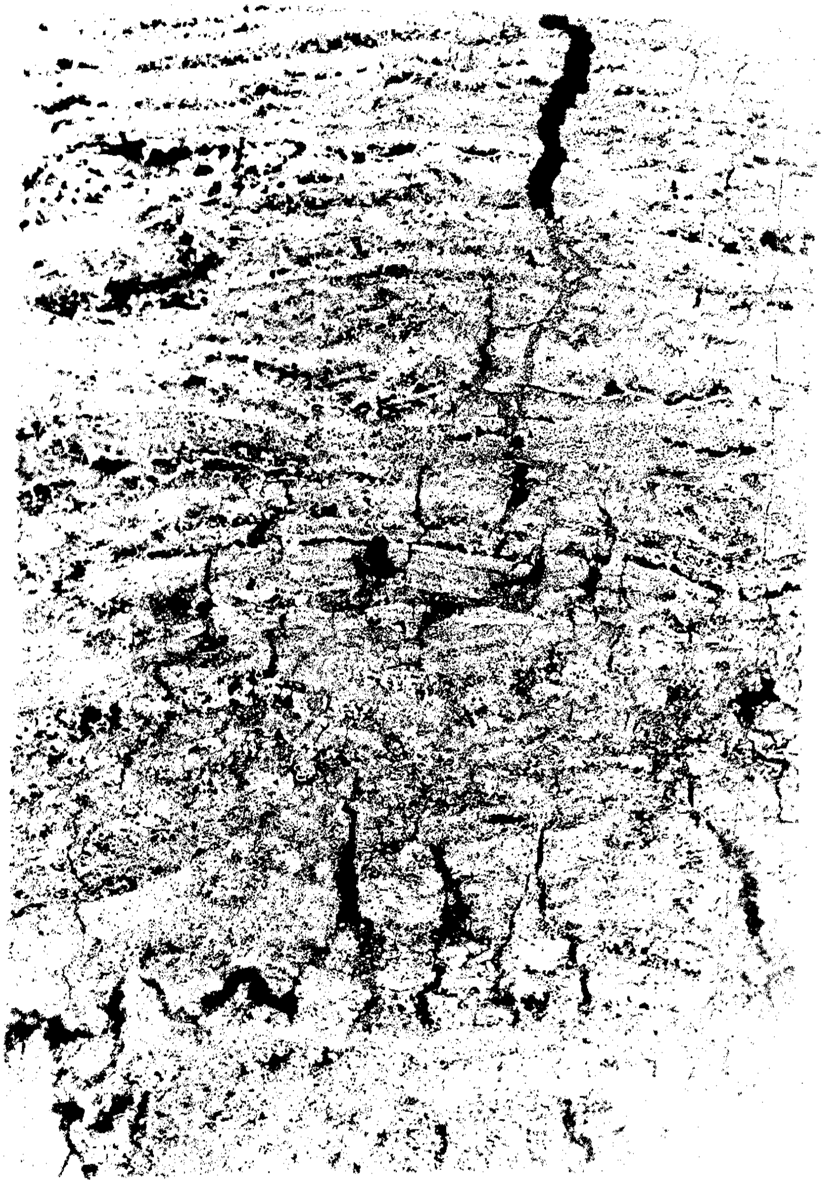


Figure 14. Photomicrograph of thin section from the lowermost silty lime mudstone unit of the Caloso Member exhibiting traits attributed to stromatolitic origins. Thin section from sample number CC-7b. (Approximately 3.8x).

Except for two samples collected from the lowermost silty lime mudstone unit, thin sections from the Caloso Member at Cerro de Colorado came from the upper 5.5 m of the fossiliferous wackestone and packstone unit. It is from this interval that Armstrong and Mamet (1974, 1976 and 1977a) obtained foraminifers. Therefore, in the present investigation, sampling efforts were focused on this position. Biomicrites are the dominant rock type studied from this interval. The most abundant fossils observed in these biomicrites are foraminifers, calcispheres, and crinoid ossicles; other samples singly contain abundant gastropods, brachiopods, or mollusks. Pellets and peloids are also common constituents. Also examined in this interval are rocks with equal or subequal amounts of spar and micrite (biomicrites/biosparites and biopelmicrites/biopelsparites). These are similar to the biomicrites in terms of fossil content; however, they have larger relative abundances of pellets.

Most biomicrites in the Caloso Member are classified as poorly fossiliferous or sparse, i.e. fossil constituents range from 1-10% and 10-40%, respectively. In biomicrites from North Peak and Chupadera Peak sections, the most abundant fossil grains are crinoid columnals and unidentified fossil fragments, respectively.

The remaining thin sections from the Caloso Member are sparites. These have high percentages (40% or greater) of fossils; the dominant fossil grains are crinoid columnals.

Brachiopods and bryozoans are also important constituents. Degrading neomorphism is evident, but not a dominant feature, except sample Ch-4c from Chupadera Peak in which most crinoid columnals and spar cement have been micritized. In the Caloso, conodont elements were found primarily in sparites; the only exception is Field Unit 2 (micrite/lime mudstone) from the lower part of the Corkscrew Canyon section.

Ladron Member. Mamet and Skipp (1971) list biomicrites, biosparites, biopelsparites, and intrasparites as Mississippian rocks which usually contain abundant foraminifers. Kelly Limestone sparites, however, contain very few or no foraminifers. Thin-bedded, fine-grained carbonate rocks should contain foraminifers in rocks older than Middle Pennsylvanian according to Douglas (1965). Fewtrell et al. (1981, p. 16) stated: "Generally, foraminifera [sic] are found in the bioclastic limestones which contain a limited proportion of finer crinoid debris." For these reasons, mud-rich rocks were sought in order to obtain foraminifer specimens. Ladron packstones and wackestones were sampled for thin section analysis, even though these rock types are atypical of the upper Kelly Limestone.

Thin sections were made from Ladron Member samples from three localities: North Peak, Corkscrew Canyon, and Cerro de Colorado. In the Magdalena Mountains, the effort to collect samples for thin section analysis was concentrated at North Peak because of its proximity to the type locality, and because all important lithologic units are present including the dolomitic mudstone unit (silver pipe) and the bryozoan-crinoidal unit (Bryozoan-Pentremites conoideus zone of Armstrong, 1963). Twenty four thin sections were studied from the Ladron: 13 from North Peak; 8 from Corkscrew Canyon; and 3 from Cerro de Colorado. Of these 24 thin sections, 12 are micrites (packstones and wackestones), 11 are sparites (grainstones), and one is an argillaceous dolomitic micrite (argillaceous dolomitic mudstone).

Sixteen thin sections were analyzed from the upper and lower crinoidal unit. Ten of these are biosparites/biosparrudites (grainstones): 5 from North Peak; 4 from Corkscrew Canyon; and 1 from Cerro de Colorado. The 6 remaining thin sections from the crinoidal unit are biomicrites/biomicrudites (packstones). These micritic rocks were selectively chosen to obtain foraminifers. Few rocks from the North Peak section contain a lime mud matrix. In the Corkscrew Canyon and Cerro de Colorado sections, however, rocks with a lime mud matrix are more abundant. Thin sections indicate a median allochem size greater than 1 mm for the crinoidal unit. The dominant fossil grains are crinoid columnals and bryozoan debris. Some crinoid ossicles and spar cement have undergone degrading neomorphism and replacement by silica.

The olive green dolomitic micrite (dolomitic mudstone unit) at North Peak displays discontinuous light and dark laminations of varying thicknesses. These bands are either straight and parallel to bedding planes or are gently curved, convex side up. Silt particles (less than 5%) are generally rounded.

Eight thin sections were examined from the bryozoan-crinoidal unit: 5 from North Peak; 2 from Corkscrew Canyon; and 1 from Cerro de Colorado. Of these eight thin sections, only two sparites (both from the North Peak section) were studied. The first is a crinoidal bryozoan biosparite; the other a crinoidal bryozoan biosparrudite. Carbonate mud in these rocks occurs mostly as void fill within fossil grains. Both sparites exhibit degrading neomorphism of bioclasts (crinoid columnals are affected in particular) and spar cement. Crinoid ossicles and spar cement crystals are occasionally replaced by silica.

The remaining 6 thin sections from the uppermost Ladron Member are dominated by bryozoan and crinoidal bryozoan biomicrites. One is a crinoidal bryozoan biomicrudite. Wholesale replacement of micrite by silica occurs in some portions of these North Peak biomicrites. For example, one sample has been extensively silicified so that its bioclastic texture is almost completely destroyed. Spar typically occurs as void fill within fossil grains and as fracture fill. Aggrading neomorphism is present in about half the biomicrite thin sections.

In summary, the major rock types in the crinoidal facies of the Ladron Member are biosparites/biosparrudites (grainstones). The predominant bioclasts in these rocks are crinoid columnals and bryozoan fragments. Average grain size is relatively large, i.e. greater than 1 mm. Towards the north, rocks (biomicrite/biomicrudite, i.e. wackestones and packstones) of the crinoidal unit tend to contain more mud matrix. These relatively micrite-rich rocks were subjectively sampled for foraminifer specimens. The dolomitic mudstone marker unit (silver pipe) in the Magdalena Mountains, is composed of argillaceous dolomitic micrite (mudstone). In the thinner-bedded and finer-grained uppermost bryozoan-crinoidal unit, biomicrite (wackestones and packstones) is the dominant rock type with bryozoan fragments as the most abundant fossils, followed by crinoid ossicles.

VIII. BIOSTRATIGRAPHY OF THE KELLY LIMESTONE

Conodont Biostratigraphy

Caloso Member. The lowermost limestones of the silty lime mudstone unit at Chupadera Peak (Figure 15), Chihuahua Gulch (Figure 16), and Corkscrew Canyon (Figure 17) produced a conodont fauna consisting of *Bispathodus aculeatus plumulus*, *Patrognathus variabilis*, *Polygnathus inornatus inornatus*, and *Polygnathus inornatus lobatus*. At Chupadera Peak this fauna is found in crinoidal packstones and grainstones of the silty lime mudstone unit, about 7 m above its base (Figure 17).

Only reworked Pa elements of *Bispathodus* sp., *Patrognathus variabilis* and *Polygnathus communis communis* were recovered from the wackestone and packstone unit of the Caloso Member at North Peak (Figure 18).

At Corkscrew Canyon conodont elements were also produced from crinoidal grainstones of the wackestone and packstone unit in the uppermost 3 m of the Caloso Member (Figure 17). Important conodont form taxa from this stratigraphic position include *Polygnathus communis communis*, *Pseudopolygnathus oxypageous* Morphotype 2, *Bispathodus stabilis*, *Gnathodus typicus* Morphotypes 1 and 2, *Gnathodus delicatus*, and *Gnathodus* cf. *G. punctatus*.

Ladron Member. The lower crinoidal unit below the dolomitic mudstone unit contains a conodont fauna different than the

Figure 15. Range chart illustrating conodont distribution for Chupadera Peak section. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.

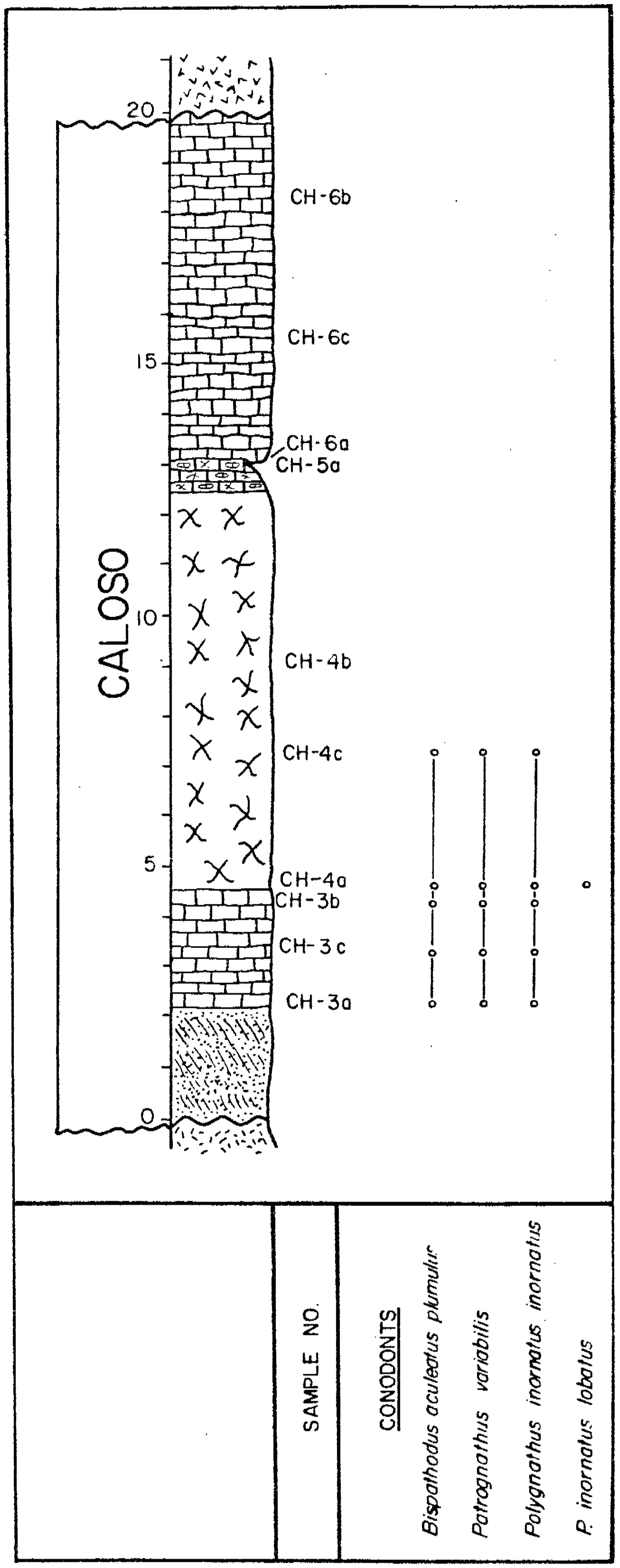

20
15
10
5
0
CALOSO
CH-6b
CH-6c
CH-6a
CH-5a
CH-4b
CH-4c
CH-4a
CH-3b
CH-3c
CH-3a
SAMPLE NO.
CONODONTS
Bispathodus aculeatus plumulus
Patrognathus variabilis
Polygnathus inornatus inornatus
P. inornatus lobatus

Figure 16. Range chart illustrating conodont distribution for Chihuahua Gulch section. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.

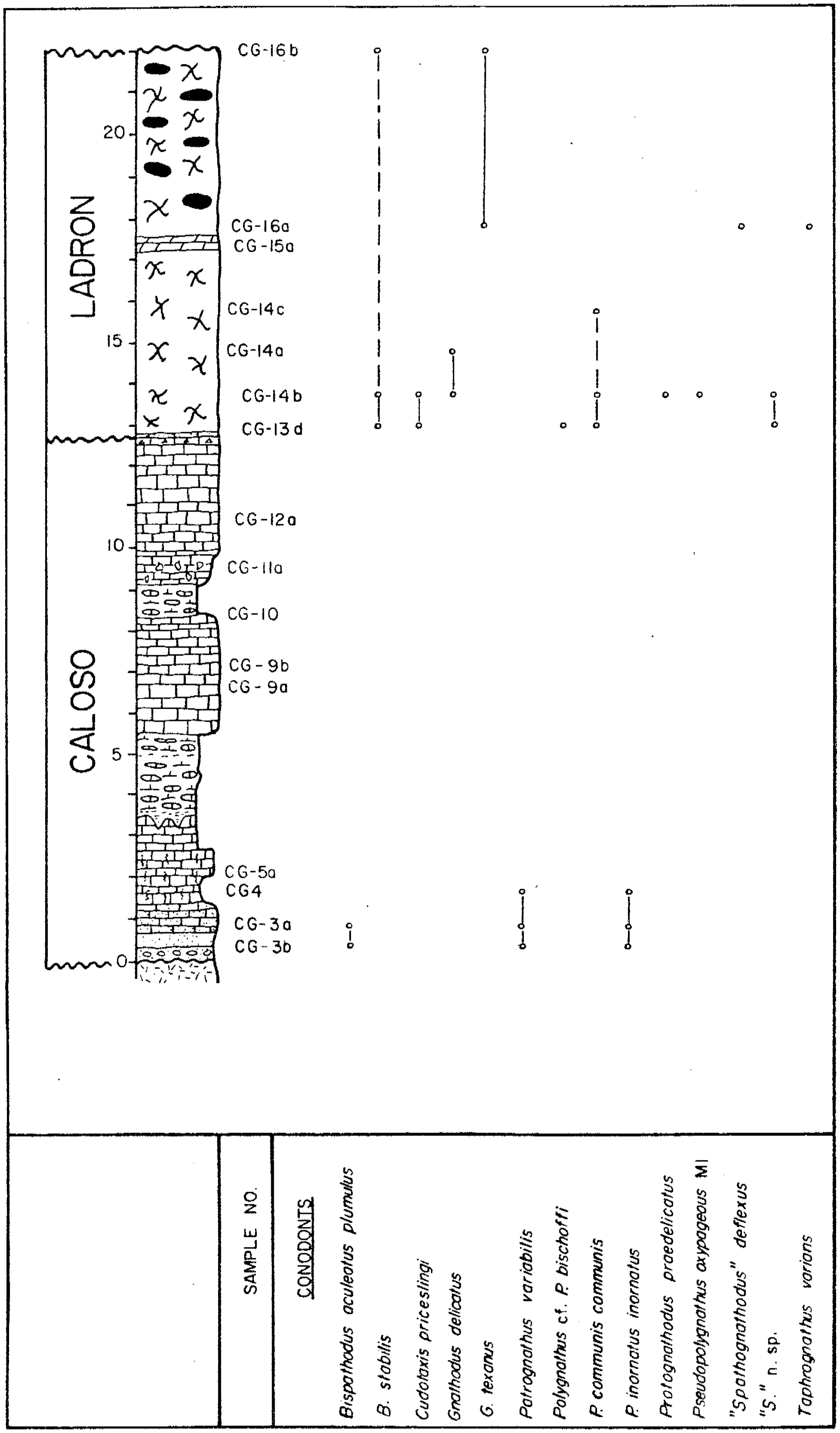

LADRON
CALOSO
0
5
10
15
20
CG-16b
CG-16a
CG-15a
CG-14c
CG-14a
CG-14b
CG-13d
CG-12a
CG-11a
CG-10
CG-9b
CG-9a
CG-5a
CG4
CG-3a
CG-3b
SAMPLE NO.
CONODONTS
Bispathodus aculeatus plumulus
B. stabilis
Cudotaxis priceslingi
Gnathodus delicatus
G. texanus
Patrognathus variabilis
Polygnathus cf. P. bischoffi
P. communis communis
P. inornatus inornatus
Protognathodus praedelicatus
Pseudopolygnathus oxypageous M1
"Spathognathodus" deflexus
"S." n. sp.
Taphrognathus varians

Figure 17. Range chart illustrating conodont distribution for Corkscrew Canyon section. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.

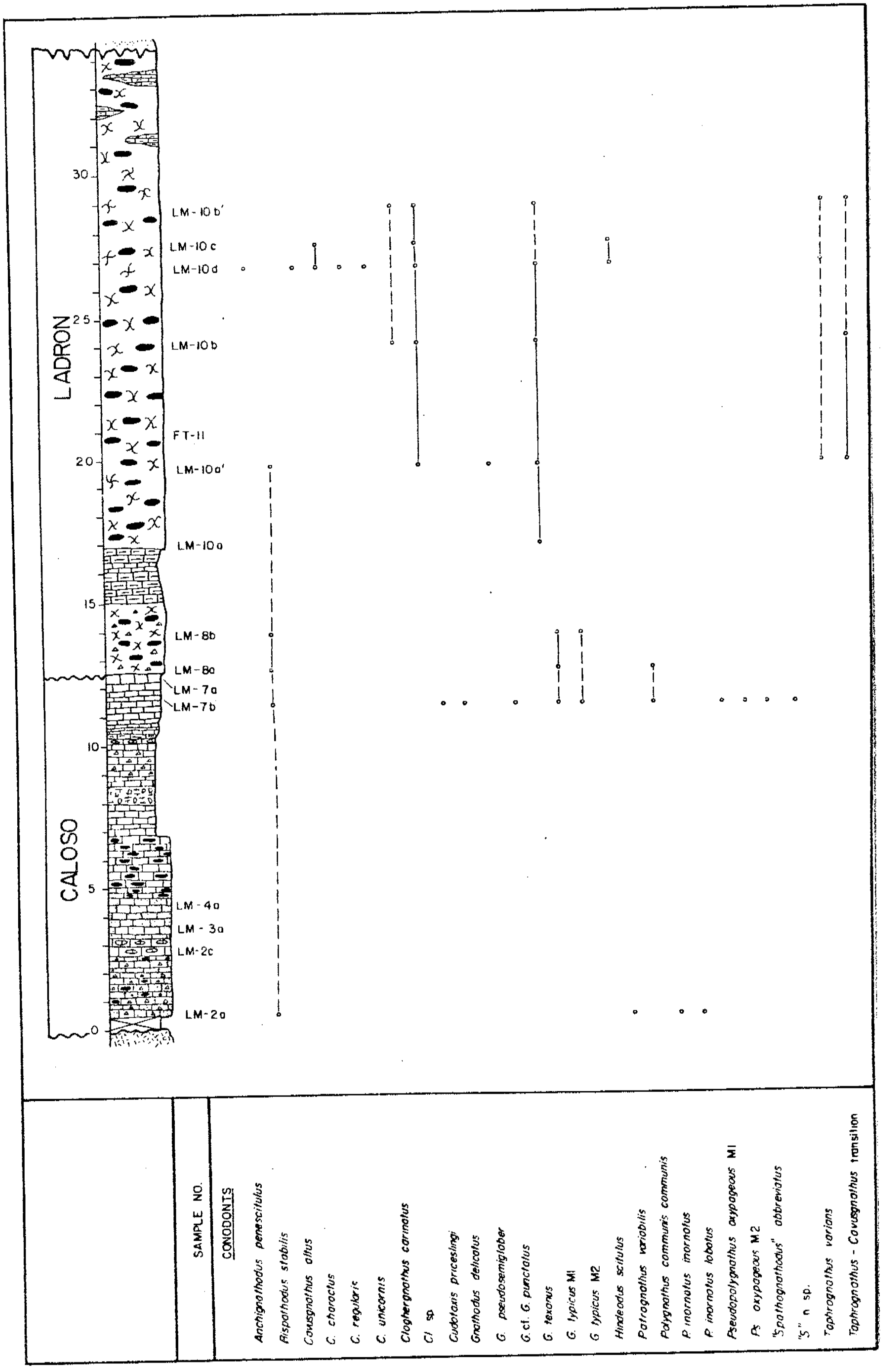
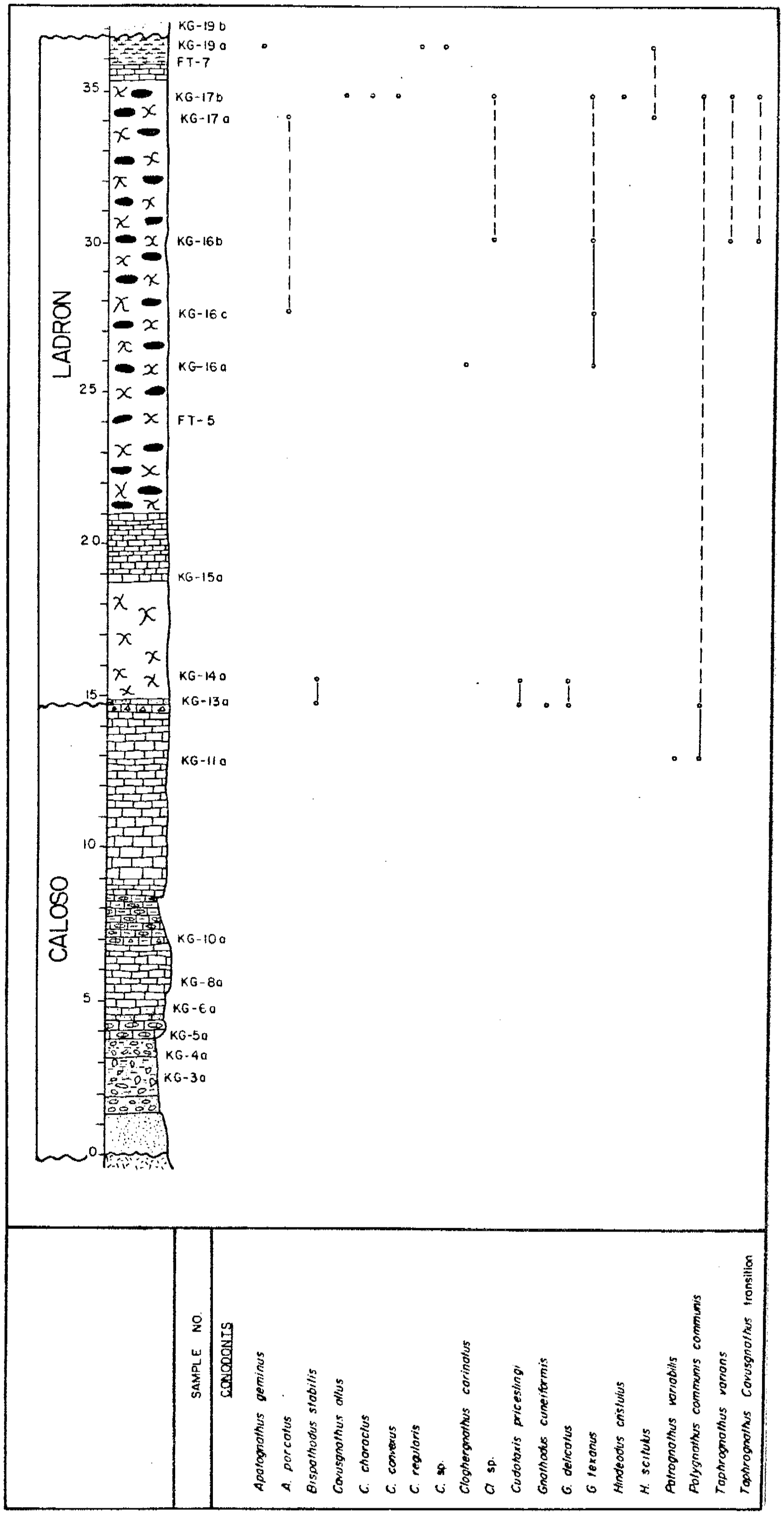

LADRON
CALOSO
0
5
10
15
20
25
30
LM-10b'
LM-10c
LM-10d
LM-10b
FT-11
LM-10a'
LM-10a
LM-8b
LM-8a
LM-7a
LM-7b
LM-4a
LM-3a
LM-2c
LM-2a
SAMPLE NO.
CONODONTS
Anchignathodus penescitulus
Rispathodus stabilis
Cavusgnathus altus
C. charactus
C. regularis
C. unicornis
Cloghergnathus carinatus
Cl sp.
Cudotaxis pricesingi
Gnathodus delicatus
G. pseudosemiglaber
G. cf. G. punctatus
G. texanus
G. typicus M1
G typicus M2
Hindeodus scitulus
Patrognathus variabilis
Polygnathus communis communis
P. inornatus inornatus
P. inornatus lobatus
Pseudopolygnathus oxypageous M1
Ps. oxypageous M2
"Spathognathodus" abbreviatus
"S" n. sp.
Taphrognathus varians
Taphrognathus - Cavusgnathus transition

Figure 18. Range chart illustrating conodont distribution for North Peak section. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.


LADRON
CALOSO
0
5
10
15
20
25
30
35
KG-19 b
KG-19 a
FT-7
KG-17b
KG-17 a
KG-16b
KG-16 c
KG-16 a
FT-5
KG-15a
KG-14 a
KG-13a
KG-11 a
KG-10 a
KG-8a
KG-6 a
KG-5a
KG-4a
KG-3a
SAMPLE NO.
CONODONTS
Apatognathus geminus
A. porcatus
Bispathodus stabilis
Cavusgnathus altus
C. charactus
C. convexus
C. regularis
C. sp.
Cloghergnathus carinatus
Cl sp.
Cudotaxis pricelingi
Gnathodus cuneiformis
G. delicatus
G texanus
Hindeodus cristulus
H. scitulus
Patrognathus variabilis
Polygnathus communis communis
Taphrognathus varians
Taphrognathus Cavusgnathus transition

upper crinoidal unit. Important conodonts recovered from the lower crinoidal unit at Chihuahua Gulch include the following:

Gnathodus delicatus
Polygnathus communis communis
Spathognathodus linguiferis
Spathognathodus n. sp.
Polygnathus cf. *P. bischoffi*
Protognathodus praedelicatus
Pseudopolygnathus oxypageous Morphotype 1

At North Peak the lower crinoidal unit yielded the conodonts listed below.

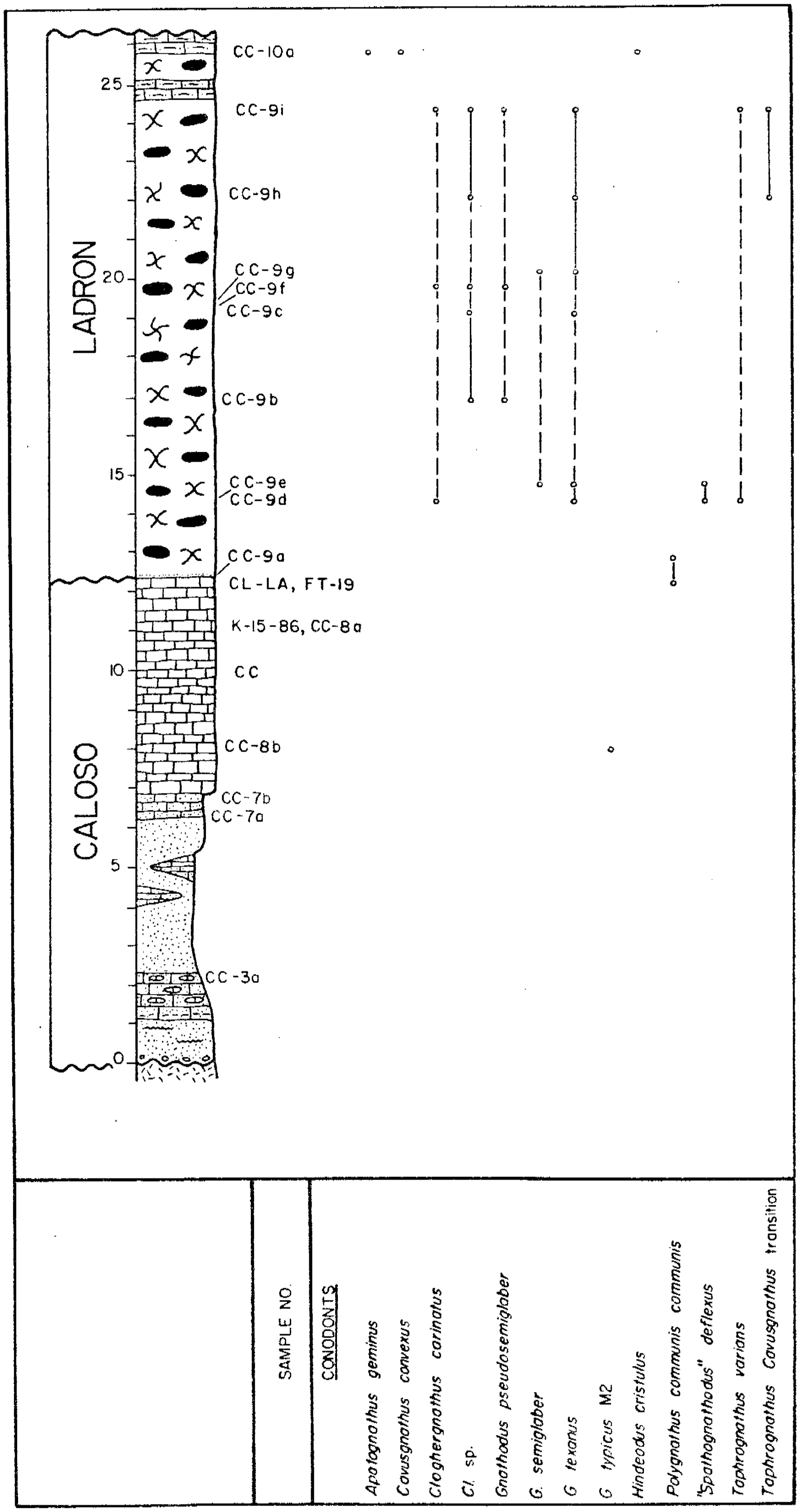
Gnathodus cuneiformis
Gnathodus delicatus
Bispathodus stabilis
Polygnathus communis communis
Spathognathodus linguiferis

The following is a list of important conodonts recovered from the lower crinoidal unit of the Ladron Member at Corkscrew Canyon.

Gnathodus typicus Morphotypes 1 and 2
Gnathodus delicatus
Bispathodus stabilis
Polygnathus communis communis

At Chihuahua Gulch, North Peak and Corkscrew Canyon, the upper crinoidal unit is situated above the dolomitic mudstone unit. In the Cerro de Colorado section (Figure 19)

Figure 19. Range chart illustrating conodont distribution for Cerro de Colorado section. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.


LADRON
CALOSO
25
20
15
10
5
0
CC-10a
CC-9i
CC-9h
CC-9g
CC-9f
CC-9c
CC-9b
CC-9e
CC-9d
CC-9a
CL-LA, FT-19
K-15-86, CC-8a
CC
CC-8b
CC-7b
CC-7a
CC-3a
SAMPLE NO.
CONODONTS
Apatognathus geminus
Cavusgnathus convexus
Cloghergnathus carinatus
Cl. sp.
Gnathodus pseudosemiglaber
G. semiglaber
G. texanus
G. typicus M2
Hindeodus cristulus
Polygnathus communis communis
"Spathognathodus" deflexus
Taphrognathus varians
Taphrognathus Cavusgnathus transition

the upper crinoidal unit actually begins at the Caloso Member - Ladron Member contact. The first appearance of *Gnathodus texanus* in the Ladron occurs in the crinoidal unit above the dolomitic mudstone unit. Other important conodonts in the upper crinoidal unit include the following:

Polygnathus communis communis
Gnathodus semiglaber
Gnathodus pseudosemiglaber
Taphrognathus varians
Cloghergnathus carinatus
Taphrognathus - *Cavusgnathus* transition
Hindeodus scitulus
Hinedodus cristulus
Cavusgnathus charactus
Cavusgnathus regularis
Cavusgnathus convexis
Cavusgnathus unicornis

See Figures 16, 17, 18, and 19 for distributions of these conodonts in each of the measured sections.

In the Corkscrew Canyon and North Peak stratigraphic sections, the first appearance of the genus *Cavusgnathus* occurs in the Kelly Limestone just below the bryozoan-crinoidal unit in the upper crinoidal unit. These first occurrences happen about 4 m below the bryozoan-crinoidal unit at Corkscrew Canyon (Figure 17). At North Peak *Cavusgnathus* first occurs less than 1 m below the bryozoan-crinoidal unit (Figure 15). Specimens of *Cavusgnathus* were recovered from the bryozoan-crinoidal unit at both North Peak and Cerro de Colorado. Other conodonts occurring with *Cavusgnathus* are *Hindeodus cristulus*, *Hindeodus scitulus*, *Cloghergnathus carinatus*, *Cloghergnathus* sp., *Taphrognathus* - *Cavusgnathus* transition, *Taphrognathus varians*, and *Apatognathus* spp.

Foraminifer Biostratigraphy

Approximately 100 thin sections were prepared for this study to obtain foraminifer specimens. Dr. Paul L. Brenckle of Amoco Production Company, Research Center, Tulsa, Oklahoma identified calcareous microfossils from about 35 of these thin sections. A comprehensive list of these fossils is presented in Appendix III, p. 306. Figures 20, 21, and 22 are graphic representations of the occurrences and stratigraphic ranges of this microfossil fauna for the Corkscrew Canyon, Cerro de Colorado, and North Peak stratigraphic sections, respectively.

Caloso Member. The Caloso Member produced calcareous microfossils from the stratigraphic sections at Corkscrew Canyon and Cerro de Colorado. At Corkscrew Canyon (Figure 20) in the upper 3 m of the wackestone and packstone unit, the crinoidal grainstone which produced conodont elements also yielded the following microfossils.

indeterminate multilocular foraminifer

indeterminate Aoujgaliaceae

Figure 20. Range chart illustrating foraminifer distribution for Corkscrew Canyon section. Xs represent specimens which are indeterminate. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.

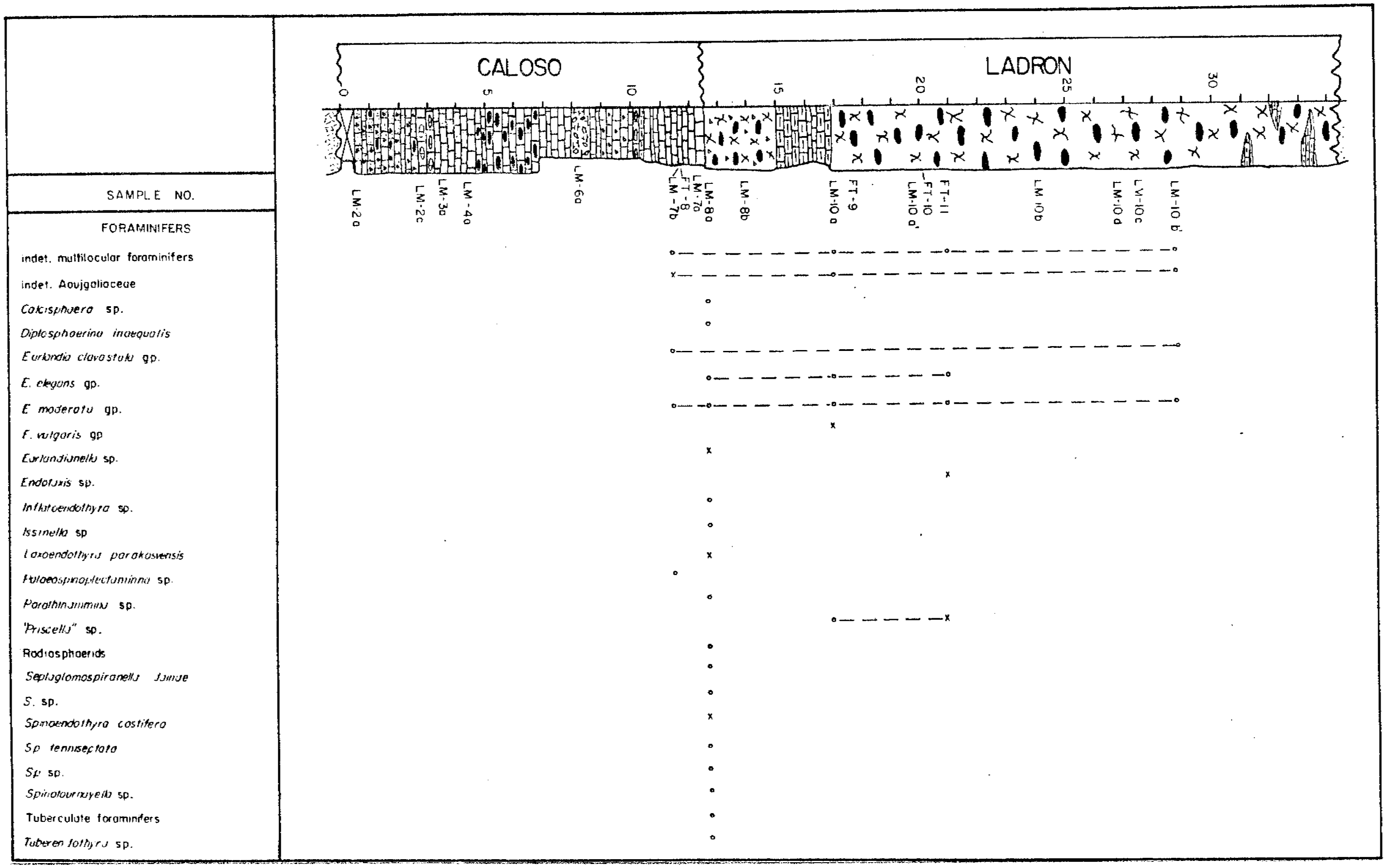

CALOSO
LADRON
0
5
10
15
20
25
30
LM-2a
LM-2c
LM-3a
LM-4a
LM-6a
LM-7b
FT-8
LM-7a
LM-8a
LM-8b
LM-10a
FT-9
LM-10 a'
FT-10
FT-11
LM 10b
LM-10d
LM-10c
LM-10 b'
SAMPLE NO.
FORAMINIFERS
indet. multilocular foraminifers
indet. Aoujgaliaceae
Calcisphaera sp.
Diplosphaerina inaequalis
Earlandia clavatula gp.
E. elegans gp.
E. moderata gp.
E. vulgaris gp
Earlandinella sp.
Endotaxis sp.
Inflatoendothyra sp.
Issinella sp
Laxoendothyra parakosvensis
Palaeospiroplectammina sp.
Parathurammina sp.
'Priscella" sp.
Radiosphaerids
Septaglomospiranella dainae
S. sp.
Spinoendothyra costifera
Sp. tenuiseptata
Sp. sp.
Spinotournayella sp.
Tuberculate foraminifers
Tuberendothyra sp.

Figure 21. Range chart illustrating foraminifer distribution for Cerro de Colorado section. Xs represent specimens which are indeterminate. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.

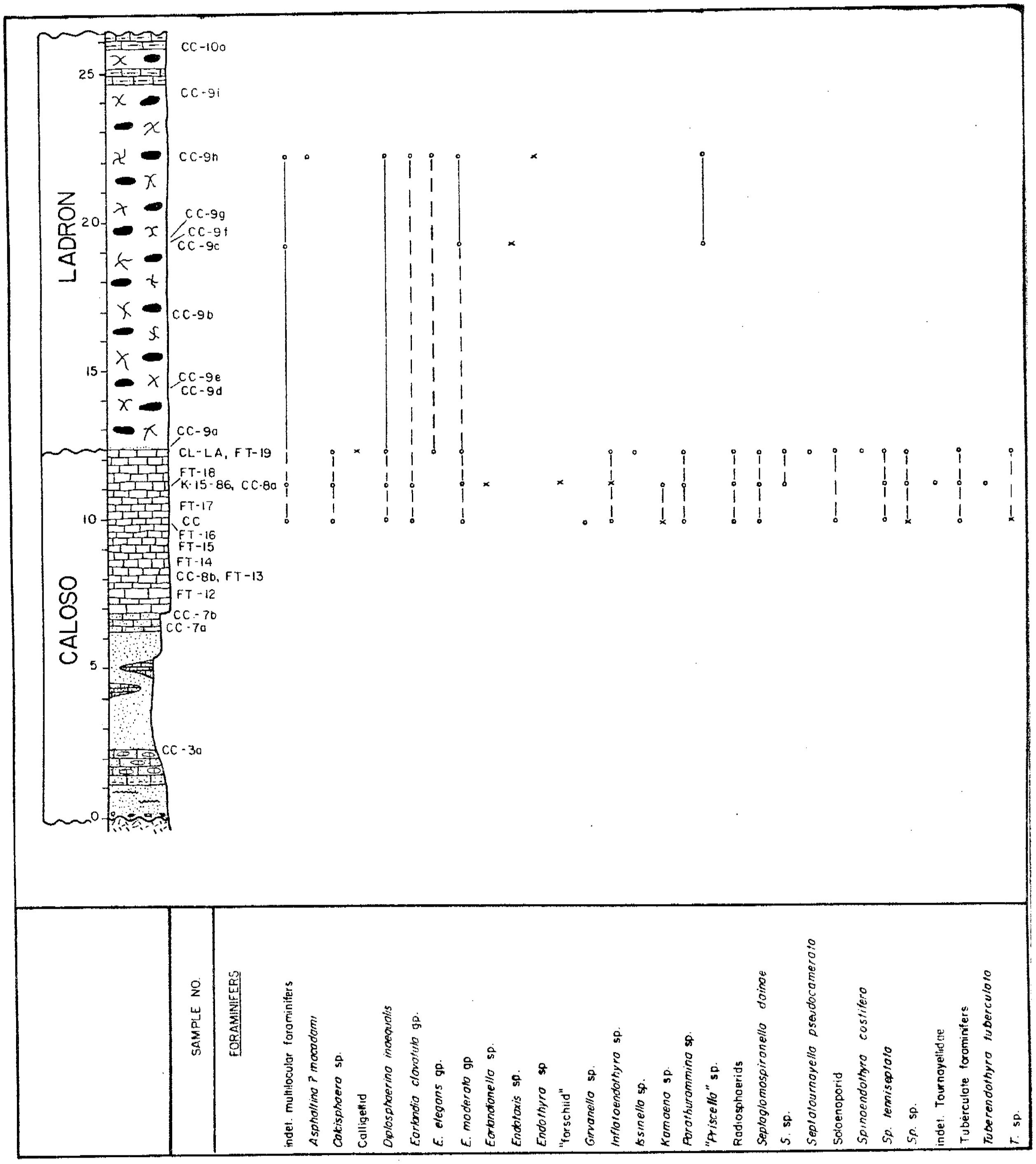
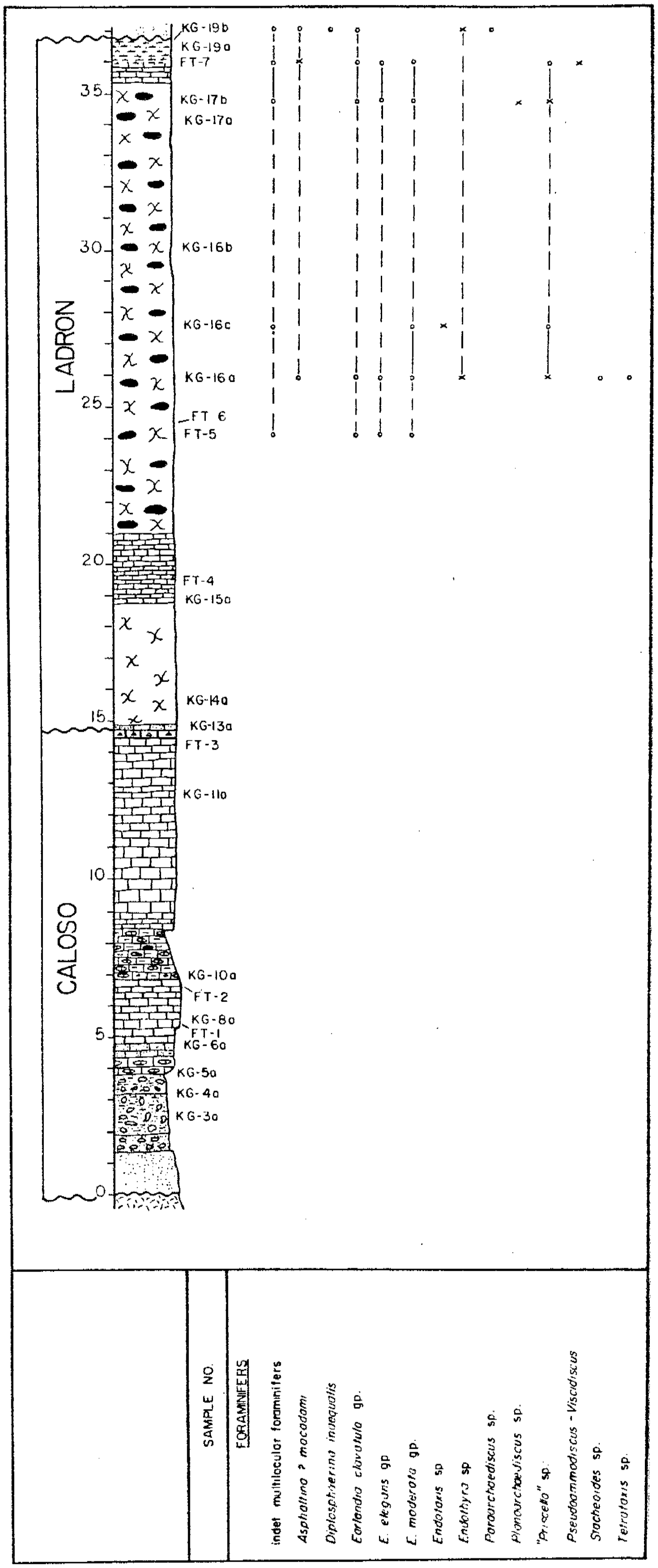

LADRON
CALOSO
25
20
15
10
5
0
CC-10a
CC-9i
CC-9h
CC-9g
CC-9f
CC-9c
CC-9b
CC-9e
CC-9d
CC-9a
CL-LA, FT-19
FT-18
K-15-86, CC-8a
FT-17
CC
FT-16
FT-15
FT-14
CC-8b, FT-13
FT-12
CC-7b
CC-7a
CC-3a
SAMPLE NO.
FORAMINIFERS
indet. multilocular foraminifers
Asphaltina ? macadami
Calcisphaera sp.
Calligelid
Diplosphaerina inaequalis
Earlandia clavatula gp.
E. elegans gp.
E. moderata gp
Earlandonella sp.
Endotaxis sp.
Endothyra sp
"forschiid"
Girvanella sp.
Inflatoendothyra sp.
Issinella sp.
Kamaena sp.
Parathurammina sp.
"Priscella" sp.
Radiosphaerids
Septaglomospiranella dainae
S. sp.
Septatournayella pseudocamerata
Solenoporid
Spinoendothyra costifera
Sp. tenuiseptata
Sp. sp.
indet. Tournayellidae
Tuberculate foraminifers
Tuberendothyra tuberculata
T. sp.

Figure 22. Range chart illustrating foraminifer for North Peak section. Xs represent specimens which are indeterminate. Solid lines indicate continuous occurrence from one sample to the next for a particular taxon. Dashed lines indicate barren sample intervals for a particular taxon.


LADRON
CALOSO
0
5
10
15
20
25
30
35
KG-19b
KG-19a
FT-7
KG-17b
KG-17a
KG-16b
KG-16c
KG-16a
FT 6
FT-5
FT-4
KG-15a
KG-14a
KG-13a
FT-3
KG-11a
KG-10a
FT-2
KG-8a
FT-1
KG-6a
KG-5a
KG-4a
KG-3a
SAMPLE NO.
FORAMINIFERS
indet. multilocular foraminifers
Asphaltina ? macadami
Diplosphaerina inaequalis
Earlandia clavatula gp.
E. elegans gp.
E. moderata gp.
Endotaxis sp.
Endothyra sp.
Paraarchaediscus sp.
Planoarchaediscus sp.
"Priscella" sp.
Pseudoammodiscus - Viscidiscus
Stacheoides sp.
Tetrataxis sp.

Earlandia clavatula gp.
Earlandia moderata gp.
Palaeospiroplectammina sp.

At Cerro de Colorado, the uppermost 5.5 m of the Caloso wackestone and packstone unit (Figure 21) yielded the calcareous microfossils listed below.

indeterminate multilocular foraminifer
Calcisphaera sp.
Calligellid
Diplosphaerina inequalis
Earlandia clavatula gp.
Earlandia elegans gp.
Earlandia moderata gp.
Earlandianella sp.
"forschiid"
Girvanella sp.
Inflatoendothyra sp.
Issinella sp.
Kamaena sp.
Parathurammina sp.
Radiosphaerids
Septaglomospiranella sp.
Septaglomospiranella dainae
Septatournayella pseudocamerata
Soloenoporid
Spinoendothyra sp.
Spinoendothyra costifera

Spinoendothyra _tenniseptata_
indeterminate Tournayellidae
Tuberendothyra sp.
Tuberendothyra _tuberculata_
Tuberculate foraminifer

These Caloso foraminifer faunas are very similar to those reported by Armstrong and Mamet (1976). Based on this new foraminifer data, the upper Caloso should lie within Mamet Zones 8 and/or 9. _Spinoendothyra_ _costifera_, whose first occurrence marks the base of Mamet Zone 9, was found in the uppermost few centimeters of the wackestone and packstone unit of the Caloso at Cerro de Colorado (Figure 21).

Ladron _Member_. Calcareous microfossils were retrieved from the Ladron Member at Corkscrew Canyon (Figure 20), Cerro de Colorado (Figure 21), and North Peak (Figure 22). Directly above the Caloso Member-Ladron Member contact the first appearance of foraminifers in the Ladron occurs within the very lowermost arenaceous lime mudstone to quartz sandstone in the lower crinoidal unit (Figure 20). The following is a list of the calcareous microfossils found at this stratigraphic level at Corkscrew Canyon.

Calcisphaera sp.
Diplosphaerina _inequalis_
Earlandia _elegans_ gp.
Earlandia _moderata_ gp.
Earlandianella sp.
Inflatoendothyra sp.

Issinella sp.

Laxoendothyra parakosvensis gp. (*Latiendothyra* of Mamet)

Parathurammina sp.

Radiosphaerids

Septaglomospiranella sp.

Septaglomospiranella dainae

Spinoendothyra sp.

Spinoendothyra costifera

Spinoendothyra tenniseptata

Spinotournayella sp.

Tuberculate foraminifer

Tuberendothyra sp.

These microfossils appear to be whole specimens, unbroken and/or abraded. They are similar to those reported from the lowermost Ladron at Cerro de Colorado by Armstrong and Mamet (1976). These fossils suggest Mamet Zones 8 and/or 9, but because *Spinoendothyra costifera* occurs in the Caloso immediately below, this assemblage should be no older than Mamet Zone 9. It is be noted that this foraminifer fauna was retrieved from arenaceous lime mudstones to quartz arenites whose sand grains are typically very coarse and well rounded.

The upper crinoidal unit and bryozoan-crinoidal unit of the Ladron Member yielded foraminifers from the outcrops at North Peak, Corkscrew Canyon, and Cerro de Colorado (Figures 22, 20, and 21). Because of the nature of these units (principally crinoidal and crinoidal-bryozoan grainstones) foraminifers are rare. The following calcareous microfossils are produced from the upper Ladron.

indeterminate multilocular foraminifer
indeterminate Aoujgaliaceae
Asphaltina ? *macadami*
Diplosphaerina inaequalis
Earlandia clavatula gp.
Earlandia elegans gp.
Earlandia moderata gp.
Earlandia vulgaris gp.
Endotaxis sp.
Endothyra sp.
Paraarchaediscus sp.
Planoarchaediscus sp.
"*Priscella*" sp.
Pseudoammodiscus - *Viscidiscus*
Stacheoides sp.
Tetrataxis sp.

This microfossil fauna is similar to the fauna listed in Armstrong and Mamet (1976).

Previous Biostratigraphy of the Kelly Limestone

Armstrong (1955) first interpreted brachiopod faunas of the Caloso Member as Kinderhookian; the Ladron Member as early Osagean. Subsequently he interpreted the Caloso brachiopod fauna as Kinderhookian to lower Osagean; the Ladron was assigned as upper Osagean based on brachiopods and blastoids (Armstrong, 1958b). In the Ladron Member the following fossil taxa were described by Armstrong (1958b).

Brachiopoda

- *Rhipidomella* sp.
- *Linoproductus* sp.
- *Chonetes* cf. *illinoisensis* Worthen
- *Tetracamera* cf. *subtrigona* (Meek and Worthen)
- *Tetracamera* *subcuneata* (Hall)
- *Rhynchopora* *persinuata* (Winchell)
- *Spirifer* *tennicostatus* Hall
- *Spirifer* *grimesi* Hall
- *Brachythyris* *suborbicularis* (Hall)
- *Athyris* aff. *lamellosa* (Leveille)
- *Cleiothyridina* *hirsuta* (Hall)
- *Cleiothyridina* *obmaxima* (McChesney)
- *Dimegelasma* *neglectum* (Hall)

Blastoidea

- *Pentremites* *conoideus* Hall

Coelenterata

- *Zaphriphyllum* *casteri* Armstrong

With the addition of foraminifer data (the occurrence of *Plectogyra* sp. in the Kelly) the Ladron was correlated to the Keokuk Limestone of the Midcontinent (Armstrong, 1958a). Armstrong (1962, 1963 and 1967) reassigned the Caloso to a lower Osagean (Fern Glen Limestone) age based on the same previous brachiopods listed above. He also assigned the Ladron to the upper Osagean (upper Burlington Limestone - Keokuk Limestone). This assignment was based in part on the blastoid *Pentremites conoideus* even though it is primarily a Meramecian fossil (Armstrong, 1962, p. 12). Specimens of *P. conoideus* were found in the highest beds of fine crystalline limestone in the Ladron (Armstrong, 1958b). Armstrong (1962 and 1963) believed the Caloso - Ladron disconformity represented time in the middle Osagean (lower Burlington and part of Fern Glen).

Armstrong and Mamet (1976 and 1977a) reexamined the calcareous microfauna of the Kelly Limestone. Armstrong and Mamet (1976) recognized the following calcareous microfossils in the Caloso Member type section, 8.5-11.6 m above the Precambrian-Mississippian contact (wackestone and packstone unit of the Cerro de Colorado section herein).

Calcisphaera sp.
Calcisphaera laevis Williamson
Earlandia sp.
Kamaena sp.
Kamaena of the group *K. delicata* Antropov
Medioendothyra sp.
Latiendothyra sp.
Palaeoberesella sp.
Parathurammina sp.
Proninella sp.
Septabrunsiina sp.

Septabrunsiina parakrainica Skipp, Holcomb, and Gutschick

Septaglomospiranella sp.

Septaglomospiranella dainae Lipina

Septatournayella sp.

Tuberendothyra sp.

Tuberendothyra safanovae Skipp in McKee and Gutschick

Tuberendothyra tuberculata (Chernysheva)

Armstrong and Mamet (1976 and 1977a) reported that Mamet examined a single thin section from the upper Caloso (wackestone and packstone unit) containing a foraminifer fauna composed mostly of the endothyrids Latiendothyra, Medioendothyra, and Tuberendothyra. Based on this foraminifer collection, they (Armstrong and Mamet, 1976, p. 19) interpreted the Caloso Member foraminifer assemblage as Mamet Zone 8 (upper Osagean; early late Tournaisian).

The lowest part of the Ladron Member, i.e. the arenaceous lime mudstone to quartz sandstone (12 m above the Precambrian-Mississippian contact at the Cerro de Colorado section) directly above the Caloso Member - Ladron Member contact (lower crinoidal unit), is reported by Armstrong and Mamet (1976) to contain the following calcareous microfossils.

Calcisphaera sp.

Calcisphaera laevis Williamson

Earlandia of the group E. elegans (Rauzer - Chernoussova)

Earlandia of the group E. clavatula (Howchin)
  cf. Earlandinella? sp.
Kamaena sp.
Latiendothyra sp.
Latiendothyra of the group L. latispiralis (Lipina)
Latiendothyra parakosvensis (Lipina)
Palaeoberesella sp.
Parathurammina sp.
Proninella sp.
Pseudokamaena sp.
Septabrunsiina sp.
Septaglomospiranella dainae Lipina
Spinoendothyra sp.
Spinoendothyra spinosa (Chernysheva)
Tuberendothyra sp.
Tuberendothyra aff. T. tuberculata (Chernysheva)
Vicinesphaera sp.

This lowermost Ladron (lower crinoidal unit herein) yielded a Mamet Zone 8-9 transitional foraminifer fauna according to Armstrong and Mamet (1976 and 1977a); a late Tournaisian (upper Osagean) age.

Higher in the section, at 12-23.5 m above the Precambrian-Mississippian nonconformity (upper crinoidal unit to bryozoan-crinoidal unit), Armstrong and Mamet (1976) listed the following microfossils from the Ladron Member at Cerro de Colorado.

Calcisphaera sp.
Calcisphaera laevis Williamson
Earlandia sp.
Earlandia clavatula (Howchin)
Latiendothyra sp.
Priscella sp.
Priscella prisca (Rauzer - Chernoussova and Reitlinger)
Pseudotaxis sp.
Septaglomospiranella dainae Lipina
Tetrataxis sp.

Armstrong and Mamet (1976 and 1977a) reported the Ladron Member foraminifers as Mamet Zone 9 (upper Osagean; late Tournaisian age) based on the "first occurrences" of *Priscella*, *Pseudotaxis*, and *Tetrataxis*. These foraminifers were found just below or at the lowermost bryozoan-crinoidal unit in the Cerro de Colorado section. Armstrong and Mamet (1976 and 1977a) considered the only occurrence of these specimens in the Ladron as first occurrences with respect to their range zones. This is a potentially faulty assumption.

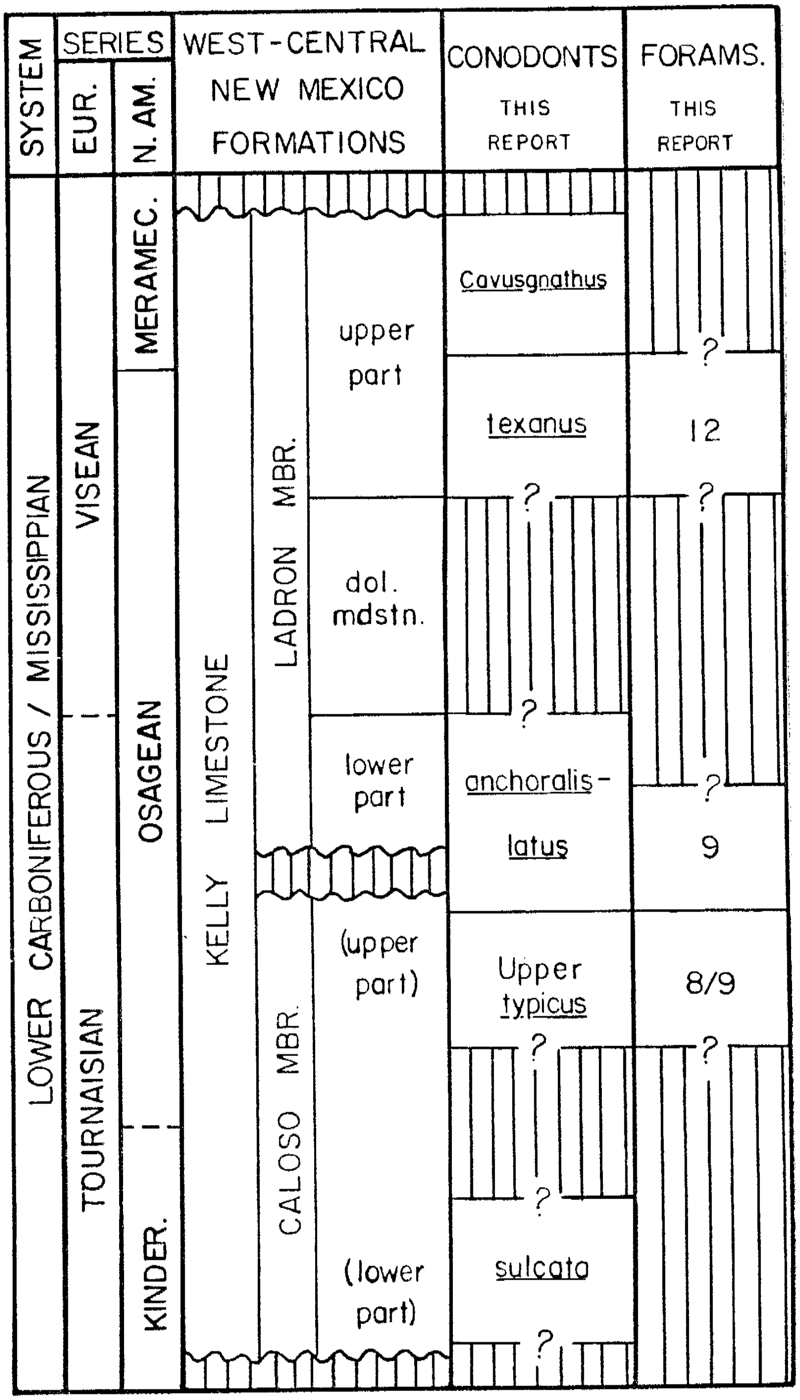
Results

Earlier works by Armstrong (1955, 1958b, 1962, 1963 and 1967), Armstrong and Mamet (1976, 1977a and 1979), and Armstrong *et al*. (1979 and 1980) had assigned the Kelly Limestone an Osagean age. Conodonts recovered from the lowermost silty lime mudstone unit of the Caloso Member, however, did not resemble conodonts from the Lake Valley Formation (Osagean) described by Carman (1987). These lowermost limestones of the Caloso contained an early Kinderhookian conodont fauna (see Figure 23) from the upper *Siphonodella sulcata* Zone (*Bispathodus aculeatus plumulus*, *Patrognathus variabilis*, *Polygnathus inornatus inornatus*, and *Polygnathus inornatus lobatus*).

The last occurrence of *B. aculeatus plumulus* in North America is the *Siphonodella sulcata* Zone (Ziegler in Ziegler, 1975) which defines the base of the Mississippian (Kinderhookian). Sandberg (personal communication, 1990) places the last occurrence of *B. a. plumulus* in the *Siphonodella sandbergi* Zone. In the United Kingdom, however, Varker and Sevastopulo (1985, table 6, p. 250-251) show *B. a. plumulus* occurring above the *Siphonodella* Zone. *Polygnathus inornatus* is found in the Lower Carboniferous (Kinderhookian) of North America (Klapper in Ziegler, 1975). *Patrognathus variabilis* is also a Kinderhookian form.

The uppermost Caloso Member at Corkscrew Canyon lies within the interval of the Upper *typicus* Zone to the lower *anchoralis*-*latus* Zone (Figure 23). This indicates an early Osagean age for the upper Caloso at Corkscrew Canyon (Figure 23). Figure 5 (p. 24-25 herein) shows that *Pseudopolygnathus oxypageous* ranges from the base of the Upper *typicus* Zone to the middle *anchoralis*-*latus* Zone. Also, the last appearance of *Gnathodus typicus* M1 is in the lower half of the Upper *typicus* Zone, while *G. typicus* M2

Figure 23. Stratigraphic chart showing conodont and foraminifer occurrences for the Kelly Limestone. Chronostratigraphic assignments are based on standard conodont zonations as presented in Figure 6 herein, and the "adjusted zones" of Baxter and Brenckle (1982).


SYSTEM
SERIES
EUR.
N. AM.
WEST-CENTRAL NEW MEXICO FORMATIONS
CONODONTS THIS REPORT
FORAMS. THIS REPORT
LOWER CARBONIFEROUS / MISSISSIPPIAN
VISEAN
TOURNAISIAN
MERAMEC.
OSAGEAN
KINDER.
KELLY LIMESTONE
LADRON MBR.
CALOSO MBR.
upper part
dol. mdstn.
lower part
(upper part)
(lower part)
Cavusgnathus
texanus
anchoralis-latus
Upper typicus
sulcata
?
12
9
8/9

ranges up through the anchoralis-latus Zone. Gnathodus delicatus ranges from the Kinderhookian Siphonodella zones to its last appearance in the middle anchoralis-latus Zone (Figure 5, p. 24-25 herein).

The lower crinoidal unit of the Ladron Member also has a conodont fauna of Upper typicus Zone to the middle anchoralis-latus Zone (Figure 23). Bispathodus stabilis and Polygnathus communis communis are long-ranging species. Gnathodus cuneiformis and Gnathodus typicus M2 have almost identical ranges from the Lower typicus Zone through the anchoralis-latus Zone (Figure 5 herein, p. 24-25). The conodonts Protognathodus praedelicatus, Gnathodus delicatus, and Pseudopolygnathus oxypageous range up into the middle anchoralis-latus Zone. A lower limit for this stratigraphic interval, is the first occurrence of Ps. oxypageous at the base of the Upper typicus Zone (Figure 5 herein, p. 24-25). The last appearance of G. typicus M1 is documented as the lower half of the Upper typicus Zone. These indicate an early Osagean age for the lower crinoidal unit (Figure 21).

Conodont taxa (Gnathodus texanus, Cloghergnathus, "Spathognathodus" deflexus, and Taphrognathus varians) from the upper crinoidal unit of the Ladron Member indicate an upper texanus Zone (late Osagean). (See Figure 19). First occurrences of Cloghergnathus and T. varians are nearly coincidental with G. texanus (Figure 5 herein, p. 24-25). The gnathodids Gnathodus semiglaber and Gnathodus pseudosemiglaber first appear in the isosticha-Upper crenulata Zone and the middle anchoralis-latus Zone, respectively. Their uppermost occurrences range through and beyond the texanus Zone and the unzoned interval of Lane et al. (1980). (See Figure 5 herein, p. 24-25).

At Corkscrew Canyon (Figure 17) and North Peak (Figure 18) the first appearance of Cavusgnathus in the Kelly Limestone, occurs in the upper crinoidal unit of the Ladron Member, just below the bryozoan-crinoidal unit. Specimens of Cavusgnathus also were recovered from the bryozoan-crinoidal unit at both North Peak (Figure 18) and Cerro de Colorado (Figure 19). The first occurrence of Cavusgnathus defines the base of the unzoned interval of Lane et al., (1980), and FU 8 of Lane (1974 and 1978) and Lane and Ormiston (1982). (See Figure 6 herein, p. 26-27). According to Sando (1985), a fauna (Cavusgnathus spp., Hindeodus cristulus, Hindeodus scitulus, Cloghergnathus spp., Taphrognathus-Cavusgnathus transition, Taphrognathus varians, and Apatognathus spp.) similar to that found in the uppermost Kelly (bryozoan-crinoidal unit), can be no older than Meramecian (Figure 21).

Armstrong (1963) suggested a possible lower Meramecian age for the uppermost Kelly Limestone based on blastoid (Pentremites. conoideus), brachiopod and coral faunas. Armstrong and Mamet (1976 and 1977a), however, assigned the uppermost Kelly to the late Osagean despite Armstrong's earlier suggestion. The conodont assemblage from the upper Ladron bears little resemblance to that found in the Lake

Valley Formation (Osagean) described by Carman (1987). This conodont fauna corresponds to conodont assemblages of Meramecian rocks in the midcontinent.

In the present investigation the sample intervals of Armstrong and Mamet (1976 and 1977a) were reexamined and resampled for foraminifers. Foraminifer faunas reported herein are similar to those reported by Armstrong and Mamet (1976 and 1977a). The endothyrid *Medioendothyra* was not found in new collections. The occurrence of *Spinoendothyra costifera* discovered in the uppermost Caloso Member is significant, because its first appearance defines, in part, the base of Mamet Zone 9.

Most of the foraminifer taxa listed in works by Armstrong and Mamet (1976 and 1977a), and new collections herein, are long-ranging. The first occurrences of many of these foraminifers are in Mamet Zones 9 and 10, and their last occurrences are within Mamet Zone 16; some even ranging into younger zones. Age assignments made from either collection alone are tenuous. In addition, Armstrong and Mamet (1976 and 1977a) assumed that singular occurrences of particular foraminifers within the Kelly Limestone coincided with their first biozone appearances, *e.g.* the occurrences of *Priscella*, *Pseudotaxis* and *Tetrataxis* in the upper crinoidal unit of the Ladron Member.

The present study shows calcareous microfossils from the upper part of the Caloso Member are similar to those of the lowermost Ladron Member. The uppermost Caloso and lowermost Ladron foraminifer faunas are transitional between Mamet Zones 8 and 9. The fact that *Spinoendothyra costifera* was found in the uppermost Caloso in this investigation (Cerro de Colorado, Figure 21) indicates that the lowermost Ladron can be no older than Mamet Zone 9. Use of the Baxter and Brenckle (1982) "adjusted zones" in this report (Figure 8, p. 40-41 and Figure 9, p. 42-43) indicates an early Osagean age for the upper Caloso and lowermost Ladron (Figure 23).

Sand grains from the lowermost Ladron Member are typically very coarse and well rounded indicating a high energy environment capable of reworking and/or transporting these particles. The association with large sand grains, the proximity to the erosional contact surface, and the similarity with foraminifer faunas directly below, suggest that lowermost Ladron foraminifers were probably transported and redeposited. The absence of broken and/or abraded foraminifer specimens, however, may contradict this.

This investigation utilizes the new foraminifer data reported herein as well as those listed from Armstrong and Mamet (1976 and 1977a) due to the long-ranging nature of the taxa involved. This provides greater precision in determining foraminifer biozone associations, and in assigning age dates.

In the upper crinoidal unit of the Ladron Member, the overlapping range zones of *Laxoendothyra* sp. (*Latiendothyra* sp. of Mamet and Skipp, 1970 and 1971) and *Stacheoides* indicate Mamet Zone 12. The last appearance of _Laxoendothyra_ sp. coincides with the top of Mamet Zone 12. The first occurrence of _Stacheoides_ sp. coincides with the base of Mamet Zone 12 according to Mamet and Skipp (1970 and 1971). This assignment may be tenuous because _Stacheoides_ is known to appear earlier, as low as Mamet Zone 9 (Brenckle, oral personal communication, 1988). Using the "adjusted zones" (Figure 8, p. 40-41 and Figure 9, p. 42-43) of Baxter and Brenckle (1982), the upper crinoidal unit and bryozoan-crinoidal unit is an early Meramecian age (Figure 23).

IX. CONODONT PALEOECOLOGY

Anomalous patterns of conodont distribution became apparent from studies in the 1960s and 1970s, and were increasingly attributed to the influence of facies. Facies control models by Druce (1970 and 1973), Seddon and Sweet (1971), Barnes *et al*.(1973), Barnes and Fahraeus (1975), Austin (1976), and Klapper and Barrick (1978), expounded the earlier ideas of Shaw (1964) and Irwin (1965) in the application of their ideas to conodont biostratigraphy. These models were based on both depth-stratification and proximity to shore. Austin and Davies (1984) considered sedimentological implications in relating sediment types and conodont genera, and applied knowledge of environments of deposition of modern sediments to conodont distribution patterns. Sandberg and Gutschick (1979, 1980 and 1984), Sandberg in Lane *et al*. (1980), and Gutschick and Sandberg (1983) have suggested a biofacies model for Lower Carboniferous conodont distribution from deep basin to shoreline.

Sandberg in Lane *et al*. (1980) summarized and updated the biofacies of Sandberg and Gutschick (1979). This is particularly pertinent to the upper part of the Caloso Member and lower and upper crinoidal units of the Ladron Member (Upper *typicus*, lower *anchoralis*-*latus*, and *texanus* Zones, respectively). *Polygnathus communis communis* is ubiquitous and interpreted to have lived at shallow depths (photic zone according to Sandberg). *Gnathodus* and *Pseudopolygnathus* lived in the lower part of the aerobic zone and were probably nektobenthic. They are absent from far offshore hemipelagic sediments of the deep starved basin. Their occurrence extends landward onto the carbonate platform. *Bispathodus stabilis* and "*Anchignathodus*" *penescitulus* also lived in shallow depths (photic zone according to Sandberg), however, *B. stabilis* favored offshore, pelagic settings and it becomes more abundant seaward. "*Anchignathodus*" *penescitulus* becomes more abundant landward. *Bactrognathus* was a nektonic slope dweller (Sandberg and Gutschick, 1984). According to Sandberg, conodont abundances were greatest on the foreslope where upwelling provided maximum aeration and food supply.

Austin (1976), Austin and Davies (1984), Varker and Sevastopulo (1985), and Armstrong and Purnell (1987) recognized *Cavusgnathus*, *Cloghergnathus*, and *Taphrognathus* as typical of shallow intertidal and shallow subtidal environments of deposition. They also agree that *Gnathodus* is representative of genera occurring in deeper-water environments. von Bitter (1976), however, reported these genera as probably having lived in the open sea, but under conditions of variable salinity. von Bitter (1976) also admits that it is possible that they inhabited shallow-water, high-energy environments of the inner shelf.

The biofacies models of Sandberg and Gutschick (1979, 1980 and 1984), Sandberg in Lane *et al*. (1980), and

Gutschick and Sandberg (1983) do not extend across the platform. Sedimentological processes have an important effect on conodont distributions across the platform. Shoaling grainstone banks, oolite shoals, or shoaling at the platform margin have a pronounced effect on water depth, local energy conditions, salinity, and presumably, the supply of nutrients. The inferences of Sandberg and Gutschick (1979, 1980 and 1984) concerning distribution of conodont elements within the aerobic or photic zones, therefore, is tentative, especially when the conodont organism, its function and affinities, are unknown (Austin and Davies, 1984). It was Austin and Davies (1984) contention that the relatively simple model of Klapper and Barrick (1978) be employed. This model suggested nearshore confinement of a limited number of species in rigorous, fluctuating hydrographic regimes, contrasted with diverse species associations in offshore, stable hydrographic regimes independent of either a neritic pelagic or a nektobenthic way of life, i.e. independent of distributional patterns alone.

The remains of both skeletal and soft body parts of an apparent conodont animal have been found. Subsequently, conodont function and affinities have been discussed by Briggs et al. (1983 and 1987), Aldridge et al. (1986), Aldridge (1987), and Aldridge and Briggs (1989).

Carbonate platforms are well developed through the British Dinantian. No single biozonation scheme is applicable throughout the British Isles as a result of strong environmental controls caused by shallow-water conditions (Varker and Sevastopulo, 1985). Despite these environmental controls in the shallow-marine depositional settings, Armstrong and Purnell (1987) established a biozonation for Great Britain based on the genera *Taphrognathus*, *Cloghergnathus*, and *Cavusgnathus* in the Northumberland Trough and Tweed Basin.

Lower parts of the Caloso Member contain the conodonts *Bispathodus* and *Patrognathus*, indicative of nearshore carbonate sediments (Rhodes *et al*., 1969; Butler, 1973; Gayer *et al*., 1973; Austin, 1976; Klapper and Barrick, 1978; Austin and Davies, 1984; Varker and Sevastopulo, 1985). Siphonodellid conodonts are rare in Tournaisian shelf limestones (Austin and Davies, 1984). No siphonodellids were recovered from the Kelly Limestone. In the basinal sequence of South West Province, England, all but one of the Sandberg *et al*. (1978) siphonodellid zones have been recognized; however, with the absence of siphonodellids in shallow-marine carbonate shelf sediments, conodont faunal assemblages must be utilized to determine lowermost Carboniferous biofacies (Varker and Sevastopulo, 1985). The occurrence of *Bispathodus aculeatus*, *Patrognathus variabilis*, and *Polygnathus inornatus* in the nearshore depositional environments of the Caloso, are similar to findings in England (Varker and Sevastopulo, 1985).

The crinoidal packstones and grainstones of the Kelly Limestone were interpreted by Armstrong (1963 and 1967) as indicating open-marine conditions with good circulation. Any inferences, based on present knowledge, regarding the offshore topographic profile, *i*.*e*. reference to either the platform margin (shelf edge) or foreslope, can only be speculation. Use of conodont faunas alone toward this end would be in error and would consist of circular reasoning.

In the upper part of the Caloso Member (Corkscrew Canyon section only), and lower crinoidal unit of the Ladron Member, the conodont fauna is dominated by *Polygnathus communis communis*. The appearance of the genera *Gnathodus* (*G*. *typicus*, *G*. *delicatus*, and *G*. *cuneiformis*) and *Pseudopolygnathus* (*Ps*. *oxypageous*) is noted. These two genera suggest depositional environments of relatively deeper-marine waters. Some mixing of faunas is expected in an open-marine environment. This is the case, *e*.*g*. "*Anchignathodus*" *penescitulus* (nearshore form) and *Bispathodus stabilis* (offshore form), for the crinoidal grainstones in this Caloso - Ladron interval.

Conodont faunas in the upper crinoidal unit and bryozoan-crinoidal unit of the Ladron Member include the following dominant form (Pa) elements: *Gnathodus texanus*, *Gnathodus semiglaber*, *Taphrognathus varians*, *Cloghergnathus* and *Cavusgnathus*. *Gnathodus texanus* is the most abundant form taxon in the upper crinoidal unit; even in the upper portions where shallow-water forms (*Taphrognathus* and

Cloghergnathus) occur. This is similar to the situation reported for Stackpole Quay in Great Britain (Austin and Davies, 1984). At Stackpole Quay, *G*. *texanus* also dominates, but form taxa (*Apatognathus* and *Mestognathus*) which are typical of nearshore environmental settings, also occur. The low diversity of faunas is consistent with the model of Klapper and Barrick (1978) in which a small group of conodont animals inhabit nearshore, less favorable environments.

Gnathodids predominate at the lower part of the upper crinoidal unit, suggesting the relative deeper waters of an open-marine depositional environment. The three genera *Taphrognathus*, *Cloghergnathus*, and *Cavusgnathus* increase in abundance progressively towards the uppermost upper crinoidal unit; and into the bryozoan-crinoidal unit as well. This corresponds to an increase in lime mud matrix, thinner bedding, smaller grain sizes, and the occurrence of abundant, whole fenestrate bryozoans in the uppermost Ladron Member. These suggest less agitation and/or less circulation of marine waters. It is in this relatively quieter environment of deposition that *Taphrognathus*, *Cloghergnathus*, and *Cavusgnathus* predominate.

X. DEPOSITIONAL ENVIRONMENT

The arenites in the clastic unit of the Caloso Member, contain abundant carbonate and feldspathic grains. These clasts range up to small boulder size, particularly in the Chihuahua Gulch and North Peak stratigraphic sections. Arenites and mudstones contain unweathered lithic fragments of Precambrian basement rocks. Singular large pebbles and cobbles of underlying Precambrian rock types also are observed in lime mudstones and wackestones in the lowermost silty lime mudstone unit. These indicate that sedimentary particles did not travel over long distances, and that the period of transport was of short duration.

Thin section examination of rocks from the silty lime mudstone unit reveals details not observed in the field, e.g. fenestral fabrics, alternating light and dark layers, and escalloped dark patches of micrite (see "Petrography of the Kelly Limestone," p. 77). Armstrong (1958 and 1967) and Armstrong and Mamet (1976, 1977a, 1978 and 1987) interpreted these as stromatolitic, and this is also suggested by the present investigation. Flugel (1982, p. 218) states that stromatolites occur preferentially in intertidal and supratidal environments.

In the uppermost Caloso Member (wackestone and packstone unit), the amount of siliclastic material gradually diminishes and bioclastic materials become more abundant towards the top. In the Magdalena Mountains sections, most bioclastic material in this interval is rounded. Towards the north, fossils such as bivalves, brachiopods, and ostracods are disarticulated, but many are not broken. In the northern sections at Corkscrew Canyon and Cerro de Colorado, this interval is rich in calcareous microfossils, especially foraminifers. In some thin sections, dolomitization is inferred by the presence of dolomite rhombs growing within a lime mud matrix and across carbonate grain boundaries. This dolomitization was a diagenetic feature; it definitely was not a primary depositional feature.

Two meters of arenaceous fossiliferous wackestone overly the clastic unit of the Caloso Member at Chupadera Peak. Above this are several meters of crinoidal grainstones and packstones (equivalent to the silty lime mudstone unit) overlain by fine to medium crystalline limestones and lime mudstones (wackestone and packstone unit). Parts of these limestones have been recrystallized and silicified. Tertiary lavas flowed over the Caloso and penetrated into joints and fractures. The presence of Tertiary dikes in the area, overlying Tertiary lava beds, and elevated conodont Color Alteration Indices (CAI), are circumstantial evidence for these alterations in which the original sedimentary fabric was destroyed. Laramide or Tertiary hydrothermal alteration may have been partially responsible. Alternatively, alteration may have been caused by the development of an unconformity at the base of the

Sandia Formation (Pennsylvanian), or the base of the Abo Formation (Permian), or both. The elevated CAI, however, together with the other evidence, make the unconformity theory less likely.

At Chupadera Peak, Chihuahua Gulch and Corkscrew Canyon, a _Siphonodella_ _sulcata_ Zone (lowest Kinderhookian) conodont fauna was recovered from arenaceous fossiliferous wackestones in the lowermost silty lime mudstone unit. This fauna is also present in overlying crinoidal grainstones and packstones in the Chupadera Peak section. At this biostratigraphic interval in measured sections to the north, the increased abundance of siliclastic material and lime mud, scarce faunas, and burrowed and mottled lime mudstones may indicate a nearshore environment of deposition. An increase in faunal diversity and abundance in these crinoidal grainstones at Chupadera Peak suggest a relatively deeper, marine, open shelf with good circulation. Disarticulated brachiopods and crinoid columnals as well as much fragmented fossil debris provide evidence for increased agitation (possibly wave action) of marine waters. Increased wave action could be responsible for winnowing out much of the finer mud particles. Modern examples are calcarenite shoals or calcarenite banks along the platform margins in the Bahama Banks (Wilson and Jordan, 1983). On the other hand, this does not rule out the possibility that grainstones are a result of transportation and redeposition of bioclasts (particularly crinoid fragments) in areas outside their original habitat.

Criteria for nearshore environments of deposition in the Caloso Member include the following: abundance of large feldspathic and carbonate grains from basement rocks underlying the Caloso; a suggested stromatolitic origin of lower Caloso limestones; a general scarcity of fossil faunas throughout the Caloso; abundance of foraminifers, peloids and mollusks in the uppermost Caloso wackestones and packstones; burrowed and mottled lime mudstones. No single criterion above necessarily indicates a nearshore depositional environment; rather these criteria must be used together. In the upper wackestone and packstone unit, most rock types in the Caloso of the Magdalena Mountains, most grains are well-rounded fossil fragments in a lime mud matrix indicating long periods of transportation and/or reworking of sediments. Armstrong (1955, 1958b, 1962 and 1963) used similar lines of evidence in interpreting the Caloso as a restricted shelf deposit.

The disconformity between the Caloso Member and Ladron Member is diachronous. The dolomitic mudstone unit and lower crinoidal unit of the Ladron are absent in the Cerro de Colorado section. Only the upper crinoidal unit is present, and has texanus - Cavusgnathus Zones conodont faunas. The upper anchoralis-latus Zone conodonts present elsewhere are missing from the lowermost Ladron at Cerro de Colorado.

The dolomitic mudstone unit is representative of a quiet nearshore depositional environment. It is an olive green, thinly laminated, unfossiliferous dolomitic lime mudstone. In thin section, angular to rounded silt grains are a conspicuous constituent. Armstrong interprets this interval as intertidal to supratidal deposits (oral personal communication, 1988).

The crinoidal unit of the Ladron Member contains an abundant and diverse fossil fauna of crinoids, conodonts, corals, brachiopods, and bryozoans as well as lesser amounts of gastropods, trilobites, fish teeth and foraminifers. According to Armstrong (1963) the poor sorting of bioclastic material (large spirifer brachiopods and large gastropods mixed with smaller crinoid fragments) indicates that the larger invertebrates were buried where they lived, and that, at best, crinoid debris was probably transported only a short distance after death. Also, the fauna indicates agitated water of normal marine salinity which probably was consistently in exchange with the open sea.

The uppermost few meters of the Ladron Member (bryozoan-crinoidal unit) becomes finer-grained and thinner-bedded. The amount of lime mud matrix also increases in this interval. Fenestrate bryozoan impressions on bedding plane surfaces are conspicuous in this interval. Whole specimens of the blastoid Pentremites conoideus were recovered from the bryozoan-crinoidal unit by Armstrong (1958b). The presence of fenestrate bryozoans together with increased amounts of mud would suggest less agitation and/or gentler circulation of sea water. The baffling effect of the bryozoans themselves may be responsible for increased amounts of mud.

XI. BIOSTRATIGRAPHIC CORRELATIONS

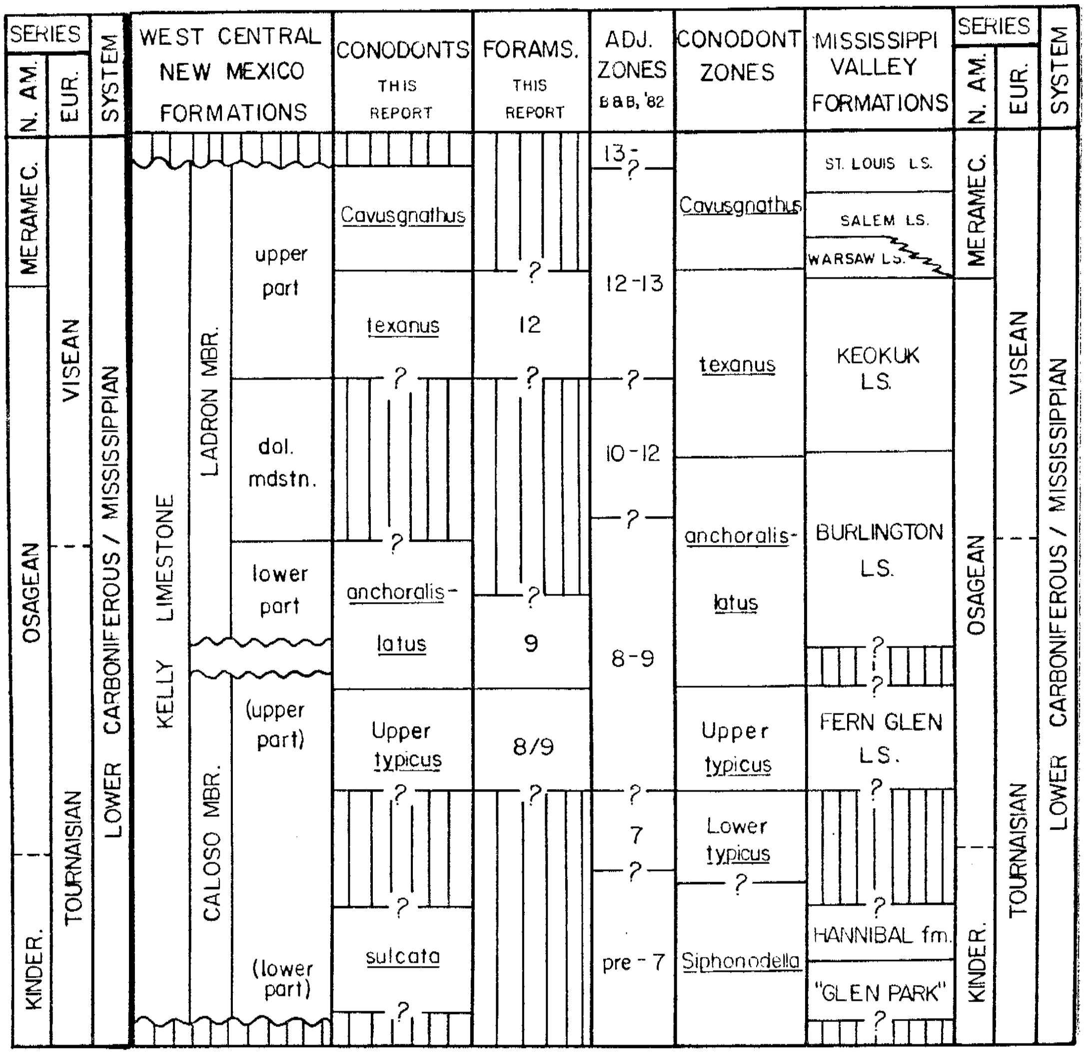
Correlation With Mississippian Stratotypes

The lowermost silty lime mudstone unit of the Caloso Member in the Kelly Limestone conodont assemblage suggests the *sulcata* Zone (Figure 23, p. 115-116). The "Glen Park" Formation and the lower Hannibal Formation of the Mississippi Valley stratotype contain *sulcata* Zone conodonts (Collinson *et al*., 1962, 1971; Sandberg *et al*., 1978). Therefore, these lower Caloso limestones are biostratigraphically equivalent to the lower Kinderhookian in the midcontinent (Figure 24).

The peloid-foraminifer wackestones and packstones of the upper part of the Caloso Member through the lower crinoidal unit of the Ladron Member, contain a conodont fauna ranging from the Upper *typicus* Zone to the lower *anchoralis*-*latus* Zone. Rocks of the Mississippian stratotypes which contain equivalent conodont faunas are the Fern Glen Formation and lower Burlington Limestone (Collinson *et al*., 1962, 1971; Lane, 1978; Lane and Brenckle in Collinson *et al*., 1981). The dolomitic mudstone unit may be equivalent to the middle and upper *anchoralis*-*latus* Zone and the lower *texanus* Zone (Figure 24).

The upper crinoidal unit of the Ladron Member yields conodonts of *texanus* Zone (Figure 23, p. 115-116). This Ladron conodont fauna correlates to the Keokuk Limestone and

Figure 24. Stratigraphic chart correlating the Kelly Limestone and its microfossil fauna to the Mississippi Valley type formations for the Lower Mississippian.


SERIES
N. AM.
EUR.
SYSTEM
WEST CENTRAL NEW MEXICO FORMATIONS
CONODONTS THIS REPORT
FORAMS. THIS REPORT
ADJ. ZONES B&B, '82
CONODONT ZONES
MISSISSIPPI VALLEY FORMATIONS
SERIES
N. AM.
EUR.
SYSTEM
MERAMEC.
OSAGEAN
KINDER.
VISEAN
TOURNAISIAN
LOWER CARBONIFEROUS / MISSISSIPPIAN
KELLY LIMESTONE
LADRON MBR.
CALOSO MBR.
upper part
dol. mdstn.
lower part
(upper part)
(lower part)
Cavusgnathus
texanus
anchoralis-latus
Upper typicus
sulcata
12
9
8/9
13-
12-13
10-12
8-9
7
pre-7
Cavusgnathus
texanus
anchoralis-latus
Upper typicus
Lower typicus
Siphonodella
ST. LOUIS LS.
SALEM LS.
WARSAW LS.
KEOKUK LS.
BURLINGTON LS.
FERN GLEN LS.
HANNIBAL fm.
"GLEN PARK"
MERAMEC.
OSAGEAN
KINDER.
VISEAN
TOURNAISIAN
LOWER CARBONIFEROUS / MISSISSIPPIAN
?

lowermost Warsaw Limestone/Salem Limestone conodont fauna of the Mississippian stratotype (Figure 24).

The uppermost Kelly Limestone, *i.e.* the uppermost crinoidal unit and the bryozoan-crinoidal unit of the Ladron Member, yields a conodont fauna of the *Cavusgnathus* Zone of Sandberg in Sandberg and Gutschick (1979) and in Gutschick and Sandberg (1980), the *Apatognathus scalenus* - *Cavusgnathus* Zone of Collinson *et al*. (1962, 1965 and 1971), and the unzoned interval of Lane *et al*. (1980). See Figure 6, (p. 26-27) and Figure 23, (p. 115-116) herein. This corresponds to the St. Louis Limestone in the Mississippian type sections as determined by Rexroad and Collinson (1963), Collinson *et al*. (1971, 1979 and 1981). See Figure 24.

This report utilizes the foraminifer biozonations of Baxter and Brenckle (1982). The foraminifer faunas found in the upper part of the Caloso Member (Figure 23, p. 115-116) indicate Mamet Zones 8 and/or 9. The occurrence of *Spinoendothyra costifera* in the uppermost few centimeters of the Caloso (wackestone and packstone unit), however, clearly indicates an age no older than Mamet Zone 9 for this horizon. Rocks immediately below this sample may be representative of a Mamet Zone 8 and/or 9 calcareous microfossil assemblage.

The lowermost Ladron Member (lower crinoidal unit) also contains a foraminifer fauna of Mamet Zone 8 and/or 9. The foraminifer assemblages found in the upper wackestone and packstone unit of the Caloso Member and in the lowermost part of the lower crinoidal unit of the Ladron, are equivalent to foraminifer faunas in the Fern Glen Limestone to upper Burlington Limestone (lower to middle Osagean; Figure 24).

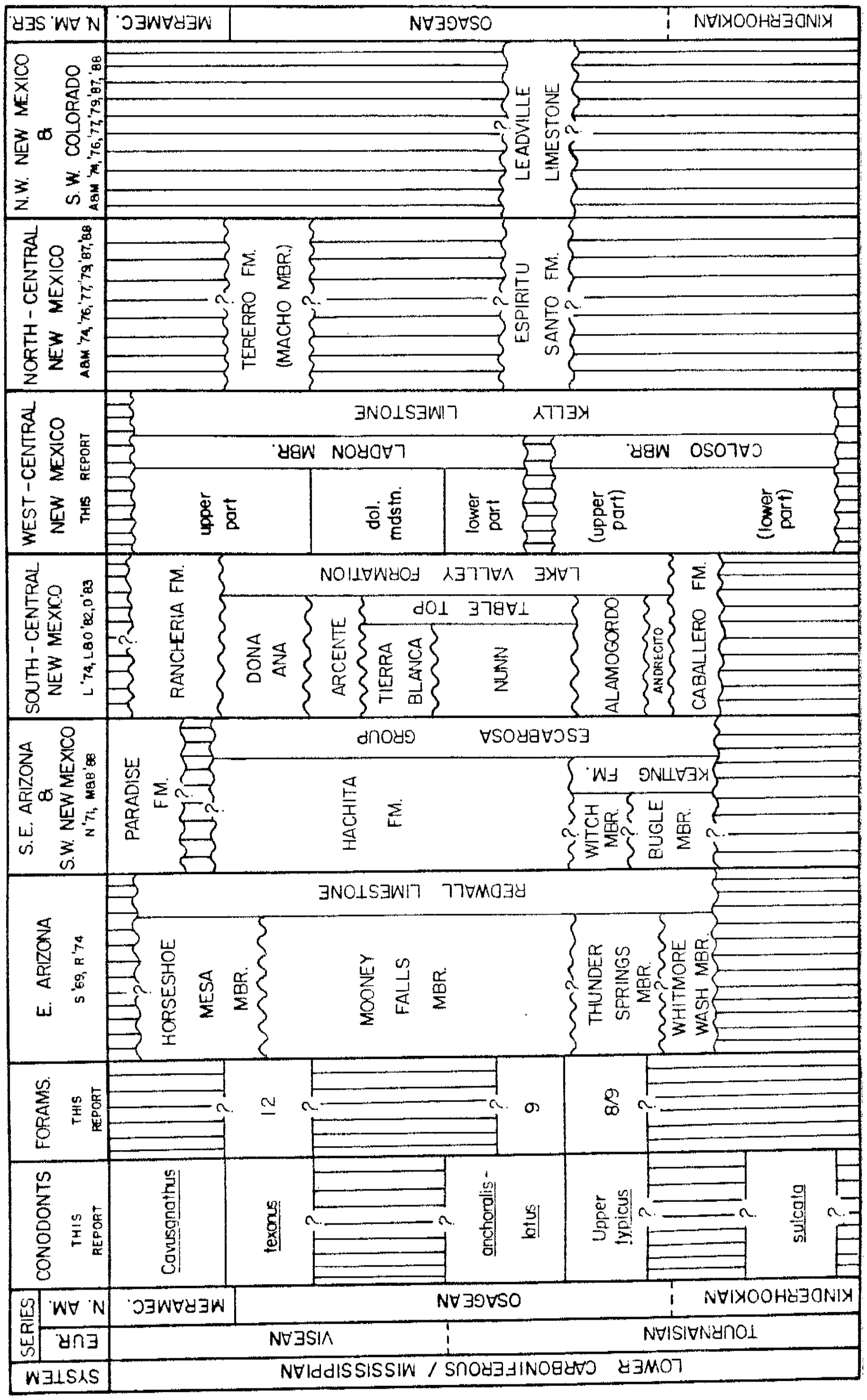
The upper crinoidal unit has a Mamet Zone 12 foraminifer fauna based on the occurrences of *Stacheoides* sp. and *Latiendothyra* sp. Mamet Zone 12 foraminifers occur in the upper Burlington Limestone to lower St. Louis Limestone interval in the midcontinent (Figure 24).

Regional Correlation

The conodont assemblage of the lowermost silty lime mudstone unit of the Caloso Member suggests the *sulcata* Zone (lower Kinderhookian). A zone barren of foraminifers, conodonts, and macrofossils exists in the Caloso and has been described herein as the silty lime mudstone facies.

The peloid-foraminifer wackestones and packstones of the upper part of the Caloso Member through the base of the lower crinoidal unit of the Ladron Member, contain a conodont fauna ranging from Upper *typicus* to lower *anchoralis*-*latus* Zone (FU 4). Norby (1971) found an equivalent conodont fauna in the upper portions of the lower Escabrosa Limestone, Member B of the Keating Formation of Armstrong (1962), in southwest New Mexico (Figure 25).

Figure 25. Correlation chart for Lower Mississippian rocks of New Mexico and adjacent areas. Locations for these rocks are given in Figure 2: 1 = Eastern Arizona; 2 = Southeast Arizona and Southwest New Mexico; 3 = South-central New Mexico; 4 = West-central New Mexico; 5 = North-central New Mexico; 6 = Northwest New Mexico and Southwest Colorado. Tererro and Espiritu Santo Formations and Leadville Limestone correlations are based on Adjusted (foraminifers) Zones presented in Figure 8 (p. 40-41) and Figure 9 (p. 42-43). South-central New Mexico rocks correlated on the basis of conodonts alone. S = Skipp (1969); R = Racey (1974); N = Norby (1971); M&B = Moore and Barrick (1988); L = Lane (1974); L&O = Lane and Ormiston (1982); D = De Keyser (1983); A&M = Armstrong and Mamet (1974, 1976, 1977, 1979, 1987 and 1988).


SYSTEM
LOWER CARBONIFEROUS / MISSISSIPPIAN
SERIES
EUR.
VISEAN
TOURNAISIAN
N. AM.
MERAMEC.
OSAGEAN
KINDERHOOKIAN
CONODONTS THIS REPORT
Cavusgnathus
texanus
anchoralis-latus
Upper typicus
sulcata
FORAMS. THIS REPORT
12
9
8/9
E. ARIZONA S '69, R '74
REDWALL LIMESTONE
HORSESHOE MESA MBR.
MOONEY FALLS MBR.
THUNDER SPRINGS MBR.
WHITMORE WASH MBR.
S.E. ARIZONA & S.W. NEW MEXICO N '71, MBB '88
PARADISE FM.
ESCABROSA GROUP
HACHITA FM.
KEATING FM.
WITCH MBR.
BUGLE MBR.
SOUTH-CENTRAL NEW MEXICO L '74, LBO '82, D '83
RANCHERIA FM.
LAKE VALLEY FORMATION
DONA ANA
ARCENTE
TABLE TOP
TIERRA BLANCA
NUNN
ALAMOGORDO
ANDRECITO
CABALLERO FM.
WEST-CENTRAL NEW MEXICO THIS REPORT
KELLY LIMESTONE
LADRON MBR.
CALOSO MBR.
upper part
dol. mdstn.
lower part
(upper part)
(lower part)
NORTH-CENTRAL NEW MEXICO ABM '74, '76, '77, '79, '87, '88
TERERRO FM. (MACHO MBR.)
ESPIRITU SANTO FM.
N.W. NEW MEXICO & S.W. COLORADO ABM '74, '76, '77, '79, '87, '88
LEADVILLE LIMESTONE
N. AM. SER.
MERAMEC.
OSAGEAN
KINDERHOOKIAN
?

Lane and Ormiston (1982) show FU 4 conodont faunas in the Alamogordo Member and lower Table Top Member of the Lake Valley Formation in the Sacramento Mountains. The southern exposures of the Nunn Member and the Tierra Blanca Member (coalescing flanks of Waulsortian-type mud mounds) also contain FU 4 conodont assemblages. These Lake Valley members correlate with the upper wackestone and packstone unit of the Caloso Member and lower crinoidal unit of the Ladron Member, based on conodont faunas, _i_._e_. Upper _typicus_ Zone to lower _anchoralis_-_latus_ Zone (Figure 25).

Calcareous microfossil data from the Espiritu Santo Formation of north-central New Mexico reported by Armstrong (1967) and Armstrong and Mamet (1976, 1977a and 1979) indicate assemblages of Mamet Zone 9. In the Leadville Limestone in the San Juan Mountains of southwestern Colorado, Armstrong and Mamet (1976) described Mamet Zone 9 fossil foraminifer assemblages. Based on this evidence, the Espiritu Santo and Leadville correlate to the Kelly Limestone interval consisting of the upper wackestone and packstone unit of the Caloso Member and lower crinoidal unit of the Ladron Member below the dolomitic mudstone unit (Figure 25).

Conodonts in the Redwall Limestone of Arizona were studied by Racey (1974). Skipp (1969) investigated the foraminifers in the Redwall. Racey's _Gnathodus_ _semiglaber_-_Pseudopolygnathus_ _multistriatus_ Zone to lower _Polygnathus_ _communis_ _communis_-_Gnathodus_ sp. A Zone in the Thunder

Springs Member and lower Mooney Falls Member, is equivalent to the Lower *typicus* to lower *anchoralis*-*latus* Zones of Lane *et al*. (1980). Foraminiferal Zones 2B-4 of Skipp (1969) are equivalent to Mamet Zones 8-9; also occurring in the Thunder Springs to lower Mooney Falls. Therefore, the Thunder Springs and lower Mooney Falls correlate with the upper wackestone and packstone unit of the Caloso Member and lower crinoidal unit of the Ladron Member of the Kelly Limestone (Figure 25).

The upper crinoidal unit and the bryozoan-crinoidal unit of the Ladron Member, contain an upper *texanus* Zone to *Cavusgnathus* Zone conodont fauna. Norby (1971) found similar conodonts at the top of the Escabrosa Limestone (Hachita Formation of Armstrong, 1962) in southeast Arizona (Figure 25). Norby (1971) recognized these faunas as the *Gnathodus* *texanus* zone and *Taphrognathus* *varians*-*Apatognathus*-*Cavusgnathus* zone.

In the Sacramento Mountains, the Lake Valley Formation equivalent to the upper crinoidal unit of the Ladron Member is the Dona Ana Member (Figure 25) which contains conodonts of upper *texanus* Zone (FU 7 of Lane, 1974 and 1978). The lowermost Rancheria Formation overlying the Lake Valley, contains conodont elements assigned to *Cavusgnathus* Zone (FU 8 in the Table Top section of Lane and Ormiston, 1982)

In north-central New Mexico, Armstrong and Mamet (1976 and 1977a) determined that the foraminifer fauna from the Macho Member of the Tererro Formation was a Mamet Zone 12 assemblage. This foraminifer fauna is equivalent to that found in the upper crinoidal unit of the Ladron Member (Figure 25).

In the Redwall Limestone of east-central Arizona, Racey (1974) showed that the upper Mooney Falls Member and the Horseshoe Mesa Member (in part) contained conodont elements assigned to his upper *Gnathodus* cf. *G*. *commutatus*-*G*. cf. *G*. *bulbosus* zone to his *Apatognathus*-*Cavusgnathus* zone. These zones correspond to the upper *texanus* Zone of Lane *et al*. (1980) and to the *Cavusgnathus* zone of Sandberg in Sandberg and Gutschick (1979) and in Gutschick and Sandberg (1980). The upper foraminiferal zone 5B from the lower Horseshoe Mesa foraminifer assemblage (Skipp 1969), is the equivalent of Mamet Zone 12 (Mamet and Skipp, 1971). Mamet Zone 12 foraminifers are found in the upper crinoidal unit of the Ladron Member. The upper crinoidal unit of the Ladron, therefore, correlates with the upper Mooney Falls - lower Horseshoe Mesa of the Redwall based on both foraminifers and conodonts (Figure 25).

XII. PALEOGEOGRAPHY OF THE KELLY LIMESTONE

Two positive topographic features, the Zuni - Defiance highlands and the Pedernal highlands (remnants of the Transcontinental Arch), were prominent in New Mexico during Mississippian time (Figure 26). The Zuni - Defiance highlands were located in northwestern New Mexico and northeastern Arizona. To the east, the Pedernal highlands extended from east-central to northeastern New Mexico. These landmasses stood as low islands in epeiric seas in Mississippian time; a surface of low relief was cut on these Precambrian crystalline rocks. These landmasses apparently did not contribute any large quantity of clastic material during Mississippian time. No shore facies has been recognized. Any such deposits probably were eroded off the highlands during lowstands of sea level. (Armstrong, 1962; Siemers, 1973; Armstrong *et al*., 1980).

Marine waters inundated west-central New Mexico during early Kinderhookian (early Tournaisian) time. In the lower Caloso Member, boulder and pebble conglomerates, arkosic sandstones, and silty lime mudstones, represent nearshore environments of deposition. The southernmost outcrop at Chupadera Peak, however, contains finer-grained sandstones and a relatively thick (4 m) interval of crinoid-bryozoan grainstones/packstones. These deposits represent a more open, shallow sea of normal marine salinity (Armstrong, 1963).

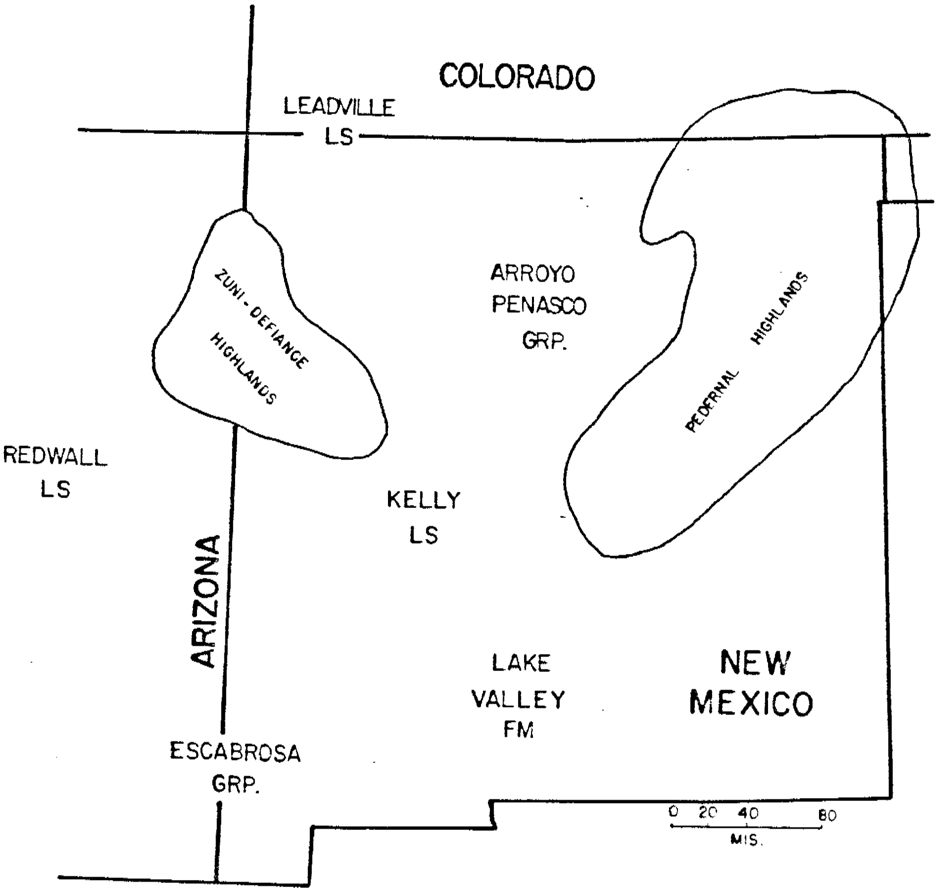


Figure 26. Position of the Zuni - Defiance Highlands and Pedernal Highlands.

The silty lime mudstone unit of the Caloso Member is a zone of stromatolitic origin deposited during a relative lowering of sea level. It represents intertidal to supratidal, carbonate deposition, and may include all or part of the remainder of Kinderhookian and earliest Osagean (late Tournaisian) times. This interval was found to be barren of conodonts, foraminifers, and macrofossils. Similar barren zones are recognized in the following correlative units: lower Escabrosa Limestone of southwest New Mexico and southeast Arizona; the lower Leadville Limestone of north-central New Mexico and southeastern Colorado; and the Whitmore Wash Member of the Redwall Limestone in eastern Arizona (Figure 25, p. 139-140).

During early Osagean time, west-central New Mexico was covered by a shallow sea of normal marine salinity. This chronostratigraphic interval (wackestone and packstone unit) is represented by a wide variety of depositional environments in the Kelly Limestone. In the Magdalena Mountains, outcrops show fine- to medium-grained packstones and grainstones of reworked fossil debris. At Corkscrew Canyon, equivalent beds are intraclastic lime mudstones, shales and crinoid-bryozoan grainstones. At Cerro de Colorado, the interval consists of peloid-foraminifer-crinoid wackestones and packstones. This stratigraphic interval represents deposition at the shoreward edge of an early Osagean shallow-marine shelf where currents were weak or absent, *e.g.* the Cerro de Colorado section. Other areas (e.g. North Peak and Corkscrew Canyon) were at or near wave base (e.g. packstones/grainstones of reworked fossil debris, intraclastic lime mudstones).

The disconformity between the Caloso Member and Ladron Member represents a short hiatus in which a relative lowering of sea level occurred during the early Osagean. This may have been caused by a eustatic lowering of sea level, local tectonic uplift, or both. In the Sacramento Mountains, Lane and Ormiston (1982) show the tops of Mississippian mud mounds as erosional surfaces. These surfaces are correlative with the Ladron-Caloso contact. Deposition was continuous in the topographic lows between the mounds.

During the next advance of the sea, the lower crinoidal unit of the Ladron Member was deposited in a shallow, open-marine environment where extensive crinoid and bryozoan "gardens" covered the sea floor. Armstrong (1958b, 1963 and 1967) suggests that these probably extended several kilometers to the north.

Dark, calcareous, deep-marine shales are found in the middle Osagean part of the Mississippian (Lower Carboniferous) in many parts of the world. The middle Osagean is characterized by a relative paucity of sedimentation. Because the middle to upper anchoralis-latus Zone (middle Osagean) is missing in the Kelly Limestone, the middle Osagean may be absent. Alternatively, it may be represented by the thinly laminated dolomitic mudstone unit.

In the Arroyo Penasco Group in north-central New Mexico, the Tererro Formation (Mamet Zone 12) unconformably overlies the Espiritu Santo Formation (Mamet Zone 9). The sea had retreated from north-central New Mexico sometime between the deposition of the Espiritu Santo and the Tererro. The dolomitic mudstone unit of the Ladron Member was probably deposited during the time when the unconformity to the north was developed; the lower crinoidal unit contains Mamet Zone 9 foraminifers, and the upper crinoidal unit contains Mamet Zone 12 foraminifers. The dolomitic mudstone unit represents the northern extent of the sea at this time.

In west-central New Mexico, during latest Osagean time, another transgressive pulse occurred in which the upper crinoidal unit of the Ladron Member was deposited. This unit was deposited in an agitated, open, shallow sea of normal marine salinity.

In early Meramecian time, the shallow sea began to retreat. The increase in silt and lime mud, finer crystallinity and a thinner bedded character of the uppermost Ladron Member are evidence for shoaling. The crinoidal grainstones in the upper Escabrosa Limestone and Mooney Falls - Horseshoe Mesa Members of the Redwall Limestone resemble the upper part of the Kelly Limestone in terms of litho- and biostratigraphy. In the Sacramento Mountains, the Dona Ana Member of the Lake Valley Formation, the equivalent to the upper part of the Kelly, is disconformably overlain by the Rancheria Formation. Lane and Ormiston (1982) determined the lowermost shales of the Rancheria to be early Meramecian, representing a change in the mode of deposition; from the Dona Ana shelf-edge environment to the deep-marine transgressive Rancheria.

During late Meramecian and Chesterian time, Mississippian strata were beveled and dissected in the area of northern and central New Mexico, and (partly) in southern Arizona (Armstrong *et al*., 1980). During Pennsylvanian and Permian time, large areas of Mississippian strata were eroded from structurally active areas in the Zuni - Defiance, Pedernal, and Florida uplifts. In the Ladron Mountains, strata of the Kelly Limestone are folded and faulted, and form an angular unconformity with overlying Pennsylvanian rocks (Armstrong, 1955 and 1958a; Hammond, 1987). Dissolution of Mississippian limestones produced extensive karst development and breccia zones according to Armstrong (1958a, 1962 and 1967), Armstrong and Mamet (1976 and 1977a), and Armstrong *et al*. (1980). The contact of the Kelly Limestone with the overlying Pennsylvanian is an erosional surface. The top of the Ladron Member exhibits cut-and-fill structures with up to 2 m of relief.

XIII. SUMMARY AND CONCLUSIONS

The Kelly Limestone is composed of the Caloso Member and the overlying Ladron Member. The Caloso ranges in age from early Kinderhookian to early Osagean (early to late Tournaisian). The Caloso is separated from the overlying Ladron by a disconformity representing time in the early Osagean (late Tournaisian) age. The Ladron is early Osagean (late Tournaisian) to Meramecian (early middle Visean).

These Mississippian rocks were deposited in a shallow-marine environment. The Caloso Member represents a shallow-marine nearshore environment of varying salinity; the Ladron was deposited in a well-agitated, open shallow sea of normal marine salinity. The disconformity separating the two members indicates a relatively rapid retreat of the early Osagean (late Tournaisian) sea. The sea slowly retreated in early to middle Meramecian (middle Visean) time.

The Caloso Member is subdivided into three informal lithostratigraphic units: a lower clastic unit; a silty lime mudstone unit; and a fossiliferous wackestone and packstone unit. Similarly, the Ladron Member consists of four informal lithostratigraphic units: a lower crinoidal unit; a conspicuous, thinly laminated, argillaceous, dolomitic lime mudstone unit; an upper crinoidal unit; and a bryozoan-crinoidal unit.

Most conodonts were found in fossiliferous crystalline limestones, particularly bryozoan-crinoid grainstones/packstones. These limestones represent open-marine conditions with good circulation.

Conodont faunas representing the global conodont zonation (Osagean) of Lane *et* *al*. (1980) were found in the Kelly Limestone. In addition, conodont assemblages of the *sulcata* Zone (early Kinderhookian) and *Cavusgnathus* Zone (Meramecian) were also found. The *typicus*, *anchoralis-latus*, and *texanus* Zones of Lane *et* *al*. (1980) are present, in part, in the Kelly. Several disconformities and intervals barren of conodonts, foraminifers and macrofossils, interrupt the succession and make it difficult to evaluate.

In the Caloso Member, the lowermost limestones of the silty lime mudstone unit yielded conodonts suggesting the upper *sulcata* Zone. Conodonts were also found in the upper wackestone and packstone unit of the Caloso. These are assigned to the Upper *typicus* Zone (FU 4L) to lower *anchoralis*-*latus* Zone (FU 4U). Intervening strata in the Caloso are barren of conodonts. The lower crinoidal unit of the Ladron Member yielded a conodont fauna similar to the upper wackestone and packstone unit of the Caloso; however, the former contains more gnathodids indicating a position farther from shore in relatively deeper water. The uppermost part of the upper crinoidal unit contains a conodont assemblage of upper *texanus* Zone (FU 7) predominated by *Gnathodus* *texanus*. The top of the crinoidal unit and the bryozoan-crinoidal unit yielded conodonts of the Cavusgnathus Zone.

Five conodont zones are recognized in the Kelly Limestone: four are recognized worldwide, and the youngest, Cavusgnathus Zone (FU 8), is recognized in the western cordillera. Comparisons of these zones to the midcontinent show that the lowermost limestones in the silty lime mudstone unit of the Caloso Member correlate to the "Glen Park" formation and lower Hannibal Formation (lower Kinderhookian). The wackestone and packstone unit of the Caloso and lower crinoidal unit of the Ladron Member correspond to the Fern Glen Formation - lower Burlington Limestone (early Osagean). The upper crinoidal unit of the Ladron correlates to the Keokuk Limestone to lowermost Warsaw - Salem Limestones (latest Osagean to earliest Meramecian). The uppermost part of the upper crinoidal unit and bryozoan-crinoidal unit have conodonts of the Cavusgnathus Zone which correspond to the St. Louis Limestone (Meramecian).

New foraminifer data from the Kelly Limestone indicate Mamet Zones 8-9 for the wackestone and packstone unit of the Caloso Member, and lowest part of the lower crinoidal unit of the Ladron Member. The uppermost few centimeters of the Caloso (wackestone and packstone unit) contain Spinoendothyra costifera, indicating an age no older than Mamet Zone 9. The lowest few centimeters of the Ladron (lower crinoidal unit) contain a foraminifer fauna similar to that found in the upper part of the wackestone and packstone unit of the Caloso; but, it may be reworked. Based on its stratigraphic position, the lowermost part of the Ladron (lower crinoidal unit) can be no older than Mamet Zone 9. New data show that the upper crinoidal unit of the Ladron contains a Mamet Zone 12 foraminifer fauna.

Conodont assemblages of the global conodont biozonation, which occur in the Kelly, are concurrent with fossil foraminifers. These permitted a comparison between the conodont zonation of Lane et al. (1980), and the foraminifer zonation of Mamet and Skipp (1970 and 1971).

Recent studies of foraminifers in the Midcontinent corroborate conodont biostratigraphic zonations for Mississippian stratotypes in which the Tournaisian-Visean boundary is located within the early Osagean (Burlington Limestone). These authors recommend shifting Mamet Zones based on foraminifers down to correspond to well-established conodont biozonations within the midcontinent stratotype. Baxter and Brenckle (1982) determined that Mamet Zone 12, previously assigned to the upper Salem Limestone (Meramecian), is probably in the Keokuk Limestone (late Osagean; early Visean).

Age assignments for the Kelly Limestone have been changed by studies of conodonts and foraminifers in the present investigation. In the uppermost part of the Caloso Member (wackestone and packstone unit) to the lower crinoidal unit of the Ladron Member, Mamet Zones 8-9 and 9 foraminifers are concurrent with conodonts of Upper *typicus* - lower *anchoralis*-*latus* Zones (Fern Glen Formation - lower Burlington Limestone; early Osagean/late Tournaisian). The upper crinoidal unit of the Ladron has foraminifers of Mamet Zone 12 together with conodonts of *texanus* Zone (upper Keokuk; late Osagean - early Meramecian, early Visean).

XIII. SYSTEMATIC PALEONTOLOGY

Phylum CONODONTA PANDER, 1856
Class CONODONTA PANDER, 1856
Order CONODONTOPHORIDA EICHENBERG, 1930
Superfamily POLYGNATHACEA BASSLER, 1925
Family ANCHIGNATHODONTIDAE CLARK, 1972

Genus *Anchignathodus* SWEET, 1970

Type species: *Anchignathodus typicus* SWEET, 1970

Anchignathodus penescitulus (REXROAD & COLLINSON), 1965

Plate I, Figures 18 and 19.

Only Pa elements of this seximembrate species were recovered from Kelly Limestone insoluble residues.

1941 *Spathognathodus regularis* BRANSON & MEHL - BRANSON & MEHL, p. 187, pl. 6, fig. 7.

1965 *Spathognathodus penescitulus* REXROAD & COLLINSON, p. 22-23, pl. 1, figs. 13-15.

Original Diagnosis (Rexroad and Collinson, 1965): This is a short spathognathodid with a large pit extending about three-fourths of its length. There is a prominent anterior denticle generally followed by eight denticles, three small and deeply inserted, three larger, and two small and unfused.

Original Description (Rexroad and Collinson, 1965): The unit is straight to slightly bowed and is approximately twice as long as high. Posterior to the prominent anterior cusp are three, or rarely four, narrow, deeply inserted denticles followed by three, or rarely four, larger denticles. At the posterior are two smaller, unfused denticles. The outline viewed laterally is convex upward, curving regularly downward toward the posterior. The deep pit, which has widely flaring lips, is about three-fourths the length of the individual. The aboral margin anterior to the pit is sharp edged and inclined aborally toward the anterior... .

Discussion. The general shape is similar to *Hindeodus scitulus* but in the latter the basal cavity is confined to the mid-length and is strongly asymmetrical on the outer lateral margin. Most authors do not illustrate the basal cavity of specimens so comparisons with other illustrations is impossible. Rexroad and Scott (1964), Rexroad and Collinson (1965), and Sweet (1970) considered *Anchignathodus penescitulus* as occurring along the phylogenetic line of the form genus *Spathognathodus* beginning with the form species *Spathognathodus regularis*. Rexroad and Collinson believed that *A. penescitulus* was ancestral to *H. scitulus*. Rexroad and Thompson (1979), however, show the former branching off the *Anchignathodus abbreviatus* - *H. scitulus* phylogenetic line of descent.

Material studied: Three Pa elements from the Ladron Member of the Kelly Limestone.

Genus *Hindeodus* REXROAD & FURNISH, 1964

Hindeodus cristulus (YOUNGQUIST & MILLER), 1949

Plate I, Figures 20 and 21.

For an earlier synonymy of the seximembrate apparatus see Sweet (1977). Ruppel and Lemmer (1986) give an earlier synonymy for the discrete Pa element of *Hindeodus cristulus* as *Spathognathodus cristulus*. The following synonymy is for the discrete Pa element of *H. cristulus*.

1973 *Spathognathodus crassidentatus* (BRANSON & MEHL) - BUTLER, p. 512-514, pl. 59, fig. 18 [only].

1980 *Anchignathodus cristulus* (YOUNGQUIST & MILLER) - TYNAN, p. 1300, pl. 2, fig. 10.

1981 *Spathognathodus cristulus* YOUNGQUIST & MILLER - METCALFE, pl. 8, figs. 6a-e.

1981 *Hindeodus cristula* (YOUNGQUIST & MILLER) - REXROAD, p. 10, pl. 2, figs. 1-2.

1984 *Hindeodus cristulus* (YOUNGQUIST & MILLER) - AUSTIN & DAVIES, pl. 1, fig. 14; pl. 3, fig. 11.

1985 *Hindeodus cristula* (YOUNGQUIST & MILLER) - ORCHARD & STRUIK, pl. 1, fig. 18.

1985 Hindeodus? cf. cristulus (YOUNGQUIST & MILLER) - VARKER & SEVASTOPULO, pl. 5.2, fig. 20.

1986 Spathognathodus cristulus YOUNGQUIST & MILLER - RUPPEL & LEMMER, p. 33, pl. 2, fig. 5.

Original Description (Youngquist and Miller, 1949): Blade short, moderately arched, much compressed, composed of about 10 denticles fused nearly to their apices, and very slightly bowed. Base of blade broadly flared reaching maximum lateral extent about mid-length on the blade. Cusp equal in width to three or four of the denticles; no denticles appear to be present anterior of cusp.

Discussion: This species has a dominant large anterior denticle. When viewed laterally this Pa element is curved downward posteriorly. The basal cavity is expanded laterally and underlies about two-thirds of the element, reaching to the posterior tip. According to Youngquist and Miller (1949) H. cristulus can be distinguished from Spathognathodus minutus by the former's fewer number of denticles posterior to the cusp, and particularly by the absence of denticles anterior of that structure. In addition Youngquist and Miller note that S. minutus bears three short denticles anterior to the cusp.

Rexroad and Furnish (1964) describe the seximembrate apparatus of Hindeodus cristulus. In the Kelly Limestone only Pa elements were recovered. The Ladron Member of the Kelly produced only fragments of other discrete elements making any apparatus reconstruction impossible.

Material studied: Three Pa elements from the Ladron Member of the Kelly Limestone were studied.

Hindeodus scitulus (HINDE, 1900)

Plate I, Figures 15 and 16.

For an earlier synonymy see Ruppel and Lemmer (1986).

1975 Spathognathodus scitulus (HINDE) - AUSTIN & MITCHELL, pl. 2, fig. 26.

1981 Spathognathodus scitulus (HINDE) - METCALFE, pl. 8, figs. 4a-b.

1984 Spathognathodus scitulus (HINDE) - AUSTIN & DAVIES, pl. 1, fig. 15; pl. 3, fig. 18.

1986 Spathognathodus scitulus (HINDE) - RUPPEL & LEMMER, p. 33, pl. 2, fig. 12.

1987 Hindeodus scitulus (HINDE) - ARMSTRONG & PURNELL, pl. 2, fig. 15.

Original Description (Hinde, 1900): Tooth somewhat triangular, with a slightly curved basal margin with a subcentral well-developed cup-shaped cavity. At one extremity of the tooth is a large, compressed, triangular denticle with an acute outer edge; behind this is a series of 7 to

14 minute elongate denticles, closely disposed side by side.

Description: The blade is short and high, the height of the unit nearly two-thirds the length. In lateral view the oral outline is relatively straight in the anterior half, but curves downward rapidly in the posterior half. The anteriormost denticle is the highest and widest. The basal cavity is asymmetrical reaching to the posterior tip; the outer margin is widely flared.

Discussion: This species has previously been extracted from rocks of late Meramecian age. According to Rexroad and Thompson (1979) *Anchignathodus abbreviatus* is ancestral to *Hindeodus scitulus*.

Material studied: Fifteen specimens of *Hindeodus scitulus* (Pa element only) were recovered and studied from the Ladron Member of the Kelly Limestone.

Family CAVUSGNATHIDAE AUSTIN & RHODES, 1981

Genus _Cavusgnathus_ HARRIS & HOLLINGSWORTH, 1933

type species: _Cavusgnathus_ _altus_ HARRIS & HOLLINGSWORTH, 1933

Apparatus at least quinquimembrate, and possibly seximembrate (Rexroad, 1981), but it is distinguished by its Pa element having a short free blade on the right side of the platform's anterior, conspicuous central trough, and transverse ridges on the platform's lateral margins.

The original description of the genus was presented by Harris and Hollingsworth (1933, p. 200-201):

> This genus is erected to include those lanceolate plated conodonts with no semblance of a median crest in the median oral channel. Outline of plate lanceolate to claviform; oral face of plate with complete, deep, median longitudinal channel without crest and bordered by marginal rims ornamented with denticles, nodes, corrugations, or combination of the same; posterior bar denticulate.

Ellison (1941, p. 125-126) presented a revised description as follows:

> Elongate platform-like teeth with high sides extending parapet-like above a median longitudinal trench; one parapet continued into a free longitudinal blade and connected at the posterior end to opposite parapet whose length is limited by the length of the platform; aboral surface of platform smooth, deeply excavated as a longitudinally elongate laterally asymmetrical, spathodid-like cup, pointed at each end, traversed by a median longitudinal groove which extends to the ends of the platform and along the aboral edge of the blade; sides of platform

somewhat constricted laterally above the aboral margin to produce a lip-like lateral margin of variable width; oral surface of platform more or less grooved transversely; oral edge of blade denticulate and crenulate.

For purposes of description the blade is directed anteriorly. It is continued posteriorly as the outer edge of platform, the blade parapet. The elevated inner edge of the platform is the inner parapet.

Remarks.--This genus differs from Idiognathodus in that the blade of the latter is median. It differs from Polygnathodella Harlton in that the latter has no oral trough.

Cavusgnathus charactus REXROAD, 1957

Plate I, Figures 31 and 32.

1957 Cavusgnathus characta n. sp. - REXROAD, p. 15-16, pl. 1, figs. 1-2.

1963 Cavusgnathus characta REXROAD - REXROAD & COLLINSON, p. 8, pl. 1, fig. 29.

1968 Cavusgnathus characta REXROAD - THOMPSON & GOEBEL, p. 22, pl. 1, figs. 1, 4, 7.

1969 Cavusgnathus charactus REXROAD - RHODES, AUSTIN & DRUCE, p. 79-80, pl. 13, figs. 7a-d, 13a-c.

1979 Cavusgnathus charactus REXROAD - RUPPEL, p. 66, pl. 2, figs. 6-7, 9.

1980 Cavusgnathus charactus REXROAD - TYNAN, pl. 2, fig. 18-19.

1985 Cavusgnathus charactus REXROAD - VARKER & SEVASTOPULO, pl. 5.6, figs. 14-15.

1986 Cavusgnathus charactus REXROAD - RUPPEL & LEMMER, p. 26, pl. 1, fig. 7.

Original Description (Rexroad, 1957): Oral View.--Outer parapet convex outward, anterior end offset outward from blade; inner parapet nearly straight except convex at tip; trough straight, deep, with one to several median nodes commonly present posteriorly; both parapets ornamented with regularly spaced, parallel, transverse ridges obsolescent into trough; blade straight, parallels trough, denticles much compressed laterally.

Lateral View.--Platform high; oral margin of both parapets gently convex, outer one the higher; postero-aboral angle strongly obtuse; distinct notch between outer parapet and blade; blade composed of six to eight denticles, subequal, but generally smaller at anterior, thus presenting low, crenulate, slightly convex oral margin; blade slightly over one-third length of specimen, as much as one-third free; platform constricted above navel; attachment scar present immediately anterior to navel.

Aboral View.--Navel shallow, asymmetric, lanceolate outline, pointed posteriorly, not quite reaching posterior tip, greater flare by inner lateral lip, which extends farther anteriorly than outer lip; navel divided by a groove which extends to both anterior and posterior lips of specimen on otherwise sharp aboral edge.

Discussion: The distinctive notch separating the outer parapet and blade is thought to be a primitive feature which reflects the transition from *Taphrognathus* to *Cavusgnathus* (Rexroad and Collinson, 1963).

Material studied: Eight Pa elements were studied from the upper Ladron Member of the Kelly Limestone.

Cavusgnathus convexus REXROAD, 1957

Plate I, Figure 24.

1957 *Cavusgnathus convexa* n. sp. - REXROAD, p. 17, pl. 1, figs. 3-6.

1958 *Cavusgnathus convexa* REXROAD - REXROAD, p. 16, pl. 1, figs. 12-14.

1961 *Cavusgnathus convexa* REXROAD - REXROAD & BURTON, p. 1151, pl. 138, fig. 14.

1964 *Cavusgnathus convexa* REXROAD - REXROAD & FURNISH, p. 670, pl. 111, fig. 1.

1965 *Cavusgnathus convexa* REXROAD - REXROAD & NICOLL, p. 17, pl. 1, figs. 14-15.

1968 *Cavusgnathus convexa* REXROAD - THOMPSON & GOEBEL, p. 22, pl. 1, figs. 14, 18, 20-21.

1970 *Cavusgnathus convexus* REXROAD - DUNN, p. 329, pl. 61, figs. 18-19.

1980 *Cavusgnathus convexus* REXROAD - TYNAN, pl. 2, fig. 24.

1986 *Cavusgnathus convexus* REXROAD - RUPPEL & LEMMER, p. 26-27, pl. 1, fig. 9.

Original Description (Rexroad, 1957): *Oral View*.--Platform long, narrow; deep trough straight, one or two nodes may be present at posterior end; parapets nearly straight, ornamented with regularly spaced, parallel, transverse ridges becoming obsolescent into the trough; denticles of blade laterally compressed.

Lateral View.--Oral margin of both parapets convex, more convex posteriorly; posterior end rounded; blade composed of four to six denticles fused nearly to apices, blade with regularly convex oral outline, highest at midlength, length of blade less than one-third length of specimen, a small part free.

Aboral View.--Navel of moderate depth, asymmetric, lanceolate-shaped outline, point reaching posterior tip, inner lip with greater flare; central groove extends anteriorly from navel along otherwise sharp aboral margin.

Discussion: *Cavusgnathus* has been interpreted as a shallow water form by Higgins and Varker (1982) and Armstrong and Purnell (1987). The cavusgnathids found in the Kelly Limestone have been recovered from the upper parts of the Ladron Member primarily from bryozoan-rich channel deposits.

Material studied: Two Pa elements were studied from the upper Ladron Member (Bryozoan-*Pentremites conoideus* zone) of the Kelly Limestone.

Cavusgnathus regularis YOUNGQUIST & MILLER, 1949

Plate I, Figures 27 and 28.

1949 *Cavusgnathus regularis* n. sp. - YOUNGQUIST & MILLER, p. 619, pl. 101, figs. 24-25.

1961 *Cavusgnathus regularis* YOUNGQUIST & MILLER - REXROAD & BURTON, p. 1152, pl. 138, figs. 13, 15.

1963 *Cavusgnathus regularis* YOUNGQUIST & MILLER - REXROAD & COLLINSON, p. 9, pl. 1, fig. 28.

1964 *Cavusgnathus regularis* YOUNGQUIST & MILLER - REXROAD & FURNISH, p. 670, pl. 111, fig. 2.

1965 *Cavusgnathus regularis* YOUNGQUIST & MILLER - REXROAD & NICOLL, p. 18, pl. 1, figs. 16-17.

1967 *Cavusgnathus regularis* YOUNGQUIST & MILLER - GLOBENSKY, p. 439, pl. 57, fig. 20.

1970 *Cavusgnathus regularis* YOUNGQUIST & MILLER - DUNN, p. 329, pl. 61, fig. 26.

1975 *Cavusgnathus regularis* YOUNGQUIST & MILLER - HIGGINS, p. 27, pl. 8, figs. 1-2.

1979 *Cavusgnathus regularis* YOUNGQUIST & MILLER - RUPPEL, pl. 2, fig. 8.

1985 *Cavusgnathus regularis* YOUNGQUIST & MILLER - VARKER & SEVASTOPULO, pl. 5.4, figs. 13-14.

1986 *Cavusgnathus regularis* YOUNGQUIST & MILLER - RUPPEL & LEMMER, p. 27, pl. 1, figs. 10-11.

Original Description (Youngquist and Miller, 1949): Specimen stout; blade short, platform large and high. A deep groove occurs medianly the length of the platform's oral surface. Aboral margin of mid-portion of platform is flared laterally, chiefly on inner side. Escutcheon, except for a narrow central longitudinal groove, is wide and shallow. Blade consists of about five or six stout, laterally compressed denticles which are fused approximately three-fourths their length. These denticles are in a more or less regularly gradational series with the larger ones toward the posterior. The posterior two or three are approximately equal in size.

Discussion: The posteriormost blade of _Cavusgnathus regularis_ does not have as pronounced and hornlike a denticle as does _Cavusgnathus_ _unicornis_. Also, _C_. _regularis_ can be distinguished from _C_. _unicornis_ by the somewhat shorter and more compact form of the former, and by the rather regular series of denticles of the blade instead of the prominent posterior denticle of _C_. _unicornis_.

Material studied: Four Pa elements of _Cavusgnathus regularis_ were studied from the upper Ladron Member (Bryozoan-_Pentremites_ _conoideus_ zone) of the Kelly Limestone.

Cavusgnathus unicornis YOUNGQUIST & MILLER, 1949

Plate I, Figure 26.

For earlier synonymy see Ruppel and Lemmer (1986).

1980 *Cavusgnathus unicornis* YOUNGQUIST & MILLER - TYNAN, pl. 2, figs. 25, 27-28.

1985 *Cavusgnathus unicornis* YOUNGQUIST & MILLER - VARKER & SEVASTOPULO, pl. 5.6, figs. 18, 20.

1986 *Cavusgnathus unicornis* YOUNGQUIST & MILLER - RUPPEL & LEMMER, p. 27, pl. 1, figs. 8, 12.

1987 *Cavusgnathus unicornis* (YOUNGQUIST & MILLER) - ARMSTRONG & PURNELL, pl. 1, figs. 11-12 (Pa element only).

Original Description (Youngquist and Miller, 1949): Platform high, narrow, and deeply grooved orally. Both outer and inner parapets are crenulated along their oral margins. Outer parapet extends anteriorly to form a short, high blade which is a fourth or less the total length of the specimen. Blade composed of about five to seven closely appressed denticles which are more or less gradational in size with the exception of the posterior-most one, and increasing in magnitude from anterior to posterior. Posterior-most denticle is appreciably larger and higher than any of the other denticles of the blade and it stands out from the rest of the series. Remaining denticles fused nearly to their apices and compressed laterally. Aboral central portion of platform strongly flared laterally, more so on inner than on outer side, forming a flange-like structure. Entire specimen very gently bowed and arched.

Discussion: Discrete Pa elements of *Cavusgnathus unicornis*, *Cavusgnathus convexus* and *Cavusgnathus regularis* were argued to be intergradations of *C. unicornis* by Rexroad (1981), however, no support for this idea has appeared in the literature since 1981. *Cavusgnathus unicornis* is found in late Meramecian rocks.

Material studied: One specimen (Pa element only) was recovered from the upper Ladron Member (Bryozoan-*Pentremites conoideus* zone) of the Kelly Limestone.

Genus *Cloghergnathus* AUSTIN & MITCHELL, 1975

Type species: *Cloghergnathus globenskii* AUSTIN & MITCHELL, 1975

Cloghergnathus is closely related to *Taphrognathus*, but the former has the anterior blade developed laterally and does not possess a short carina on the anterior portion of the platform. The laterally developed blade may be on either the right or left side but does not extend onto the platform as in Cavusgnathus. The margins of the elongate platform are ornamented by transverse ridges. The basal cavity is asymmetrical and flared.

Several Pa elements were assigned "Cloghergnathus indeterminate." These specimens had broken posterior platforms in which there was no obvious carina present, or lacked oral surface ornamentation as in "New genus and species" of Thompson and Fellows (p. 115, pl. 4, figs. 11, 14; 1970).

Cloghergnathus carinatus HIGGINS & VARKER, 1982

Plate I, Figures 34 and 35.

1982 Cloghergnathus carinatus sp. nov. - HIGGINS & VARKER, p. 160-162, pl. 18, figs. 1-11 (Pa elements only).

1984 Cloghergnathus sp. - AUSTIN & DAVIES, pl. 2, fig. 27.

1985 Cloghergnathus carinatus HIGGINS & VARKER - VARKER & SEVASTOPULO, pl. 5.5, figs. 6, 8, 10.

1987 Cloghergnathus carinatus (HIGGINS & VARKER) - ARMSTRONG & PURNELL, pl. 1, fig. 17.

Diagnosis (Higgins & Varker, 1982): A right- and left-sided element with the anterior blade developed on the inner side of the unit. A central trough runs the length of the platform but is occupied by a short carina in the posterior quarter. The blade is short, one-quarter to one-third the length of the platform, and does not extend on to the platform. It is extended above the platform and is convexly curved. The unit is arched.

Discussion: Cloghergnathus carinatus was first described as an apparatus consisting of P (Pa), O (Pb), N (M), A1 (Sc), and A2 (Sb) elements by Higgins and Varker (1982), but discrete elements other than P (Pa) elements were not found in Kelly Limestone samples.

The anterior blade consists of up to five blade denticles, however, most specimens recovered from the Kelly Limestone have broken blades. Fortunately, the posterior tips of most elements were intact and identified as Cloghergnathus carinatus by their posterior carinas.

Material studied: Forty Pa elements of Cloghergnathus carinatus were studied from the Ladron Member of the Kelly Limestone.

Genus Patrognathus gen. nov. RHODES, AUSTIN & DRUCE, 1969

Type species: Patrognathus variabilis RHODES, AUSTIN & DRUCE, 1969

Patrognathus variabilis RHODES, AUSTIN & DRUCE, 1969

Plate I, Figures 22 and 23.

1969 Patrognathus variabilis gen. et sp. nov. - RHODES, AUSTIN & DRUCE , p. 179-180, pl. 2, figs. 8a-11c.

1981 Patrognathus variabilis RHODES, AUSTIN & DRUCE - AUSTIN & RHODES, p. W159-W160, fig. 108: 2a-c.

1984 Patrognathus variabilis RHODES, AUSTIN & DRUCE - AUSTIN & DAVIES, pl. 1, figs. 8-13b.

1985 Patrognathus variabilis RHODES, AUSTIN & DRUCE - VARKER & SEVASTOPULO, pl. 5.1, figs. 1, 4, 7.

1987 Patrognathus variabilis RHODES, AUSTIN & DRUCE - ARMSTRONG & PURNELL, pl. 3, figs. 8-9, 10-12(?).

Diagnosis (Rhodes et al., 1969): Elongate, symmetrical form, possessing lanceolate platform and medial blade. Carina absent. Posterior denticle of blade twice as large as other blade denticles. Cavity flared, elongate, covering most of platform. Base of cavity and blade grooved.

Discussion: Blade varies in length with denticles equal, or gradually increasing in size posteriorly. Platform margins composed of paired, laterally elongate nodes. The anteriormost basal cavity occurs just posterior of the free blade and is slightly asymmetrical, the inner half slightly shorter and more inflated.

Klapper (1971) distinguished Patrognathus variabilis from Patrognathus andersoni based on the narrower basal cavity of the latter. Also, P. variabilis does not have as well developed a medial trough, and P. andersoni's posteriormost blade denticle is twisted to the right side.

In this study, however, specimens were recovered with expanded basal cavities, well-developed medial troughs, and the skewed posteriormost blade denticle. Some elements possessed basal cavities intermediate between these two species suggesting perhaps the existence of transitional forms.

Austin and Mitchell (1975) retained the specific name *Patrognathus andersoni* until its phylogeny could be determined, but suggested that *P. andersoni* may be a growth stage of either *Patrognathus variabilis* or *Capricornognathus capricornis*.

Armstrong and Purnell (1987) illustrated what they consider to be the Pa, Sc, Sa, and M elements of *Patrognathus variabilis*.

Material studied: There were 57 Pa elements which were recovered and studied from the basal limestones of the Caloso Member of the Kelly Limestone.

Genus *Taphrognathus* BRANSON & MEHL, 1941

Type species: *Taphrognathus varians* BRANSON & MEHL, 1941.

Taphrognathus varians BRANSON & MEHL, 1941

Plate I, Figure 14.

1963 *Taphrognathus varians* BRANSON & MEHL - REXROAD & COLLINSON, p. 21, pl. 1, figs. 18, 22.

1965 Taphrognathus varians BRANSON & MEHL - REXROAD & COLLINSON, pl. 1, figs. 30-32.

1968 Taphrognathus varians BRANSON & MEHL - THOMPSON & GOEBEL, p. 44-45, pl. 5, figs. 1-9.

1969 Taphrognathus varians BRANSON & MEHL - RHODES, AUSTIN & DRUCE, p. 241-242, pl. 13, figs. 4-5.

1970 Taphrognathus varians BRANSON & MEHL - THOMPSON & FELLOWS, p. 114-115, pl. 4, figs. 10, 15.

1975 Taphrognathus varians BRANSON & MEHL - NICOLL & REXROAD, p. 27, pl. 4, figs. 7-16.

1979 Taphrognathus varians BRANSON & MEHL - RUPPEL, p. 34, pl. 2, figs. 1-3, 10.

1986 Taphrognathus varians BRANSON & MEHL - RUPPEL & LEMMER, p. 34, pl. 1, figs. 1-5.

1987 Taphrognathus varians (BRANSON & MEHL) - ARMSTRONG & PURNELL, pl. 3, fig. 14.

Original Diagnosis (Branson and Mehl, 1941): Long and narrow with axis more or less curved laterally, concave inward. Outline of platform in oral view lanceolate, greatest width near mid-length, with a tendency toward lateral constriction, chiefly of the inner side, between mid-length and the anterior end; posterior end extended, acuminate. Median trench narrow and deep, smooth bottomed except for the anterior end which is occupied for a short distance by an abruptly ending carina, and the posterior end that is nodose to carinate; internal faces of lateral bounding parapets irregularly transverse ridges. Blade long, with sharply crenulate oral edge highest at or slightly in front of mid-length. Aboral cup with flaring lateral margins much longer than wide, extending as a groove along the blade and the elongated posterior end of the plate, anterior and posterior ends sharp; greatest depth in front of mid-length.

Description: Free blade located centrally between high lateral margins at anterior end of platform. Consequentially median trough of platform is deep. Margins of platform may be either smooth or consist of transverse ridges. Basal cavity is elongate, widely flared, extending anteriorly beneath the anterior blade and tapering to the posterior tip.

Discussion: _Taphrognathus_ _varians_ is the only species belonging to the genus. It is known only by its Pa element. Thompson and Goebel (1968) and Nicoll and Rexroad (1975) address the wide range of variation in _T_. _varians_ such as platform width, length of free blade, basal cavity and so on. This variation is neither significant in terms of time (Thompson and Goebel, 1968) nor stratigraphy and geographic distribution (Nicoll and Rexroad, 1975). Sandberg and Gutschick (1979) and Higgins and Varker (1982) interpreted _T_. _varians_ as a shallow water form. The first occurrence of _T_. _varians_ is slightly later than the first occurrence of Gnathodus texanus at the base of the texanus Zone in the western United States (Lane et al., 1980).

Material studied: Fourteen Pa elements of T. varians were studied from the Ladron Member of the Kelly Limestone.

Taphrognathus - Cavusgnathus transition

Plate I, Figure 13.

1941 Taphrognathus varians, BRANSON & MEHL (part), p. 182, pl. 6, fig. 34.

1963 Taphrognathus - Cavusgnathus transition - REXROAD & COLLINSON, p. 20-21, pl. 1, figs. 21, 24.

1968 Taphrognathus varians BRANSON & MEHL - THOMPSON & GOEBEL, pl. 5, figs. 12, 15.

1969 Taphrognathus - Cavusgnathus transition - RHODES, AUSTIN & DRUCE, p. 241-242, pl. 13, figs. 1-3c.

1979 Taphrognathus - Cavusgnathus transition - RUPPEL, pl. 2, figs. 4-5.

1981 Taphrognathus? sp. - METCALFE, p. 45, pl. 10, figs. 3a-b.

1984 Taphrognathus sp. - AUSTIN & DAVIES, pl. 2, fig. 3.

1986 Taphrognathus - Cavusgnathus transition - RUPPEL & LEMMER, p. 34, pl. 1, fig. 6.

1987 Cloghergnathus - Taphrognathus intermediate - ARMSTRONG & PURNELL, pl. 2, figs. 2-3.

Discussion: In these specimens, in the anterior portion of the platform, the blade occupies a position intermediate between the medial blade position of *Taphrognathus* and the outer lateral position of *Cavusgnathus*. Branson and Mehl (1941, p. 183) included such specimens in their discussion on the variability within *Taphrognathus varians*.

Austin and Mitchell (1975) argued that *Cloghergnathus* is not intermediate between *Taphrognathus* and *Cavusgnathus*, but rather, is an offshoot of the former based on having the anterior blade developed laterally, free from the platform, and by not bearing a short carina anteriorly on the platform. This accounts for some authors, *e. g.* Armstrong and Purnell (1987), assigning specimens as *Cloghergnathus* - *Taphrognathus* intermediates rather than *Taphrognathus* - *Cavusgnathus* transitions after Rexroad and Collinson (1963). The case for *Taphrognathus* - *Cavusgnathus* transition is argued by Higgins and Varker (1982) in that all known species of *Cloghergnathus* are either right- or left-sided or only left-sided, whereas *Cavusgnathus* species are all right-sided.

Ruppel and Lemmer (1986) report recovery of *Taphrognathus* - *Cavusgnathus* transition elements at the boundary of the Osagean and Meramecian. Previously these transition elements were recovered from early late Meramecian rocks.

Material studied: Eleven specimens of Pa elements of *Taphrognathus* - *Cavusgnathus* transition were studied from the upper Ladron Member of the Kelly Limestone.

Family IDIOGNATHODONTIDAE HARRIS & HOLLINGSWORTH, 1933

Genus *Gnathodus* PANDER, 1856

Type species *Gnathodus* *mosquensis* PANDER, 1856.

The type species of Pander (1856) are irretrievably lost and so Lane and Ziegler (1979) proposed *Gnathodus texanus* ROUNDY (1926) to become the type species. However, based on objections from fellow conodont scientists concerning the restricted basal cavity and platform of *G. texanus* ROUNDY (1926), and the fact that its apparatus has never been described, Lane and Ziegler (1984) withdrew their proposal and offered instead that the type species should be *Gnathodus* *bilineatus* ROUNDY (1926). *Gnathodus bilineatus* was proposed because it is best regarded as typical of the traditional concept of the genus and because its apparatus is known based on the collection of natural assemblages of Schmidt and Muller (1964).

Most gnathodids recovered for this study were incomplete; the free blade usually was broken off just anterior to the platform cup.

Gnathodus cuneiformis MEHL & THOMAS, 1947

Plate I, Figure 5.

For an earlier synonymy see Lane *et al*. (1980).

1980 *Gnathodus cuneiformis* MEHL & THOMAS, 1947 - LANE, SANDBERG & ZIEGLER, p. 130, pl. 4, figs. 5-13.

1981b *Gnathodus cuneiformis* MEHL & THOMAS, 1947 - ZIEGLER, p. 123-126, pl. 1, figs. 1-5.

1985 *Gnathodus cuneiformis* MEHL & THOMAS, 1947 - VARKER & SEVASTOPULO, pl. 5.1, figs. 21, 25.

Original diagnosis (Mehl and Thomas, 1947): Axis nearly straight, but slightly curved laterally near posterior end. Blade comparatively thick, edged with laterally compressed sub-equal denticles, with free short apices. Carina slightly elevated, consisting of a nodose ridge, oral edge down-curved at its posterior end to meet the aboral outline, extending beyond posterior end of plate. Cup large, longer than wide, greatest diameter at anterior end and slightly diagonal to axis. Outer margins of oral surface marked by elevated, slightly nodose ridges that nearly parallel the carina. The elevated outer margins form a moderately deep depression on each side of the carina.

Revised diagnosis (Lane *et al*., 1980): This species has a long parapet formed by a row of nodes or cross ridges extending to or near the posterior tip of the blade and a second row of nodes or cross ridges paralleling the blade on the outer cup.

Discussion: The posterior tip of the blade is characteristically simple; the posterior blade denticles are not expanded laterally into large nodes or cross ridges. Lane *et al*. (1980) and Ziegler (1981b) discussed the occurrence of three morphotypes. An early and common morphotype is characterized by well-developed marginal nodes extending to the posterior tip. An additional row of nodes parallels the anterior margin of the outer cup. Some forms may have lateral rows of nodes that may fuse posteriorly with carina nodes. The second morphotype conforms to the holotype of the species. It is small and is characterized by marginal ridges that converge posteriorly as rows of nodes. This morphotype is the predominant form found in the Kelly Limestone. In the third morphotype the parapet has a tendency to bend outward at the anterior end of the cup.

Transitional specimens exist between *Gnathodus cuneiformis* and *Protognathodus praedelicatus*, and also, between G. cuneiformis and Gnathodus delicatus. Characteristics of these species may be found on any one platform element making assignments difficult, however, this was not a problem in this study.

Material Studied: There were 6 Pa elements of Gnathodus cuneiformis studied from the Kelly Limestone.

Gnathodus delicatus BRANSON & MEHL, 1938

Plate I, Figures 4, 6 and 7.

For an earlier synonymy see Lane et al. (1980).

1980 Gnathodus delicatus BRANSON & MEHL, 1938 - LANE, SANDBERG & ZIEGLER, p. 129, pl. 3, fig. 17; pl. 4, figs. 2-4.

1981b Gnathodus delicatus BRANSON & MEHL, 1938 - ZIEGLER, p. 129-132, pl. 1, figs. 6-9.

1984 Gnathodus delicatus BRANSON & MEHL - AUSTIN & DAVIES, pl. 2, figs. 19, 24.

1985 Gnathodus delicatus BRANSON & MEHL, 1938 - VARKER & SEVASTOPULO, pl. 5.1, figs. 20, 24.

Original diagnosis (Branson and Mehl, 1938): Axis straight or slightly curved; blade much longer than cup, thickened above aboral edge, greatest width at anterior end, oral edge thin. Blade denticles about twelve, appressed but not greatly flattened, with free pointed termini. Carina high, consisting of coarse rounded nodes that decrease in size and height backward, extending slightly beyond the posterior side of the cup proper. Cup small, longer than wide, pointed posteriorly; oral surface rounded rapidly from the carina rather than flat, wider on the outer than on the inner side; inner side of oral surface marked by a row of pointed nodes that closely parallels the carina; outer side marked by a small number of scattered nodes that in the middle part curves slightly away from the carina.

Revised diagnosis (Lane _et_ _al_. 1980): A species of _Gnathodus_ that has a long parapet formed by a row of nodes or cross ridges extending to or close to the posterior tip of the blade. The low, outer cup is ornamented by randomly scattered nodes.

Discussion: The posterior tip of the blade is characteristically simple; posterior blade denticles are not expanded into large nodes or cross ridges. The cup is generally small, longer than wide, but may be of varying outline; the outer cup occasionally expanded laterally.

Material studied: Eighteen specimens of the Pa element were studied from the Kelly Limestone. One specimen, however, was lost during the study.

Gnathodus cf. G. punctatus (COOPER, 1939)

Plate I, Figure 17.

1939 Dryphenotus punctatus n. sp. - COOPER, p. 386, pl. 41, figs. 42-43; pl. 42, figs. 10-11.

1939 Dryphenotus oxys n. sp. - COOPER, p. 386, pl.42, figs. 12-13.

1959 Gnathodus punctatus (COOPER) - HASS, pl. 47, figs. 16-17.

1959 Gnathodus punctatus (COOPER) - VOGES, p. 283-284, pl. 33, figs. 36-37.

1970 Gnathodus punctatus (COOPER) - THOMPSON & FELLOWS, pl. 1, figs. 15-16.

1972 Gnathodus punctatus (COOPER) - MATTHEWS, SADLER & SELWOOD, p. 560-562, pl. 110, fig. 1.

1977 Gnathodus punctatus (COOPER) - GROESSENS, CONIL & LEES, pl. 3, fig. 2.

1980 Gnathodus punctatus (COOPER) - LANE, SANDBERG & ZIEGLER, p. 132, pl. 3, fig. 18.

1981b Gnathodus punctatus (COOPER, 1939) - ZIEGLER, p. 141-144, pl. 2, figs. 5, 7.

1985 Gnathodus punctatus (COOPER) - VARKER & SEVASTOPULO, pl. 5.1, fig. 22-23.

Description: This unit's cup is irregularly outlined; the platform width about equal to its length. The small inner side of the cup has a long parapet consisting of a row of nodes which anteriorly are slightly convex to the carina, and parallel to the blade posteriorly. The large outer cup bears a row of fused nodes along and parallel to the anterior margin. A rare tiny node may be distinguished on the upper surface of the outer cup. The posterior tip of the blade is composed of laterally expanded denticles forming small crossridges.

Discussion: Lane *et al*. (1980) and Ziegler (1981b) remark that the upper surface of *Gnathodus punctatus* varies greatly. According to Ziegler (1981b), *G*. *punctatus* gave rise to *Gnathodus semiglaber* in the upper part of the *isosticha* - Upper *crenulata* Zone by decreasing the side of the parapet and by the reduction in surface ornamentation on the oral surface of the outer cup. This specimen may represent a transitional element since its inner cup is slightly narrower than one would expect for *G*. *punctatus* and the anterior portion of the parapet is reduced in size and outline. The outer cup margin still possesses the row of fused nodes parallel to the anterior margin, however, surface ornamentation is lacking on the outer cup opposite the parapet and posteriorly.

Material studied: one specimen.

Gnathodus pseudosemiglaber THOMPSON & FELLOWS, 1970

Plate I, Figure 8.

1964 *Gnathodus typicus* COOPER - REXROAD & SCOTT, p. 31, pl. 2, fig. 3.

1969 *Gnathodus* sp. A - DRUCE, p. 64, pl. 7, fig. 7.

1970 *Gnathodus texanus pseudosemiglaber* n. subsp. - THOMPSON & FELLOWS, p. 88, pl. 2, fig. 6, 8-9, 11-13.

1973 *Gnathodus semiglaber* BISCHOFF - MATTHEWS & NAYLOR, pl. 35, fig. 22.

1974 *Gnathodus texanus pseudosemiglaber* THOMPSON & FELLOWS - MATTHEWS & THOMAS, pl. 50, figs. 23, 25-26.

1974 *Gnathodus texanus texanus* (ROUNDY) - MATTHEWS & THOMAS, pl. 50, fig. 24.

1974 *Gnathodus typicus* COOPER - PIERCE & LANGENHEIM, pl. 3, fig. 6.

1977 *Gnathodus texanus pseudosemiglaber* THOMPSON & FELLOWS - GROESSENS & NOEL, pl. 7, fig. 25.

1980 *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS - LANE, SANDBERG & ZIEGLER, p. 132-133, pl. 4, figs. 15-17, 19; pl. 5, figs. 8-15; pl. 6, fig. 14.

1981 *Gnathodus texanus pseudosemiglaber* THOMPSON & FELLOWS - METCALFE, p. 29, pl. 6, fig. 3.

1981b *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS - ZIEGLER, p. 135-138, pl. 2, figs. 1-4.

1984 *Gnathodus texanus pseudosemiglaber* THOMPSON & FELLOWS - AUSTIN & DAVIES, pl. 2, fig. 12-13; pl. 3, figs. 15-16.

1985 Gnathodus pseudosemiglaber THOMPSON & FELLOWS - VARKER & SEVASTOPULO, pl. 5.3, figs. 15, 18.

1987 Gnathodus pseudosemiglaber THOMPSON & FELLOWS - AUSTIN, pl. 13.1, figs. 6, 8, 14, 16-17, 23, 25; pl. 13.2, figs. 27-28; pl. 13.3, figs. 1, 3, 16, 19.

Original diagnosis (Thompson and Fellows, 1970): Broad platform ornamented by single elongate node or short parapet on inner side parallel to carina and single rounded node on outer side. Posterior half of carina laterally expanded and cut by short transverse ridges, extending posteriorly beyond end of platform.

Revised diagnosis (Lane et al., 1980): A species of Gnathodus having a somewhat elongate triangular cup, the margins of which reach the posterior tip. The strong parapet parallels the blade in the anterior part of the inner side of the cup and consists of cross ridges or fused nodes. It is slightly curved with the concave side toward the blade. On the outer side of the cup, a few nodes form a very short pseudoparapet, which is situated opposite the parapet; a few random nodes may be present in addition to the pseudoparapet. The posterior expansion of the blade begins opposite the pseudoparapet.

Discussion: Lane et al. (1980) and Ziegler (1981b) reported that faunas in the texanus Zone contain small specimens with reduced cup and ornamentation which are difficult to assign but may represent juvenile forms of *Gnathodus pseudosemiglaber*. The phylogenetic relationship between *Gnathodus semiglaber* and *G. pseudosemiglaber* is demonstrated by the latter's outline of the cup, ornamentation on the outer cup, and expanded blade (Lane *et al*., 1980, Figure 1).

Material studied: Twenty one Pa elements were studied from the Kelly Limestone.

Gnathodus semiglaber BISCHOFF, 1957

Plate I, Figure 9.

1957 *Gnathodus bilineatus semiglaber* n. subsp. - BISCHOFF, p. 22, pl. 3, figs. 1-10, 12, 14. [not confirmed]

1959 *Gnathodus semiglaber* (BISCHOFF) (sic) - VOGES, p. 284, pl. 33, figs. 38-39.

1967 *Gnathodus bulbosus* n. sp. - THOMPSON, p. 37, pl. 6, figs. 2, 7; pl. 3, figs. 7, 11, 14-15, 18-21.

1969 *Gnathodus* cf. *G. semiglaber* - MATTHEWS, pl. 51, fig. 17.

1969 *Gnathodus texanus* ROUNDY - DRUCE, pl. 7, figs. 1-2.

1970 *Gnathodus semiglaber* (BISCHOFF) - THOMPSON & FELLOWS, p. 87, pl. 2, figs. 7, 10.

1980 *Gnathodus semiglaber* BISCHOFF - LANE, SANDBERG & ZIEGLER, p. 132, pl. 4, figs. 1, 18; pl. 5, figs. 1-2.

1981b *Gnathodus semiglaber* BISCHOFF - ZIEGLER, p. 145-147, pl. 2, figs. 8-11; pl. 3, fig. 11.

1981 *Gnathodus semiglaber* BISCHOFF - METCALFE, p. 29, pl. 6, figs. 4a, b.

1984 *Gnathodus bulbosus* THOMPSON - AUSTIN & DAVIES, pl. 2, fig. 15.

Original diagnosis (Bischoff, 1957): A subspecies of *G. bilineatus* in which the surface of the outer cup is ornamented with only few nodes and is smooth in part.

Revised diagnosis (Lane *et al.*, 1980): A species of *Gnathodus* characterized by an asymmetric platform that bears on the inner side of the cup a very short, high parapet composed of fused nodes. This parapet may be straight, oblique, or curved convexly from the blade. The wide outer side of the cup is unornamented or bears in its anterior part a few scattered nodes that may be arranged in an indistinct row. The nodes of the blade opposite or posterior to the parapet are widely expanded to form transverse ridges or three rows of nodes that extend to the posterior tip.

Discussion: Lane *et al.*, (1980) and Ziegler (1981b) regarded *Gnathodus bulbosus* THOMPSON, a junior synonym of *Gnathodus semiglaber*, as an intermediate form possessing one or two high nodes close to the carina at the anterior margin of the outer cup. Later forms have either a few nodes or are smooth.

Gnathodus semiglaber, although exhibiting a wide variability in shape of the cup, can be distinguished from *Gnathodus pseudosemiglaber* in that *G. semiglaber* has a more expanded cup and lacks the parapet-like structure on the outer cup opposite the inner cup's true parapet.

Material studied: Four specimens of the Pa element of *Gnathodus semiglaber* were studied from the Kelly Limestone.

Gnathodus texanus ROUNDY, 1926

Plate I, Figure 10.

For earlier synonymy see Lane *et al*. (1980).

Note: Hass (1953) should be United States Geological Survey Professional Paper 243-F *not* 286 as referenced in Lane *et al*., 1980.

1980 *Gnathodus texanus* ROUNDY - LANE, SANDBERG & ZIEGLER, p. 133, pl. 6, figs. 8-9, 11-12, 16.

1981b *Gnathodus texanus* ROUNDY - ZIEGLER, p. 149-152, pl. 3, figs. 5-10.

1984 *Gnathodus texanus texanus* ROUNDY - AUSTIN & DAVIES, pl. 3, fig. 14.

1986 *Gnathodus texanus* ROUNDY - RUPPEL & LEMMER, p. 28-29, pl. 2, figs. 9, 16-17.

Original diagnosis (Roundy, 1926): Seen from above this species consists of a long, nearly straight row of thin, short, sharp-edged teeth which resemble somewhat saw teeth without any set. Near the center the wide-spreading upper surface of the pulp chamber is conspicuous, and from its top, a little to one side of the row of teeth, there arises a single tusk or tooth, whose top usually but not in all specimens is slightly depressed in the middle, giving it the appearance of having two small nodes. Seen in side view, the bottom is rather straight at the wide end, gradually bends downward on the sharper or thinner front (?) end. The teeth are largest on the back or higher end and show a gradual though not constant reduction in size until at the front end they are not much more than mere points on some specimens. Seen from below, this species shows the higher or posterior (?) end to consist of a narrow projection with a very fine line in the center. Under strong magnification this line is shown in fractured specimens to be the lower contact of two thin plates actually in contact but not fused until in the vicinity of the base of the individual teeth. About the middle of the base these plates rapidly separate to form the pulp cavity. At the front end the bottoms of the two plates again unite but only at the point.

Revised diagnosis (Lane *et al.*, 1980): A species of *Gnathodus* having a high, short pillar-like parapet that is straight or arcuate with the concave side facing the blade, a tiny inner cup that lies entirely beneath the parapet, and a short outer cup that terminates anterior of the posterior tip of the blade. The posterior blade denticles are expanded, with the expansion beginning opposite the parapet. In lateral view, the posterior margin of the blade is steep or descends gradually. The parapet is formed by a single large node or two or three fused nodes. The outer cup may be smooth or ornamented by a single high node opposite the parapet.

Discussion: *Gnathodus texanus* is close in appearance to *Gnathodus typicus* Morphotype 2 but can be easily distinguished by the laterally expanded denticles at the posterior tip of the blade of *G. texanus*. *Gnathodus texanus* has been phyletically linked to *G. typicus* (Sandberg, 1979) and to *Gnathodus pseudosemiglaber* (Lane *et al.*, 1980).

Most specimens in this study possess parapets that consist of fused nodes that are arranged in either a straight line or are slightly arcuate. Only a few specimens have a slightly expanded cup, and parapets consisting of one or two fused nodes.

The first occurrence of *Gnathodus texanus* marks the base of the *texanus* Zone (upper Osagean) of Lane *et al.* (1980). Belka and Groessens (1986), however, reported *G. texanus* occurring within the *anchoralis*-*latus* Zone. The occurrence of only two *G. texanus* specimens at this low biostratigraphic level, however, is not statistically significant.

Material studied: The number of Pa elements studied was 321. All were recovered from the Ladron Member of the Kelly Limestone.

Gnathodus typicus COOPER, 1939

Plate I, Figures 1 and 2.

1939 *Gnathodus typicus* n. sp. - COOPER, p. 389, pl. 42, figs. 77-78.

1964 *Gnathodus antetexanus* n. sp. - REXROAD & SCOTT, p. 28, pl. 2, figs. 7-10.

1980 *Gnathodus typicus* COOPER - LANE, SANDBERG &ZIEGLER, p. 130-131, pl. 3, figs. 2-4, 10; pl. 10, fig. 6.

1981b *Gnathodus typicus* COOPER - ZIEGLER, p. 153-155, pl. 3, figs. 1-4.

1987 *Gnathodus typicus* COOPER - AUSTIN, pl. 13.1, figs. 9, 18, 27; pl. 13.2, fig. 20; pl. 13.3, figs. 2, 7, 9.

Original Diagnosis (Cooper, 1939): Plate small, pointed, asymmetrical, right side very narrow, nodose, bar thin, wide and finely denticulated, teeth free at tips.

Revised diagnosis (Lane *et al.*, 1980): A species of *Gnathodus* with a narrow cup, a simple posterior blade, and a short high parapet. The outer cup is smooth or ornamented by one node or several small random nodes. The inner cup posterior to the parapet is smooth and has several tiny nodes paralleling the blade.

Discussion: Lane *et al*. (1980) and Ziegler (1981b) recognize two morphotypes. Both morphotypes are present and illustrated in this study. *Gnathodus typicus* Morphotype 1 is older, but ranges upward to occur with Morphotype 2. Morphotype 1 has a relatively widely expanded, more inflated cup which extends to the posterior tip of the blade and is ornamented by several random nodes. Morphotype 2 has a less inflated, less ornamented outer cup, which generally terminates well short of the posterior tip, and an inner cup narrower than in Morphotype 1.

Gnathodus typicus has a range that begins at or near the Kinderhookian-Osagean boundary (Sandberg, 1979). Lane *et al*. (1980) have the first occurrence of *G*. *typicus* Morphotype 1 and Morphotype 2 corresponding to the base of the *isosticha* - Upper *crenulata* Zone and the base of the *typicus* Zone respectively. Ziegler (1981b) states the range of *G*. *typicus* extends from within the *isosticha* Zone - Upper *crenulata* Zone through the *anchoralis*-*latus* Zone.

Gnathodus typicus specimens were recovered from the Corkscrew Canyon and Cerro de Colorado sections in the Lemitar and Ladron Mountains, respectively. Specimens represent conodont faunas at the very top of the Caloso

Member and the base of the Ladron Member of the Kelly Limestone here.

Material studied: Thirteen Pa elements of Gnathodus typicus M1 and 5 Pa elements of Gnathodus typicus M2 were studied from the Kelly Limestone.

Protognathodus praedelicatus LANE, SANDBERG & ZIEGLER, 1980

Plate I, Figure 3.

For an earlier synonymy see Lane et al. (1980).

1980 Protognathodus praedelicatus n. sp. - LANE, SANDBERG & ZIEGLER, p. 134-135, pl. 3, figs. 5-9, 11.

1985 Protognathodus cf. P. praedelicatus - ORCHARD & STRUIK, pl. 1, fig. 5.

1987 Protognathodus praedelicatus LANE, SANDBERG & ZIEGLER - CARMAN, p. 56, pl. 4, figs. 15, 18.

Original Diagnosis (Lane et al., 1980): A species of Protognathodus characterized by an oval-shaped cup with subequal halves, the anterior margins of which are slightly offset. The cup is ornamented by widely to closely set nodes that may be randomly or arranged in indistinct longitudinal rows.

Discussion: The arrangement of nodes in indistinct longitudinal rows is reminiscent of Gnathodus cuneiformis.

Protognathodus praedelicatus is connected to *G. cuneiformis* by transitional specimens (Lane *et al*., 1980).

Material studied: One specimen was studied from the Kelly Limestone.

Family POLYGNATHIDAE BASSLER, 1925

Genus *Bispathodus* MULLER, 1962b

Type species: *Spathodus spinulicostatus* E. R. BRANSON, 1934.

Bispathodus aculeatus plumulus (RHODES, AUSTIN & DRUCE, 1969)

Plate I, Figure 29.

For an earlier synonymy see Ziegler (1975b).

1975b *Bispathodus aculeatus plumulus* (RHODES, AUSTIN & DRUCE) - ZIEGLER, p. 29-30, pl. 1, figs. 8-10.

1982 *Bispathodus aculeatus plumulus* (RHODES, AUSTIN & DRUCE) - SAVAGE, p. 108, pl. 1, figs. 13-16.

1985 *Bispathodus aculeatus plumulus* RHODES, AUSTIN & DRUCE - BELKA, pl. 16, fig. 15.

1985 *Bispathodus aculeatus plumulus* RHODES, AUSTIN & DRUCE - VARKER & SEVASTOPULO, pl. 5.1, figs. 23, 25.

Original Diagnosis (Rhodes *et al*, 1969): Spathognathodid with plume-like anterior blade, denticles of which decrease rapidly in size anteriorly from a massive denticle at posterior end of blade. Series of lateral nodes present, developed on the outer side only, above the basal cavity.

Description: For complete description as used herein see Rhodes *et al* (1969, p. 228). See also Ziegler (1975b, "Remarks... ," p. 29).

Discussion: The large denticles of the plume-like anterior blade are recurved posteriorly. Three or four side denticles are present on the right side of the blade, rising from a slightly developed bulge or platform.

These specimens were recovered from the basal limestones of the Caloso Member of the Kelly Limestone. Stratigraphic range of this species is from the uppermost Upper Devonian to the lowermost Lower Carboniferous (conodont zonation: upper part of the Lower *costatus* Zone through *Siphonodella sulcata* Zone). Due to Tertiary volcanism several specimens from the Chupadera Peak section have undergone organic metamorphism; CAI = 6-7.

Material studied: Thirty eight Pa elements of *Bispathodus aculeatus plumulus* were recovered from the lower Caloso Member of the Kelly Limestone.

Bispathodus stabilis BRANSON & MEHL, 1934a

Plate I, Figure 36.

For an earlier synonymy see Klapper (1966) and Carman (1987).

1987 Bispathodus stabilis BRANSON & MEHL - CARMAN, p. 50-51, pl. 2, figs. 7-8, 12.

Original Diagnosis (Branson and Mehl, 1934a): Blade nearly straight, comparatively thin. Outline of oral edge in lateral view straight throughout mid-length, descending regularly from the highest point near the anterior end, with a more rapid descent in the posterior third to meet the aboral edge at a low angle. Aboral edge straight throughout its length. Anterior end straight, forming an angle of 90 degrees, or slightly less, with the lower margin. Navel exceptionally large, almost twice as long as wide, centering near the middle of the blade and tapering from a broadly rounded anterior outline to a sharp point which extends to near the posterior end; lateral lips thin and sharply extended, somewhat wider on one side (outer) than the other. Oral denticles about twenty subequal, closely spaced, with very short discrete apices. Germ denticles somewhat more numerous, with some uniting near the oral edge to form single terminations and a few suppressed within the blade by the antero-posterior expansion of others.

Discussion: *Bispathodus stabilis* is the only single-rowed member of this genus. Two morphotypes were recognized by Ziegler *et al*. (1974). Morphotype 1 is characterized by a relatively small, symmetrical or slightly asymmetrical basal cavity that does not extend to the posterior tip of the blade. Morphotype 2 has a much wider basal cavity which is asymmetrical and extends to the posterior tip.

Muller (1962b) established *Bispathodus* as a subgenus of *Spathognathodus*, and Ziegler *et al*. (1974) raised *Bispathodus* to the generic level wherein all double-rowed spathognathodontids from the Late Devonian and Early Mississippian were included. *Bispathodus stabilis* is included in the genus because, according to Ziegler *et al*., the row of denticles widened as *B*. *stabilis* evolved. Klapper's (1966) revision of *Spathognathodus crassidentatus* switched earlier assigned forms to *Spathognathodus stabilis*. Klapper's synonymy for *Sp*. *stabilis* includes species *e*.*g*. *Spathognathodus elongatus* and *Spathognathodus pulcher*, which some authors still consider as having independent status. The convention of Klapper was followed in this study. Matthews and Naylor (1973) and Carman (1987) report *Bispathodus stabilis* as ranging from the Upper Devonian to the Lower Carboniferous, as high as the *anchoralis*-*latus* Zone. Lane *et al*. (1980) extended the range of "*Bispathodus stabilis*" into the *texanus* Zone.

Material studied: The number of form elements of Bispathodus stabilis studied in the Kelly Limestone was 144 specimens.

Genus Polygnathus HINDE, 1879

Type Species: Polygnathus dubius HINDE, 1879

Polygnathus is a seximembrate genus. The Pa elements were most abundant in this study. Unfortunately only Pa elements remained intact and only fragments of other discrete elements were recovered.

The Pa element of Polygnathus has a posterior platform and an anterior free blade in most forms. The platform outline is lanceolate tapering toward the posterior tip. The aboral surface has a narrow, raised medial keel and a small circular pit.

Polygnathus cf. P. bischoffi RHODES, AUSTIN & DRUCE, 1969

1969 Polygnathus bischoffi sp. nov. - RHODES, AUSTIN & DRUCE, p. 184-185, pl. 13, figs. 8a-11c.

1981 Polygnathus bischoffi RHODES, AUSTIN & DRUCE - METCALFE, pl. 9, figs. 7a-b.

1984 Polygnathus bischoffi RHODES, AUSTIN & DRUCE - AUSTIN & DAVIES, pl. 1, figs. 22a-23.

1985 Polygnathus bischoffi RHODES, AUSTIN & DRUCE - ORCHARD & STRUIK, pl. 1, fig. 25.

1985 Polygnathus bischoffi RHODES, AUSTIN & DRUCE - VARKER & SEVASTOPULO, pl. 5.2, figs. 16-17.

Description: Symmetrical, lanceolate platform element, widest in anterior, possessing a medial nodose carina. Platform ornamented by delicate transverse ridges at lateral margins; shallow adcarinal grooves. Basal cavity small; circular in outline.

Discussion: This specimen is heavily coated with silica cement and details are extremely difficult to discern. Therefore, the primary basis for the comparison of this specimen with Polygnathus bischoffi is its outline or overall shape. It was recovered from the very base of the Ladron Member of the Kelly Limestone. The posterior end has been broken, but the anterior portion has some detail allowing it to be compared with P. bischoffi.

Material studied: One Pa element was studied from the lowermost Ladron Member of the Kelly Limestone.

Polygnathus communis communis BRANSON & MEHL, 1934b

For an earlier synonymy see Carman (1987).

1985 Polygnathus communis communis BRANSON & MEHL - ORCHARD & STRUIK, pl. 1, figs. 2, 16.

1985 Polygnathuscommunis communis BRANSON & MEHL - VARKER & SEVASTOPULO, pl. 5.1, figs. 12, 16-17.

1987 Polygnathus communis communis BRANSON & MEHL - CARMAN, p. 54-55, pl. 5, figs. 3-4.

Original Description (Branson and Mehl, 1934b): Tooth very small, plate thick in comparison with the size of the tooth, smooth on the oral surface, nearly oval in outline. Carina composed of about six small nodes which grade into the high, thin, wide denticles of the blade. Blade longer than the plate and made up of about thirteen denticles. Aboral side smooth with the exception of delicate concentric growth lines. Keel very sharp on the blade, decreasing in height from the front end to the pit, low back of the pit. Pit small but compared with the size of the plate larger than normal for the genus.

Revised Diagnosis (Chauff, 1981): Pa element of Polygnathus communis is characterized by a small depression just posterior of the pit. The anterior part of the platform is ornamented by nodose, transverse ridges in P.

communis *carina*, but is unornamented, except for the carina, in *P*. *communis* *communis*.

Description: The Pa element has a nodose medial carina on the oral surface of the platform. The anterior portion of the platform is smooth and unornamented. The anterior platform margins may be slightly upturned.

Discussion: The seximembrate nature of the multielement apparatus of *Polygnathus* was established, and its vicarious elements illustrated, by Klapper and Philip (1971 and 1972). Chauff (1981, p. 150, pl. 2, figs. 1-2, 7, 11-20) illustrated and described the vicarious elements of *Polygnathus* *communis* and *Pseudopolygnathus* *multistriatus* including element types Pb, M, Sa, Sb, and Sc.

This subspecies is particularly abundant in the interval described by the base of the Ladron Member to the base of the "silver pipe" of the Kelly Limestone. It is also abundant at the top of the Caloso Member in the Corkscrew Canyon section. Most platform elements had broken free blades.

Polygnathus *communis* *communis* is the most common and widely distributed of the subspecies of *Polygnathus* *communis* (Rexroad and Scott, 1964). It is generally held that the wide distribution of *P*. *communis* *communis* is due to its ecological position in the upper photic zone in ancient open seas as hypothesized by Seddon and Sweet

(1971). *Polygnathus communis communis* ranges from Late Devonian up to the Osagean (the lower part of the *texanus* - Zone of Lane *et al.*, 1980); however, one Pa element was recovered from the bryozoan-rich channel deposits of the uppermost Ladron Member which also produced *Cavusgnathus*, *Hindeodus cristulus*, and *Hindeodus scitulus*.

Material studied: Three hundred twenty eight specimens of *Polygnathus communis communis* were studied from the Kelly Limestone.

Polygnathus inornatus BRANSON, 1934

1934 *Polygnathus inornata* n. sp. - BRANSON, p. 309, pl. 25, figs. 8, 26.

Revised diagnosis (Thompson and Fellows, 1970): Slightly curved transversely ornamented platform with raised lateral margins in anterior half. Posterior portion more level, with low nodose carina extending just to posterior end. Basal cavity small, circular.

Discussion: The convention used in this report in assigning specimens of *Polygnathus inornatus* is that of Thompson and Fellows (1970) in which *P. inornatus* and *Polygnathus lobatus* represent the same species but are recognized as two subspecies of P. inornatus based on the presence or absence of the development of a lateral lobe.

Polygnathus inornatus inornatus (BRANSON), 1934

Plate I, Figure 33.

1934 Polygnathus inornata - BRANSON, p. 309, pl. 25, figs. 8, 26.

1934b Polygnathus inornata BRANSON - BRANSON & MEHL, p. 293, pl. 24, figs. 5-7.

1938 Polygnathus inornata BRANSON - BRANSON & MEHL, p. 146, pl. 33, fig. 15, 51-52.

1964 Polygnathus inornata E. R. BRANSON - REXROAD & SCOTT, p. 35, pl. 2, figs. 19-20.

1969 Polygnathus lobatus lobatus BRANSON & MEHL (sic) - RHODES, AUSTIN & DRUCE, p. 191-192, pl. 9, figs. 8a-c.

1969 Polygnathus inornatus vexatus sub. sp. nov. - RHODES, AUSTIN & DRUCE, p. 187-188, pl. 10, figs. 1a-3c.

1969 Polygnathus inornatus inornatus BRANSON & MEHL (sic) - RHODES, AUSTIN & DRUCE, p. 186, pl. 10, figs. 4-6.

1970 Polygnathus inornatus inornatus BRANSON (sic) - THOMPSON & FELLOWS, p. 94-95, pl. 3, figs. 2, 17-18.

1971 Polygnathus inornatus sensu BRANSON & MEHL - KLAPPER, p. 6-7, pl. 1, figs. 11-12.

1973 Polygnathus inornatus BRANSON - BUTLER, p. 503, pl. 59, figs. 6-7, 19-20.

1973 Polygnathus inornatus E. R. BRANSON - MATTHEWS & NAYLOR, p. 360-363, pl. 36, figs. 15-16.

1974 *Polygnathus inornatus* E. R. BRANSON - MATTHEWS & THOMAS, pl. 50, fig. 13.

1984 *Polygnathus inornatus* E. R. BRANSON - AUSTIN & DAVIES, pl. 1, figs. 24a-27b; pl. 2, figs. 31a-b; pl. 3, figs. 8a-b.

1985 *Polygnathus inornatus* E. R. BRANSON - VARKER & SEVASTOPULO, pl. 5.1, figs. 11, 14-15.

Original description (Branson, 1934): Plate small, about three times as long as wide; nearly bilaterally symmetrical, with axis very slightly curved laterally; free margins bent upward nearly vertical to the plane of the anterior half of the plate only slightly concave; free margins subparallel to about the posterior third, thence converging to a sharp posterior end which is continued beyond the plate proper by the combined carina and keel. In some specimens the outer margin is much higher than the inner. Platforms nearly smooth with faint transverse ridges at the crenulate free margins, by transmitted light apparent to the base of the carina as opaque bands. Carina high, broad, and rounded in its anterior half, low and narrow in the posterior half with sheathed nodes distinguishable only by transmitted light. Blade thin, about a fifth the length of the plate, top only slightly above the level of the anterior free margins and the carina; highest about mid-length, sharply rounded antero-posteriorly from the low anterior end through the highest point down to the carina without conspicuous offset; regularity of the oral edge broken by about four broad flat denticles. The aboral surface has a small circular pit near the anterior end of the plate with a narrow groove extending anteriorly and a sharp keel to the posterior end.

Revised diagnosis (Thompson and Fellows, 1970): Carina nearly straight to strongly curved inward. Anterior lateral margins of platform sharply upturned,leaving deep trough bordering carina. Posterior portion of platform weakly to strongly curved inward on outer lateral margin, nearly straight on inner lateral margin.

Discussion: Thompson and Fellows (1970) report both Polygnathus inornatus inornatus BRANSON and Polygnathus inornatus lobatus BRANSON & MEHL occurring together where they are recovered, transitional elements being common. The former is used to designate those forms not possessing a lateral lobe and rostral ridge.

Material studied: Thirty two Pa elements of Polygnathus inornatus inornatus were studied from the lower wackestones and packstones of the Caloso Member of the Kelly Limestone.

Polygnathus inornatus lobatus (BRANSON & MEHL), 1938

Plate I, Figure 37.

1938 *Polygnathus lobata* n. sp. - BRANSON & MEHL, p. 146, pl. 34, fig. 44-47.

1964 *Polygnathus lobata* BRANSON & MEHL - REXROAD & SCOTT, p. 35-36, pl. 2, figs. 15-16.

1966 *Polygnathus inornatus* BRANSON - KLAPPER, p. 19-20, pl. 1, figs. 7-14; pl. 4, figs. 2-4.

1969 *Polygnathus lobatus lobatus* BRANSON & MEHL (sic) - RHODES, AUSTIN & DRUCE, p. 191-192, pl. 9, figs. 5a-7c.

1969 *Polygnathus lobatus inflexus* subsp. nov. - RHODES, AUSTIN & DRUCE, p. 192, pl. 9, figs. 9a-c.

1969 *Polygnathus inornatus rostratus* subsp. nov. - RHODES, AUSTIN & DRUCE, p. 187, pl. 10, figs. 7a-9c.

1970 *Polygnathus inornatus lobatus* (BRANSON & MEHL (sic) - THOMPSON & FELLOWS, p.95, pl. 3, figs. 12, 16, 19.

1973 *Polygnathus inornatus* E. R. BRANSON - MATTHEWS & NAYLOR, p. 360-363, pl. 36, figs. 1-2.

1984 *Polygnathus inornatus* E. R. BRANSON - AUSTIN & DAVIES, pl. 1, figs. 28a-b.

Original diagnosis (Branson and Mehl, 1938): Axis sinuous, anterior two-thirds broadly concave inward. Plate thick, nearly bilaterally symmetrical, about twice as long as wide; posterior end acutely pointed, longitudinally arched; posterior third flat transversely or cupped; markedly depressed in the anterior half between the lateral margins and the carina to produce a deep rounded groove on either side of the latter; margins nodose. The outer flange of the plate (convex side of curved axis) extends further forward than the other; in oral view it is straight in its front three-fourths and sharply bent directly orad [sic.] to produce a high parapet with a flat outer side; a marked tendency toward the development of a postero-laterally extending point or lobe at its back end; inner flange with straight or sinuous margin that is not greatly upturned; both flanges marked by rounded transverse ridges or aligned nodes that become smaller toward the carina. Carina strong, consisting of closely spaced or confluent, coarse rounded nodes. Blade very short, abruptly offset above the carina and rounding down to an antero-aboral angle of less than 90 degrees. Aboral side of plate transversely rounded, with a strong, longitudinally groved [sic.] keel that is bent laterally at the pit (concave inward) with straight anterior and posterior sections; pit of moderate size.

Revised diagnosis (Thompson and Fellows, 1970): Narrow shelf or lobe extends laterally outside of outer lateral margin on anterior portion of platform, separated from platform proper by upturned margin or "rostral ridge."

Discussion: The posterior platform of *Polygnathus inornatus lobatus* is flatter than *Polygnathus inornatus inornatus*; posterior adcarinal grooves are shallow. The medial carina ends just short of the posterior tip, disappearing within the transverse ridges of the posterior platform. Figure 33 of Plate I is a specimen which may be an example of a gerontic *P. inornatus lobatus* Pa element (personal communication, H. R. Lane).

Polygnathus lobatus BRANSON & MEHL, 1934b was argued to be a junior synonym of *Polygnathus inornatus* BRANSON, 1934 by Voges (1959) and Klapper (1966; 1971) based on the premise that the former's description conforms to the illustrated specimens of *P. inornatus* in Branson (1934). In addition, Klapper (1971) claims Branson & Mehl (1934b) mistakenly used the term "lobe" as employed in conodont terminology when they described *P. lobatus*. Klapper (1966; 1971), however, failed to offer a proposal on the name which *P. inornatus* sensu BRANSON & MEHL should finally receive. In Klapper (1966, pl. 1, figs. 7-8) he offered no proper identity for this specimen. Matthews and Naylor (1973) further go on to say that based on Klapper's (1971) assignment of *P. inornatus* E. R. BRANSON for the specimen figured in Klapper (1966, pl. 1, figs. 9-10), it should follow that *Polygnathus bischoffi* RHODES, AUSTIN & DRUCE should be referred to as *P. inornatus* E. R. BRANSON.

Material studied: Three Pa elements of *Polygnathus inornatus lobatus* were studied from the lower Caloso Member of the Kelly Limestone.

Genus *Pseudopolygnathus* BRANSON & MEHL, 1934b

Type Species: *Pseudopolygnathus primus* BRANSON & MEHL, 1934b

Pseudopolygnathus oxypageous LANE, SANDBERG, & ZIEGLER, 1980.

Plate I, Figures 40 and 41.

For an earlier synonymy see Lane *et al*. (1980).

1938 *Polygnathus corrugata* E. R. BRANSON - BRANSON & MEHL, pl. 33, fig. 26.

1980 *Pseudopolygnathus oxypageous* n. sp. - LANE, SANDBERG & ZIEGLER, p. 136, pl. 7, figs. 1, 6, 9; pl. 8, figs. 4-7, 9; pl. 9, figs. 1, 13; pl. 10, fig. 4.

1985 *Pseudopolygnathus oxypageous* LANE, SANDBERG & ZIEGLER - BELKA, pl. 12, figs. 4-7.

Diagnosis (Lane *et al*., 1980): A triangular-shaped species having a transverse-ridged posteriorly tapering platform and displaying Class II symmetry.

Discussion: Platform margins are ornamented by transverse ridges which may occasionally reach the medial nodose carina. Flared basal pit located anteriorly, just behind the posterior end of the free blade.

Three morphotypes were recognized by Lane *et al*. (1980). Morphotype 1 (Plate I, Figure 41) has a narrow platform, the carina extending beyond the posterior end of the platform proper. Morphotype 2 (Plate I, Figure 40) has a flat, thin triangular platform. Morphotype 3 (which was not recovered from the Kelly Limestone) has a conspicuously thick platform and large basal cavity.

The stratigraphic range of this species begins at the base of the Upper *typicus* Zone through the lower *anchoralis*-*latus* Zone (Lane *et al*., 1980, fig. 3; Table 3).

Material studied: One Pa element of *Pseudopolygnathus oxypageous* M1 was studied and two Pa elements of *Pseudopolygnathus oxypageous* M2 were studied from the Kelly Limestone.

Superfamily UNKNOWN
Family UNKNOWN

Genus Apatognathus BRANSON & MEHL, 1934a

Type species: *Apatognathus varians* BRANSON & MEHL, 1934a

Apatognathus geminus (HINDE), 1900

Plate I, Figure 11.

The concept of *Apatognathus geminus* in this report follows that of Rhodes *et al*. (1969, p. 70, fig. 18).

1900 *Prioniodus geminus* new species - HINDE, p. 344, pl. 10, fig. 25.

1928 *Prioniodina*? *gemina* (HINDE) - HOLMES, p. 19, pl. 5, fig. 10.

1960 *Apatognathus geminus* (HINDE) - CLARKE, p. 4, pl. 1, figs. 1-2.

1963 *Apatognathus gemina* (HINDE) - REXROAD & COLLINSON, p. 7-8, pl. 1, figs. 12-17.

1969 *Apatognathus geminus* (HINDE) - RHODES, AUSTIN & DRUCE, p. 71-72, pl. 20, figs. 3a-4b and 6a-7b.

Original Description (Hinde, 1900): Basal portion consisting of two straight or slightly curved arms, carrying minute denticles often unequal in size; the arms meet at an acute angle, and at the apex is a large, compressed, double-edged denticle.

Description (Rhodes, Austin and Druce, 1969): The most distinctive features of this species are the prominent apical denticle and the large size of two denticles on the anterior bar adjacent to that denticle. The whole unit is strongly recurved and strongly laterally flexed, so that in outer lateral view the aboral surface is visible along almost the whole length of the unit. Both bars are strongly flexed inwards so that the denticles appear to radiate away from the apical junction. The anterior bar is relatively short and straight with a flat outer lateral face. It bears up to 7 denticles, not including the apical denticle, and these are basally confluent but apically discrete. Their outer lateral faces are strongly convex and they have sharp anterior and posterior edges and they decrease in size towards the anterior tip. The apical denticle is about twice as long as the largest of the denticles of the anterior bar. It is inclined posteriorly and is paralleled by the denticles of the anterior bar; it is straight with a very strongly convex outer lateral face and sharp anterior and posterior edges; it is not expanded on the outer aboral margin. The posterior bar is very slightly shorter than the anterior, and its denticles are conspicuously smaller; they are of more or less subequal height and they are about 7 in number. They are basally confluent but apically discrete with sharp anterior and posterior edges and feebly to gently convex outer lateral faces; these are less conspicuously convex than the faces of the faces of the anterior denticles; on the outer lateral aboral margin of the posterior bar there is a more or less conspicuous longitudinal ridge developed parallel to the base... . The angle of divergence of the two bars when viewed from the outer lateral side is about 30°-40°; they are also less strongly flexed inwardly and join each other at an angle of about 40° in the inner lateral view, in such a way that the denticles of the posterior bar are erect and those of the anterior bar point outwards towards the observer. The bars are strongly flexed inward and the denticles curve inward, as well as posteriorly; the denticles of the posterior bar are inclined anteriorly and tend to parallel the main denticle. The inner lateral faces of both the anterior and posterior bars are flat and a rather beveled aboral edge is developed from them, excavated throughout its length by a narrow, slit-like cavity, which does not increase markedly in size below the apical denticle.

Discussion: The large denticle on the posterior limb slightly anterior to its midpoint distinguishes *Apatognathus geminus* from *Apatognathus porcatus*.

Material studied: Five specimens were studied from the Ladron Member of the Kelly Limestone.

Apatognathus porcatus (HINDE), 1900

Plate I, Figure 12.

1900 Prioniodus porcatus new species - HINDE, p. 344, pl. 10, fig. 26.

1960 Apatognathus porcatus (HINDE) - CLARKE, p. 5, pl. 1, figs. 3-4.

1963 Apatognathus? porcata (HINDE) - REXROAD & COLLINSON, p. 8, pl. 1, figs. 7-11.

1969 Apatognathus porcatus (HINDE) - RHODES, AUSTIN & DRUCE, p. 73-74, pl. 31, fig. 27.

1979 Apatognathus porcatus (HINDE) - RUPPEL, pl. 1, fig. 12.

Original Description (Hinde, 1900): Tooth with a short, narrow, somewhat compressed base, which carries five or six minute, conical, obliquely placed denticles, and is terminated by a slightly curved, conical, acutely pointed larger denticle, which projects obliquely forwards.

Discussion: Rhodes et al. (1969) disagree with Rexroad and Collinson regarding Apatognathus porcatus based on the premise that the anterior bar in the latter's illustrations does not appear strongly laterally expanded. According to

Rexroad and Collinson, during ontogenetic development the angle between the two limbs, when viewed laterally, tends to increase, and at the same time the limbs become less barlike and more bladelike, while the denticles along one limb near the apical denticle tend to lengthen more than the remaining denticles.

Material studied: Five specimens were studied from the Ladron Member of the Kelly Limestone.

Genus *Cudotaxis* CHAUFF, 1981

Type species: *Cudotaxis priceslingi* CHAUFF, 1981

Cudotaxis priceslingi CHAUFF, 1981

Plate I, Figure 38.

1981 *Cudotaxis priceslingi* n. sp. - CHAUFF, p. 151-152, pl. 3, figs. 25-26, 28, 30-32[Pa element].

1987 *Cudotaxis priceslingi* CHAUFF - CARMAN, p. 51, pl. 2, figs. 13, 15-17.

Diagnosis (Chauff, 1981; Pa element only): Large unornamented basal cavity extends to posterior tip. Upper posterior and anterior margins are straight. Lower margin is concave down, the anterior portion of the blade situated well below the position of the basal cavity.

Discussion: Chauff (1981) reported the occurrence of *Cudotaxis priceslingi* at just below to just above the *Doliognathus latus* Zone. Carman (1987) found *C. priceslingi* just above the last occurrence of *D. latus* in the *anchoralis*-*latus* Zone in the Lake Valley Formation in the Sacramento Mountains of New Mexico.

Material studied: Twenty four Pa specimens of *Cudotaxis priceslingi* were studied from the Kelly Limestone.

"*Spathognathodus*" *linguiferus* (BRANSON), 1934

Plate I, Figure 39.

1934 *Spathodus linguiferus* n. sp. - BRANSON, p. 306-307, pl. 27, fig. 24.

1979 *Spathognathodus* sp. B - RUPPEL, p. 68, pl. 2, fig. 20.

Original Description (Branson, 1933): Blade of medium thickness, gently curved laterally, concave inward, outline of oral edge viewed laterally regularly sloping upward from the rounded posterior margin to the slightly higher convex anterior fourth, which is highest about mid-length. Anterior margin straight, forming an angle of slightly less than 90 degrees with the lower margin. Aboral outline very slightly arched antero-posteriorly through mid-length. Navel shallow, somewhat longer than wide with broadly flaring lateral lips, about mid-length in position. Germ denticles evident in transmitted light throughout the length of the blade; most of them continue to discrete oral edge terminations, those of the mid-third discrete only at their tips; denticles subequal in size except those of the anterior third, which are larger. On the inner side of the blade there is a coarse orally directed process discrete from the side of the blade above the flared lateral lip of the navel; through mid-length of the outer side of the blade is thickened by the lateral expansion of some of the regular oral edge series of denticles, giving to that part of the blade a distinct cross-ridged appearance.

Discussion: Ruppel (1979) describes and illustrates a specimen almost identical to Branson's (1933) Spathodus linguiferus. The following is Ruppel's description for Spathognathodus linguiferus:

> Unit narrow,long, and bears more than 13 denticles which are apparently subequal in size, except for posterior-most two which are much larger and more elongate. Unit mostly straight in lateral view except for slight arch in aboral outline at basal cavity. Basal cavity very small, lanceolate to subcircular, symmetrical, and takes up one-third or less of specimen. A lateral denticle is present on inner side of specimen above basal cavity.

In this investigation both Spathodus linguiferus BRANSON and Spathognathodus sp. B RUPPEL are considered the same species.

Material studied: Five specimens of "Spathognathodus" linguiferus were studied from the upper Caloso Member to the lower Ladron Member of the Kelly Limestone.

"Spathognathodus" deflexus BRANSON & MEHL, 1941

Plate I, Figure 25.

1941 Spathognathodus deflexus n. sp. - BRANSON & MEHL, p. 187, pl. 6, fig. 6.

1974 "Spathognathodus" deflexus BRANSON and MEHL - BRENCKLE, LANE & COLLINSON, fig. 3, no. 19.

Original Description (Branson and Mehl, 1941): Blade arched, thin, comparatively narrow, straight except for an inward bend of the lower posterior end back of the cup. Denticles small, compressed, confluent except for short blunt apices. Navel well back of mid-length, deeply excavated to a sharp point, outline elongate, chiefly anteriorly, with pointed extremities extending along the edge of the blade as a faint groove, lateral margins thin and laterally extended. Anterior terminus not known.

Discussion: Specimens from the Kelly Limestone tend to be delicate and fragile. Anterior terminus of blade almost at a right angle with basal outline in lateral view. Basal cavity is asymmetrical, more widely flared on outer margin.

This form taxon was recovered only from the upper crinoidal facies of the Ladron Member.

Material studied: Fourteen specimens of this element were studied from the Ladron Member of the Kelly Limestone.

"*Spathognathodus*" n. sp.

Plate II, Figures 1, 2, 3, 4, and 5.

Description: A robust spathognathodid with a thick, stout blade. The blade consists of 12-13 denticles fused nearly to the apices. In gerontic specimens all but the anteriormost denticles are fused to form an irregular oral outline when viewed laterally. The first two or three denticles are the most prominent; denticles gradually diminish in height posteriorly. The blade is about one-half to one third as high as it is long, and its upper portion progressively thickens posteriorly. A gnathodid-like cup occupies about one-fourth to one-fifth the length of the element in a position just posterior of mid-length terminating well short of the posterior tip of the blade. The cup is asymmetrical in oral view. Both inner and outer lateral cup margins are indented similar to the lateral cup margins of *Gnathodus punctatus*. The upper surface of the inner cup is smooth or may have a single node situated anteriorly. One or two cross ridges of fused nodes are situated on the surface of the outer cup and may extend to the carina obliquely or perpendicularly. The fused row of nodes is straight to irregular in oral view. The basal cavity is asymmetrical in aboral view extending just anterior of mid-length and stops well short of the posterior tip of the blade. The basal pit is just posterior of mid-length. The inner margin of the basal cavity extends farther laterally from the basal pit than does that of the outer cup margin. Conspicuous concentric growth lines are observed within the basal cavity and along the surfaces of the extreme lateral cup margins.

Discussion: Most specimens were comparable in size to the herein illustrated specimens of "Spathognathodus" linguiferus. One gerontic specimen was recovered and is notably more robust. It is observed that during early ontogenetic development denticles are not fused nearly to their apices; cup ornamentation is not as pronounced; cross ridges are less likely to extend to the carina; growth lines are not as conspicuous. The comparison of these specimens to "Sp." linguiferus may be more than appropriate if one considers the possibility that these may be the same species and that the latter may represent a stage of early ontogenetic development.

Material studied: Eight Pa elements were studied from the upper Caloso Member and lower Ladron Member of the Kelly Limestone.

PLATE I

All photos are approximately X 30 unless otherwise noted. Sample numbers are in parentheses in figure descriptions.

Figures 1 and 2. *Gnathodus typicus* COOPER.
1. *Gnathodus typicus* Morphotype 1, oral view, x45. (LM-8a).
2. *Gnathodus typicus* Morphotype 2, oral view, x75. (LM-8b).

Figure 3. *Protognathodus praedelicatus* LANE, SANDBERG & ZIEGLER. Oral view. (CG-14b).

Figures 4, 6, and 7. *Gnathodus delicatus* BRANSON & MEHL.
4 and 7. Oral view. (KG-13a).
6. Oral view. (LM-7b).

Figure 5. *Gnathodus cuneiformis* MEHL & THOMAS. Oral view. (KG-13a).

Figure 8. *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS. Oral view. (CC-9i).

Figure 9. *Gnathodus semiglaber* BISCHOFF. Oral view. (CC-9g).

Figure 10. *Gnathodus texanus* ROUNDY. Oral view. (CG-16a).

Figure 11. *Apatognathus geminus* (HINDE). Oral view. (KG-17a).

Figure 12. *Apatognathus porcatus* (HINDE). Oral view. (KG-19a).

Figure 13. *Taphrognathus* - *Cavusgnathus* transition. Oral view. (KG-16b).

Figure 14. *Taphrognathus varians* BRANSON & MEHL. Oral view. (KG-17b).

Figure 15 and 16. *Hindeodus scitula* (HINDE), x37.5. (KG-19a).
15. Left lateral view.
16. Aboral view.

Figure 17. *Gnathodus* cf. *G*. *punctatus* (COOPER). Oral view. (LM-7b).

Figure 18 and 19. Anchignathodus penescitulus (REXROAD & COLLINSON), x37.5. (LM-7b).
18. Left lateral view.
19. Aboral view.

Figure 20 and 21. Hindeodus cristulus (YOUNGQUIST & MILLER), x37.5. (LM-10d).
20. Left lateral view.
21. Aboral view.

Figure 22 and 23. Patrognathus variabilis RHODES, AUSTIN & DRUCE.
22. Right lateral view. (LM-2a).
23. Aboral view. (CG-4).

Figure 24. Cavusgnathus convexus REXROAD. Left lateral view. (KG-17b).

Figure 25. "Spathognathodus" deflexus BRANSON & MEHL. Left lateral view. (CG-16a).

Figure 26. Cavusgnathus unicornis YOUNGQUIST & MILLER. Left lateral view. (LM-10d).

Figure 27 and 28. Cavusgnathus regularis YOUNGQUIST & MILLER. (KG-19a).
27. Oral view.
28. Left lateral view.

Figure 29. Bispathodus aculeatus plumulus (RHODES, AUSTIN & DRUCE. Right lateral view. (CH-3a).

Figure 30. "Spathognathodus" abbreviatus. Right lateral view. (LM-7b).

Figures 31 and 32. Cavusgnathus charactus REXROAD. (KG-17b).
31. Oral view.
32. Right lateral view.

Figure 33. Polygnathus inornatus inornatus (BRANSON). Oral view. (CH-3a)

Figures 34 and 35. Cloghergnathus carinatus HIGGINS & VARKER. (CC-9i).
34. Right lateral view.
35. Oral view.

Figure 36. Bispathodus stabilis BRANSON & MEHL. Right lateral view. (CG-13d).

Figure 37. *Polygnathus inornatus lobatus* (BRANSON & MEHL). Oral view. (CH-4a).

Figure 38. *Cudotaxis priceslingi* CHAUFF. Left lateral view. (CG-13d).

Figure 39. "*Spathognathodus*" *linguiferus* (BRANSON). Right lateral view. (LM-7b).

Figures 40 and 41. *Pseudopolygnathus oxypageous* LANE, SANDBERG & ZIEGLER.

40. *Pseudopolygnathus oxypageous* Morphotype 2. Oral view. (LM-7b).

41. *Pseudopolygnathus oxypageous* Morphotype 1. Oral view. (CG-14b)

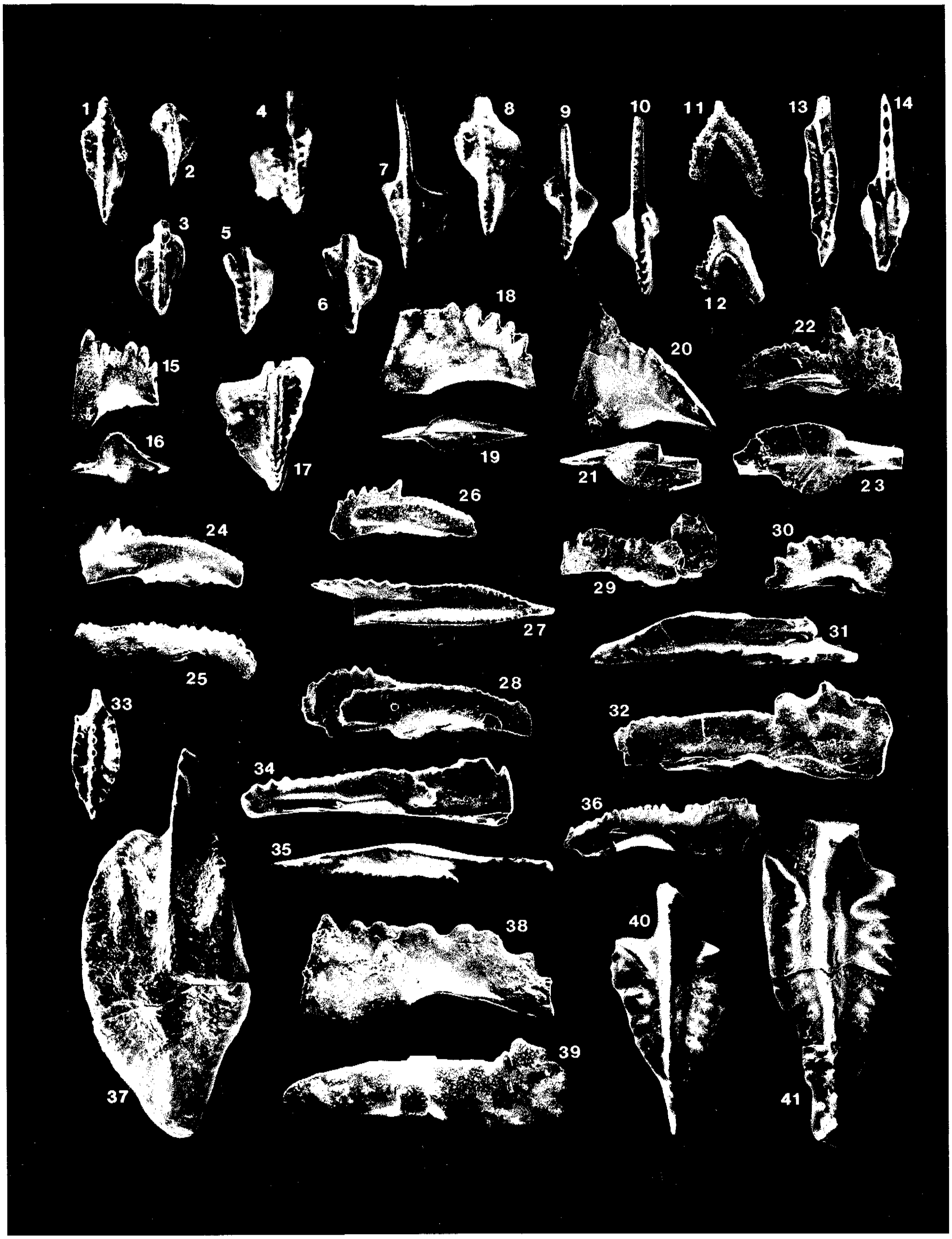

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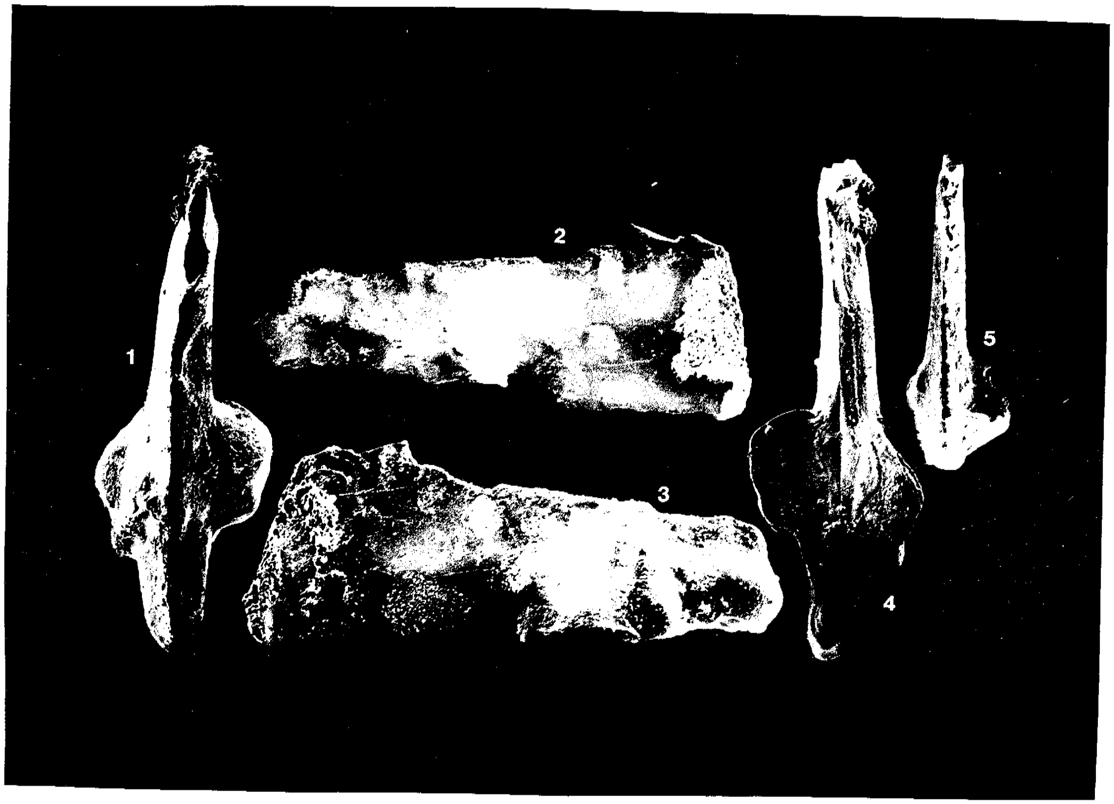
PLATE II

Figures 1, 2, 3, 4, and 5. "*Spathognathodus*" n. sp., x27.

1. Oral view. (CG-13d).
2. Right lateral view. (CG-13d).
3. Left lateral view. (CG-13d).
4. Aboral view. (CG-13d).
5. Oral view. (LM-7b).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APPENDIX I: STRATIGRAPHIC SECTIONS

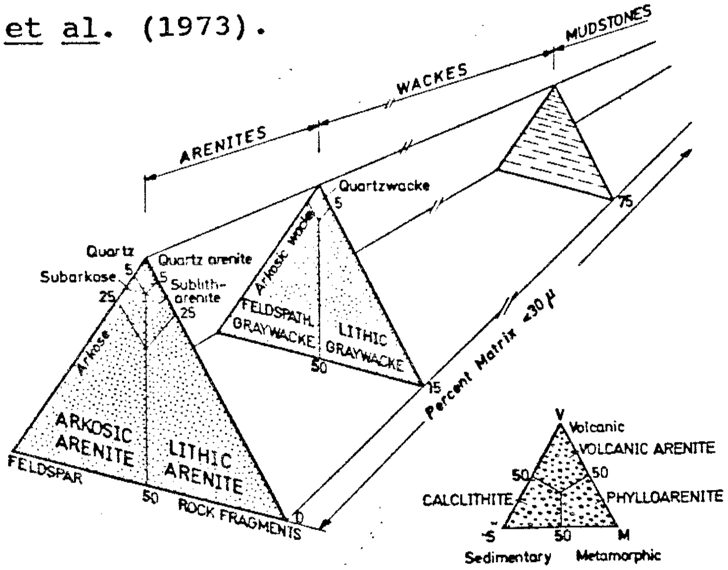
Description of terms used in measured stratigraphic sections. Carbonate mudrocks distinguished with the modifier "lime."

Carbonate Rock Classification: hand-sample description of outcrops based on Dunham (1962).

CLASSIFICATION ACCORDING TO DEPOSITIONAL TEXTURE

DEPOSITIONAL TEXTURE				
Original components not bound together during deposition				Original components were bound together during deposition ... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.
Contains mud (particles of clay and fine silt size)			Lacks mud and is grain supported	
Mud supported		Grain supported		
Less than 10 per cent grains	More than 10 per cent grains			
Mudstone	Wackestone	Packstone	Grainstone	Boundstone

Terrigenous Sandstone Classification: handsample description of outcrop based on Dott (1964) as modified in Pettijohn et al. (1973).



Terrigenous Mudrock Classification based on Blatt *et al.* (1972):

Ideal Size	Qualitative/Field Criteria	Nonfissile Mudrock
2/3 silt	abundant silt visible with handlens	siltstone
1/3-2/3 silt	feels gritty when chewed	mudstone
1/3 silt	feels smooth when chewed	claystone

The term shale is used as defined in Bates and Jackson (1980):

> A fine-grained detrital sedimentary rock, formed by the consolidation (esp. by compression) of clay, silt or mud. It is characterized by finely laminated structure, which imparts a fissility approximately parallel to the bedding, along which the rock breaks readily into thin layers and that is commonly most conspicuous on weathered surfaces, and by an appreciable content of clay minerals and detrital quartz; a thinly laminated or fissile claystone, siltstone, or mudstone... (p. 573).

Grain Size based on Wentworth's (1922) particle size grade scale for clastic constituents, and on Folk's (1959) nomenclature when describing authigenic constituents of limestones:

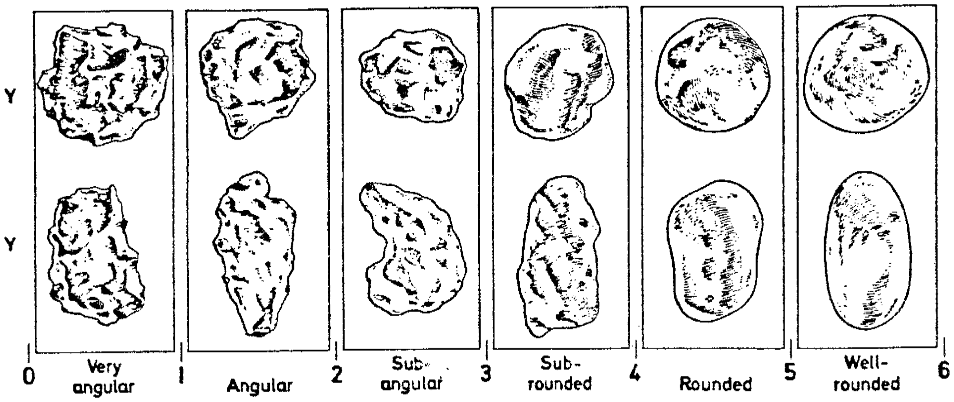
Wentworth Size Grade	Diameter of Grain (mm)
Boulder	greater than 256
Cobble	64 - 256
Pebble	4 - 64
Granule	2 - 4
very coarse sand	1 - 2
coarse sand	0.50 - 1
medium sand	0.25 - 0.50
fine sand	0.125 - 0.25
very fine sand	0.0625 - 0.125
silt	0.0039 - 0.0625
clay	less than 0.0039

Folk Size Class	Diameter of Grain (mm)
extremely coarsely crystalline	4 - 256
very coarsely crystalline	1 - 4
coarsely crystalline	0.25 - 1
medium crystalline	0.062 - 0.25
finely crystalline	0.016 - 0.062
very finely crystalline	0.004 - 0.016

Sorting: based on Kottlowski's (1965) qualitative classification.

Grain Size Distribution	Sorting
- 3 grain size grades or less present	well sorted
- most grains in 4 grain size grades	moderately sorted
- most grains in 5 or more grain size grades	poorly sorted

Roundness is based on images and classes of Powers (1953) and redrawn in Pettijohn *et al*. (1973):



Bedding Thickness is based on the scale of stratification thickness of Blatt *et al*. (1972) after Ingram (1954):

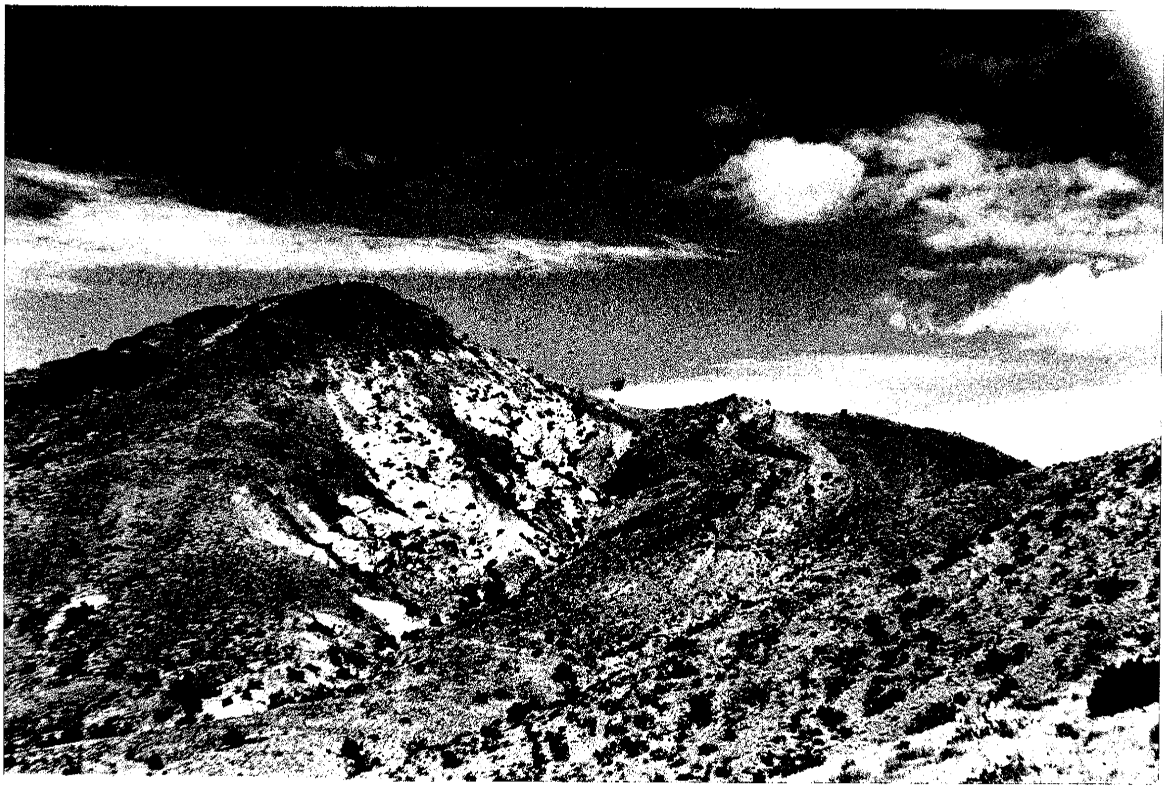
Scale of Stratification	Thickness (cm)
very thickly bedded	thicker than 1m
thickly bedded	30 - 100
medium bedded	10 - 30
thinly bedded	3 - 10
very thinly bedded	1 - 3
thickly laminated	0.3 - 1
thinly laminated	thinner than 0.3

Semiquantitative Frequency Estimates are based on comparison images/charts of Compton (1962) after Terry and Chilingar (1955).

Stratigraphic Sections

Chupadera Peak Section (Coyote Hills)

Location:	Indian Well Wilderness Quadrangle
	North Latitude 33 51′ 30″
	West Longitude 106 56′ 42″



Outcrop Photo: Sinuous hogback ridge (right-central portion of photo) capped by Kelly Limestone. View is looking west. Chupadera Peak is to the left.

This stratigraphic section is located in the Coyote Hills of U. S. Fish and Wildlife Service Indian Well Wilderness Area. Access is limited to horseback and hiking. The Mississippian section faces north along an east-west trending hogback ridge. The outcrop is about 500 m long. It is easy to spot from U. S. Interstate Highway I-25 because it is the only limestone exposure in the vicinity.

This terrain is composed mostly of volcanics and crystalline igneous rocks. The Kelly Limestone is at 5900 ft elevation. Parking near the 134-mile marker on I-25 provides the shortest hike (about 2 mi or 3.2 km) to the Kelly. The walk is a gradual westward traverse up 1000 ft of pediment slope. The climb up the hogback itself, however, may be dangerous because it is steep and covered with volcanic talus. Also, the talus on the flanks of the hogback provide habitat and shelter for rattlesnakes.

Notes: Only the Caloso Member of the Kelly Limestone is present here. The section was measured at the western extent of the hogback ridge because it contains the thickest exposure. Also, this place allows a straight line traverse with the Jacob staff and measuring tape directly up dip.

Field Unit	Lithologic Description	Thickness (cm)
	The top of the Mississippian stratigraphic section is an erosional surface or is covered by Tertiary volcanics. Limestone debris of pebble to boulder size is incorporated into the rubble zone of these volcanic flows. The nature of the contact between the volcanics and the Caloso Member is abrupt and irregular.	

Dissolution cavities towards the top of the Caloso are filled with volcanic rock, as are joints and fractures.

6 Lime mudstone. Weathered surface is grayish brown to dark gray; fresh surface is dark gray. Unit is tabular; thinly laminated to very thinly bedded; a cliff former. In some places lime mudstone grades into arenaceous quartz lime mudstone; well-rounded, fine-grained quartz may compose up to 5% of rock. Small calcite-filled vugs (3 mm) are occasionally observed. 692

Contact with unit below is abrupt and irregular.

5 Alternating nodular lime mudstone and nodular wackestone. Weathered surface is mottled light gray and pink; fresh surface is mottled light and medium gray. Unit is tabular; very thinly to thinly bedded; a slope former. Grains in wackestone are well-rounded, fine sand size, fossil debris and possible coated grains (rock does not break 60

across these grains). Nodules are a product of weathering and range up to 15 mm.

Contact with unit below is gradual from crinoidal packstone to nodular lime mudstone.

4 Alternating crinoidal grainstones and 808
crinoidal packstones. Weathered and
fresh surfaces are light gray. Unit is
tabular; wavy, thinly to medium bedded;
a cliff former. Grains are nearly 100%
crinoid columnals; occasionally some
rounded or coated grains are observed
(packstones) as is unidentifiable
fossil debris (grainstones). Columnals
range in size from fine sand to pebble
size; average size is the lower limit
of coarse sand.

Contact with unit below is abrupt and planar but irregular in places.

3 Silty lime mudstone. Weathered surface 233
is brown; fresh surface is pink to red.
Unit is tabular; thinly to medium

bedded; conspicuous dissolution cavities ranging in size up to 2 m; a slope former. Rock composed up to 20% quartz grains ranging from silt to fine sand; a rare small pebble of granite may be observed. Occasional blebs of disseminated chert observed up to 2 mm across. Grains of quartz are rounded to well-rounded. No fossils observed.

Contact with unit below is abrupt and planar to slightly undulating.

2 Quartz arenite. Weathered surface is pink to red; fresh surface is white. Unit is tabular; thinly bedded with planar cross-bedding; a cliff former. Lower 40 cm is 100% quartz grains; pink blebs of clay rarely occur (probably weathered feldspar grains). Upper 10 cm is arkosic arenite with 66-67% quartz; up to 30% feldspar; 3-4% lithic fragments. Grains are medium sand to granule size with an occasional small quartz pebble. Rounded to subrounded; moderately to poorly sorted; very well 50

indurated; silica and calcium carbonate cement.

Contact with unit below is abrupt and planar.

1 Quartz arenite. Weathered surface is pink to red; fresh surface is white. Unit is tabular; planar cross-bedding; a cliff former. Quartz grains are 97-98%; feldspar 2-3% (most badly weathered); lithic fragments much less than 1%. Particles are very fine to fine sand occasionally ranging up to medium sand; subrounded; moderately sorted; very well indurated; silica cement. 175

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Contact at nonconformity between Mississippian section and Precambrian crystalline quartzo-feldspathic igneous rock is sharp and irregular. The basal quartz arenite of the Caloso Member has a green tint on both fresh and weathered surfaces which contrasts the red and gray color of the entire outcrop.

Chihuahua Gulch Section (Magdalena Mountains)

Location: Magdalena Quadrangle
NE 1/4 sec. 6, T. 3 S., R. 3 W.

Outcrop Photo: Kelly Limestone cliffs in Chihuahua Gulch (central portion of photo). Photo was taken at about 8500 ft elevation. The view is of the south-facing wall near the head of the gulch.

Outcrops of Kelly Limestone extend about four miles (6.4 km) along the crest of the Magdalena Mountains, from North Peak (Tip Top Mountain) to North Baldy. North Peak is about four miles (6.4 km) east of the town of Magdalena. Excellent exposures occur along the crest. The type section for the Ladron Member is situated along the crest, about 1500 m south of North Peak. Most of the land here is within the confines of Cibola National Forest. To get to the Magdalena Mountains, take U. S. Highway 60 west from Socorro to the town of Magdalena (about 25 miles or 40 km). Head east at the U. S. Forestry Station in Magdalena. Where the paved road ends, head southeast (taking the left fork in the road). This improved dirt road leads to the ghost town of Kelly, about 4 miles (6.4 km) from the forestry station cut-off. Any number of unimproved dirt roads and jeep trails will lead to the crest. When hiking, stick to established trails since heavy vegetation, talus slopes, and debris-slide tracks will impair one's progress. The best exposures of Kelly Limestone occur along the northern half of the outcrop. Towards the south the Mississippian becomes progressively more silicified. At North Baldy most of the Mississippian limestone section has been replaced by silica (Iovenitti, 1978).

The Chihuahua Gulch stratigraphic section is located at an elevation of about 9000 ft; just below the crest of the Magdalena Mountains. The outcrop is exposed along the south-facing wall of the gulch. This section is dangerous in spots due to talus slopes, debris-slide tracks, and steep (45 degrees) dip slopes. Access is via U. S. Forestry Service unimproved road. Head south past the Kelly church, and where the road forks, bear southeast (left). Four-wheel drive is needed to negotiate the rutted, steep grade. The road will level off briefly. Take the bulldozed trail which heads north (left). The trail ends at an abandoned prospect pit. Climb up along the top of the limestone and quartz cliff until it coincides with the Kelly Limestone dip slope. Down below and along the talus slope is the base of the Mississippian section.

Notes: The western slopes of the Magdalena Mountains are composed of Mississippian limestone dip slopes. This section was measured along the northern wall of Chihuahua Gulch, which dissects these dip slopes. Measurement proceeded up a series of small cliffs in a stepwise fashion. The outcrop is well exposed but some lateral translation along well-defined bedding planes was necessary due to vegetation, soil, and rock debris cover. Varying degrees of silicification occur in these rocks but it is particularly evident along fractures and joints. Footing is treacherous on portions of dip slope where caliche deposits have transformed the normally irregular bedding plane surfaces into very smooth, slick surfaces.

Field Unit	Lithologic Description	Thickness (cm)
	Top of the Mississippian stratigraphic section is an erosional surface.	
16	Crinoidal grainstone. Weathered and fresh surfaces are light gray to grayish brown ; medium gray in spots. Unit is tabular; wavy, thinly to thickly bedded; a cliff former.	450

Crinoid columnals make up 90% of rock's composition with up to 10% composed of varying amounts of brachiopod shells, rugose corals, bryozoans, and unidentifiable fossil debris. Average grain size is 5 mm; matrix is coarse crystalline calcite. Laterally, in places, grainstone grades into crinoidal packstone. Chert nodules are conspicuous in this unit. Nodules are white to pink in color; lozenge-shaped (up to 1 m long and 10 cm thick). Quartz and barite are precipitated in dissolution cavities and joints.

Contact with unit below is covered.

15 Dolomitic mudstone. Weathered surface is light to medium brown; dark gray on fresh surface. Unit is tabular; thinly to medium bedded; a cliff former. Only a very rare, singular crinoid ossicle may be found on a weathered surface. 30

Contact with unit below is covered.

14 Crinoidal grainstone. Weathered and 203

fresh surfaces are a light medium gray. Unit is tabular; medium to thickly bedded; a cliff former. Up to 95% of grains are crinoid columnals with lesser amounts of brachiopod shells, rugose corals, bryozoans, trilobites and unidentifiable fossil debris. Occasionally fossils at weathered surfaces are replaced by pink or flesh tone silica. Average grain size is 2-3 mm; matrix is coarsely crystalline calcite. Laterally, in places, crinoidal grainstone grades into crinoidal packstone.

Contact with unit below is abrupt and undulating.

13 Fossiliferous arenaceous lime mudstone. Weathered surface is light gray; fresh surface is dark gray. Unit is tabular; wavy, medium to thickly bedded; a cliff former. Matrix is lime mudstone (10-80%). Fossils compose 1-5% of the rock. Crinoid ossicles are most abundant followed by rugose corals, brachiopod shells, unidentifiable 10

fossil fragments, and shark teeth and other fish bones. Quartz grains compose 20-90% of rock at any one place; the amount is highly variable along the unit's lateral extent. Typically quartz grains account for 20-25%. Quartz grains are rounded, coarse sand size.

Contact with underlying Caloso Member is abrupt and undulating.

12 Oolitic grainstone. Weathered surface is dark gray to light brown; fresh surface is light to medium gray. Unit is tabular; thinly to thickly laminated; a cliff former. Laminations are laterally continuous, displaying microfolding and microfaulting (probably penecontemporaneous deformation because these structures are confined within the unit). Calcareous grains are composed of fine to medium sand; angular to rounded. Unidentifiable fossil fragments make up 85% (although a rare crinoid columnal may be identified); 15% are well- 295

rounded, concentrically laminated particles. Moderate to well sorted; well indurated. Bedding planes contain oscillation ripple marks as viewed from atop the outcrop.

Contact with unit below is abrupt and irregular to faintly wavy.

11 Calcareous boulder conglomerate. Weathered and fresh surfaces are brown. Unit is tabular; a slope former. The lower 83 cm contains boulders (35-40%) of lime mudstone ranging in size up to 18 cm. Boulders contain 1-2% subangular to subrounded coarse quartz sand. Matrix is a structureless clastic mudstone. Boulders gradually diminish upward in the upper 65 cm of this unit. Mudstone grades into a shaley intraclastic wackestone. Angular intraclasts range up to 10 cm and are composed of thickly laminated to very thinly bedded lime mudstone. Intraclasts account for 65-75% of rock. 148

	Half the intraclasts are in grain-to-grain contact.	
	Contact with unit below is abrupt and irregular.	
10	Fossiliferous wackestone. Weathered surface is rusty brown; fresh surface is light to medium gray. Unit is tabular; wavy, thinly bedded; a cliff former. Unidentifiable fossil fragments compose 10-15% and are evident on weathered surfaces. These calcareous grains are angular, very coarse sand. Medium to coarsely crystalline spar has replaced a majority of lime mud.	135
	Contact with unit below is abrupt and irregular.	
9	Lime mudstone. Weathered surface is very light gray to white; fresh surface is mottled light to medium gray and brown. Unit is tabular; thinly to medium bedded.	137

8	Interbedded shale and nodular lime mudstone. Unit is tabular; a slope former. Basal 15 cm is dark grayish brown shale which weathers rusty brown. Upper 50 cm is composed of laterally and vertically discontinuous shales and nodular lime mudstones. Nodules are a product of weathering and range up to 60 mm in size. Nodules increase in size towards the top of the unit. Unit is clastic at the base, gradually becoming more lime-rich towards the top. Unfossiliferous.	65
	Contact with unit below is gradual.	
7	Shaley lime mudstone. Weathered surface is very light gray to white; fresh surface is medium gray to brownish gray. Unit is tabular; thickly laminated; a slope former. Basal 8 cm is dark grayish brown shale which weathers rust brown. In the middle of this unit, a 76 cm interval is composed of laterally and vertically discontinuous shales and nodular lime mudstones. Nodules are a weathering	137

product and range up to 6 cm in size. Nodules increase in size towards the top. The upper 53 cm is a nodular lime mudstone. This unit tends to resist weathering because its upper 53 cm is a cliff former. Unit is clastic at its base and gradually becomes more lime rich towards the top. No fossils observed.

Contact with unit below is gradual.

6 Lime mudstone. Weathered surface is light gray; fresh surface is light grayish brown. Unit is tabular; a slope former (unit is easily fractured into small cobble-sized blocks). Fossil fragments are rare. Clastic quartz and fossil fragments are subangular, medium sand. Occasionally 6 cm-wide clastic dikes occur in upper 30 cm. Dikes are filled with shale from overlying unit. 84

Contact with unit below is abrupt and undulating (wavelength = 200 cm; amplitude = 10-15 cm).

5	Lime mudstone. Weathered surface is medium gray; fresh surface is very dark gray to light brownish gray. Unit is tabular; wavy, thickly laminated to thinly bedded; a cliff former. Lime mudstone nodules are produced in places as a result of weathering; nodules range up to 20 mm. Less than 1% of rock's composition is fine-grained calcium carbonate particles (unidentifiable fossil fragments or perhaps microfossils). Contact with unit below is abrupt and planar.	54
4	Nodular argillaceous lime mudstone. Weathered surface is very light gray; fresh surface is dark gray. Unit is tabular; wavy, thickly laminated to thinly bedded; a cliff former. Nodules result from weathering; 1-8 cm in size. Less than 1% of unit is composed of fine- grained, unidentifiable fossil fragments (perhaps microfossils).	72

Contact with unit below is abrupt and planar to irregular.

3 Fossiliferous crystalline limestone. 72
Weathered surface is medium gray; fresh surface is light medium gray. Unit is tabular; a cliff former. Poorly preserved fossil fragments compose about 10% of unit; fragments range up to 12 mm in size. Most fragments are identified as crinoid ossicles or brachiopod shell fragments. Spar is coarsely crystalline. Disseminated silica is observed on weathered surfaces. The upper 15 cm commonly contains subangular to rounded coarse-grained quartz, and lithic pebbles of quartzite, granular metaconglomerate, and monzonite.

Contact with unit below is gradual.

2 Sublitharenite. Weathered surface is 34
grayish green; fresh surface is bright pale green. Unit is tabular; a cliff former. Grains are angular, very fine sand to pebble size. Quartz grains

	compose 85%. In decreasing abundances, the remaining 15% is composed of lithic fragments of monzonite, quartzite, and granitic rock. Occasionally pebbles of quartzite and monzonite are rounded. Poorly sorted; lower 6 cm is friable and the upper 28 cm is well indurated; cement is calcium carbonate.	
	Contact with unit below is abrupt and wavy.	
1	Lithic arenite. Weathered surface is brown to light red; fresh surface is very light green to almost white. Unit is tabular; a cliff former. Grains are angular, medium to coarse sand of equal parts quartz and lithic fragments. Grades laterally into lithic boulder conglomerate in places; cobbles and boulders are subangular quartzite and subrounded monzonite. In places a clay to silt size, green matrix is observed. Very poorly sorted; very well indurated; cement is calcium carbonate.	30
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Contact below this unit is the Precambrian-Mississippian nonconformity. The nature of the contact is abrupt and irregular, but appears undulatory in places. The Precambrian basement here is composed of quartz monzonite.

North Peak Section (Magdalena Mountains)

Location: Magdalena Quadrangle
NE 1/4 sec. 31, T. 2 S., R. 3 W.

Outcrop Photo: View taken from the North Peak section looking south at the type section of the Ladron Member of the Kelly Limestone.

See "Chihuahua Gulch Section" for detailed directions to the Magdalena Mountains from Socorro. The North Peak stratigraphic section is located at an elevation of about 9000 ft, about 100 ft below the summit of North Peak (formerly Tip Top Mountain). Actually, the section is located about 1000 ft east and south of North Peak proper. The base of the Mississippian stratigraphic section begins at the prospect pit (see reference map above) on the eastern slope of North Peak, about 100 ft below the twin summit. Access is by hiking up the Tip Top Tunnel road. The road is very badly washed out. Driving up the road in a four-wheel drive vehicle is not recommended. The road ends at Tip Top Tunnel, and a foot path up the western slopes of North Peak goes up to the crest of the Magdalena Mountains. The climb is steep. The slope is covered with loose soil making the climb more difficult. The outcrop, however, is not difficult to find once the crest is reached.

Notes: The North Peak section is about 1500 m north of the Ladron Member type locality. North Peak was chosen because the Mississippian-Pennsylvanian contact is easily observed, and because the rock units may be traced laterally at North Peak. This excellent outcrop permits a straight-line traverse directly up dip with a Jacob staff.

Field Unit	Lithologic Description	Thickness (cm)
	The Mississippian-Pennsylvanian contact is covered at North Peak; however, it can easily be dug up with spade and/or rock hammer. The contact between the Mississippian Kelly Limestone and the Pennsylvanian Sandia Formation is abrupt and irregular. Cut-and-fill structures can be observed in some places on the Ladron Member erosional	

	surface. Armstrong (1958) reported up to 30 ft of relief along this contact, but this was not apparent here. Red to purple (sometimes green) cross-bedded quartz arenites of the Sandia overly the Kelly.	
19	Alternating crinoidal grainstones and fossiliferous wackestones. Weathered and fresh surfaces are medium to dark gray or brown. Unit is tabular; wavy, thinly laminated to medium bedded; a cliff former. Crinoidal grainstones contain up to 100% crinoid columnals ranging in size from fine to medium sand. Other fossils compose less than 1% and consist of brachiopod shells, bryozoans, bivalves, unidentifiable fossil fragments, gastropods, and rugose corals. Matrix is finely crystalline calcite. Fossiliferous wackestones are composed of 20% fossil grains of which fenestrate bryozoans predominate (very conspicuous on bedding plane surfaces). In decreasing order of abundance, these fossils are: brachiopod shells, crinoid columnals,	150

unidentifiable fossil fragments, bivalves, and gastropods. Up to 25% of lime mud matrix may be replaced by silica. The lower third of this unit contains small (25 cm) orange chert nodules.

Contact with the unit below is gradual, but may be abrupt in places; slightly undulatory to planar.

There is no field unit 18.

17 Crinoidal grainstone. Weathered surface is brown to dark orange; fresh surface is brown to brownish gray. Unit is tabular; wavy, thinly to medium bedded; a cliff former. Dominant sedimentary particles are crinoid columnals which compose 95-100%. Other fossils compose 1-5%. In decreasing order of abundance, these are brachiopod shells and bryozoans, unidentifiable fossil fragments, rugose corals, and gastropods. Crinoid columnals range from fine- to coarse-grained sand. Matrix is medium crystalline calcite 218

which may sometimes grade into lime mud. Chert nodules are not readily observed, but up to 10% of the finer-grained portions of rock have been replaced by silica.

Contact with unit below is abrupt and planar to slightly undulating.

16 Crinoidal grainstone. Weathered and fresh 1231
surfaces are dark or medium gray. Unit is tabular; wavy, medium to thickly bedded; a cliff former. Crinoid columnals are the dominant sedimentary particles (95-100%). Generally, other fossils compose less than 1%, but in places may comprise up to 5%. In decreasing order of abundance, these fossils are brachiopod shells, rugose corals, bryozoans, unidentifiable fossil fragments, gastropods, and trilobites. Crinoid ossicles range from medium sand to pebble size (average size is about 5 mm). Matrix is mostly coarsely crystalline calcite which may rarely grade into lime mud. White and pink chert nodules, parallel to

subparallel to bedding, are conspicuous. Nodules are lozenge-shaped ranging up to 1 m long and 10 cm thick.

Contact with unit below is gradual.

15 Dolomitic mudstone. Weathered surface is very light brown; fresh surface is light brownish gray. Unit is tabular; thinly to thickly laminated; a cliff former. Towards the top of the unit, crinoid columnals begin to appear. This unit is known as the "silver pipe." 221

Contact with unit below is covered.

14 Crinoidal grainstone. Weathered surface is medium gray; fresh surface is dark medium gray. Unit is tabular; wavy, medium to thickly bedded; a cliff former. Crinoids are 100% of rock's composition with less than 1% composed of brachiopod shells, bryozoans, rugose corals, and unidentifiable fossil debris. Fossils are occasionally 392

replaced with pink silica on weathered surfaces. Crinoid columnals are coarse sand size but may range up to pebble size. If matrix is present it is coarsely crystalline calcite spar. Rarely does one observe lime mud matrix.

Contact with unit below is abrupt (may be gradual in places) and undulating.

13 Crinoidal arenaceous wackestone. Weathered surface is light gray; fresh surface is dark gray. Unit is wavy; a cliff former. Fossils may compose up to 40%. Crinoid ossicles are most abundant followed by a few brachiopod shell fragments and a rare rugose coral. Quartz grains may compose 10-50%; typically 10-15%. Quartz grains are rounded; coarse sand to granule size. 4-12

Contact with unit below is abrupt and undulating (wavelength = 1 m; amplitude = 15-20 cm). This is the base of the Ladron Member; top of the Caloso

	Member. At the contact the Caloso is rich in silica and is very pinkish gray.	
11-12	Alternating packstones and lime mudstones. Weathered surface is light to medium gray and light grayish brown; fresh surface is either dark gray or light brown. Unit is tabular; thickly laminated to thinly bedded; a cliff former. Grains in packstones are composed of 100% angular and well-rounded unidentifiable fossil fragments and possible coated grains (rock does not break across grains), respectively. Grains are medium sand. Rare quartz sand particles may be observed in packstones. Contact with unit below is abrupt and planar in places, or may be indiscernible where unit below is not nodular.	485
10	Nodular argillaceous lime mudstone. Weathered surface is very light brown; fresh surface is brown or dark pink.	161

Unit is tabular; thinly laminated to thinly bedded; a slope former. Unit alternates laterally from nodular lime mudstone to laminated lime mudstone. Nodules are a product of weathering, ranging in size up to 11 cm. Herkimer twins of quartz may account for up to 5% of rock in rare isolated spots on the weathered surface.

Contact with unit below is abrupt and planar in places, or may be indiscernible where unit above is not nodular.

7-9 See lithologic description of field units 11-12 above. 201

Contact with unit below is gradual.

6 Lithic quartz arenite. Weathered surface is light gray; fresh surface is dark gray. Unit is tabular; no internal sedimentary structures observed; a cliff former. Equal amounts of rounded quartz and calcium carbonate medium-grained sand. Well sorted; very well 48

indurated; calcium carbonate cement. No fossils observed.

Contact with unit below is abrupt and undulating (wavelength = 2 m; amplitude = 30 cm).

5 Nodular lime mudstone. Weathered surface 53
is pinkish gray; fresh surface is pink. Unit is wavy; pinches and swells (thickness ranges from 23-53 cm); a slope former. Nodules are a product of weathering and average 20 cm in length. No fossils observed.

Contact with unit below is abrupt and irregular due to nodules in the unit above; however, when one observes the horizon a step back from the outcrop, it appears to be undulating (wavelength = 2 m; amplitude = 30 cm).

4 Lime mudstone pebble conglomerate. 63
Weathered surfaces are brown; fresh surfaces are grayish brown to pink. Unit is tabular; upper third exhibits graded bedding; a slope former.

Pebbles constitute 30% of unit; in lower third they consist of laminated lime mudstone clasts; in middle of unit pebbles are quartz granule lime mudstone. Color of pebbles is light to medium gray. Matrix ranges from clay to granule size particles. Granules are quartz; clay coating on grains makes it difficult to distinguish mineralogy of sand particles. Upper third of unit is a medium- to coarse-grained lithic graywacke. Lithic fragments are lime mudstone (30%); the remainder are angular quartz grains. Sorting is very poor; very poorly indurated except for upper third; calcium carbonate cement.

Contact with unit below is gradual but may also appear abrupt and planar in places.

3 Lime mudstone cobble conglomerate. 129
Weathered and fresh surfaces are green to brown. Tabular massive unit; a slope former. Cobbles of quartz granule lime mudstone account for 50% of rock. Weathered and fresh surfaces

of cobbles are light pinkish gray. Matrix grains range from clay to granule size. Granules are quartz; clay coatings on grains make it impossible to discern sand particles' mineralogy. Sorting is very poor; very poorly indurated; calcium carbonate cement.

Contact with unit below is abrupt and wavy (wavelength = 2.5 m; amplitude = 30 cm) to irregular in places.

2 Lime mudstone pebble conglomerate. Weathered surface is grayish green; fresh surface is light green or olive. Tabular massive unit; a cliff former. Pebbles (20%) are composed of fossiliferous lime mudstone and quartz (chert and rock crystal) in equal amounts. The matrix is quartz arenite of angular, medium sand; 2% feldspar; much less than 1% lithic fragments. Sorting is poor; well indurated; calcium carbonate cement. 52

Contact with unit below is covered.

1	Quartz arenite. Weathered surface is pink to red; fresh surface is very light pink to white. Tabular massive unit; a cliff former. Quartz grains (100%) are angular, very fine sand; less than 1% feldspar and lithic fragments. Very well sorted; well indurated; cement is calcium carbonate.	132
		3548

Corkscrew Canyon Section (Lemitar Mountains)

Location: Lemitar Quadrangle
NW 1/4 sec. 18, T. 2 S., R. 1 W.

Outcrop Photo: Kelly Limestone steeply dipping to the west. The outcrop is situated along the southern wall of the canyon at this location.

Six miles (9.7 km) north of Socorro, located just upstream from the mouth of Canoncito de Puertecito del Lemitar (Corkscrew Canyon) in the Lemitar Mountains, is an outcrop of Kelly Limestone. The Kelly can be found along a one-mile (1.6-kilometer), north-south strip at W1/3 sec. 7 into NW1/4 sec. 18, T. 2 S., R. 1 W. The best section is on the south wall of the canyon. The Mississippian section is poorly exposed along gentle slopes above and outside the canyon proper. Secondary mineralization along the base of the section is common. Access to Corkscrew Canyon is through private property, the J. B. and Wilma Kelly Ranch. Permission must be asked well in advance of any work planned in this area. Kelly Ranch is reached by exiting I-25 at Junction N. M. 408 (Escondido Exit). Travel north on N. M. 408 for approximately three miles (4.8 km), then turn left (west) at the Kelly Ranch road. It is another two miles (3.2 km) to the ranch house and locked gate. Once passed the locked gate turn to the right (north) up and out of the arroyo and feed lot. Continue on the ranch road for 3.3 miles (5.3 km) into Corkscrew Canyon. The arroyo/canyon bed includes some rock spillways that may be negotiated with four-wheel drive vehicles; however, discretion being the better part of valor, one may park below the waterfall and hike the remaining few hundred yards (meters).

Notes: The contact at the Precambrian-Mississippian nonconformity is covered, however, one may observe this contact on the north canyon wall. Above the lowermost clastic units, the outcrop has minimal vegetative and/or soil cover. Here the Kelly Limestone is tilted steeply at 65 degrees west. Footing may be treacherous because of the steep nature of the outcrop, and due to loose cobbles and boulders of fractured limestone. The section was measured in a direct straight-line, up-dip traverse with Jacob staff and measuring tape. The Caloso Member - Ladron Member contact is not easily recognized at first because the crinoidal packstones towards the upper part of the Caloso are similar to the crinoidal grainstones of the Ladron. The contact is apparent after the horizon is traced laterally. Gnats, flies, and mosquitoes are abundant to overwhelming at this locality. The investigator is advised to dress appropriately and take adequate precautions against insect bites, *e.g.* insect repellent.

Field Unit	Lithologic Description	Thickness (cm)
	The contact between the Mississippian Kelly Limestone and Pennsylvanian Sandia Formation is abrupt and irregular. Up to 1.3 m of relief may be observed on the Ladron Member erosional surface. In places, cut-and-fill structures may be noted along this horizon. Basal Sandia is a tan to brown, hematitic, medium-grained quartz arenite.	
10	Crinoidal grainstones. Weathered surface is light medium gray; fresh surface is medium gray. Unit is tabular; wavy, thinly to thickly bedded; a cliff former. Crinoid ossicles range from medium sand to pebble size. In the	1650

uppermost 4.5 m, crinoid columnals range from coarse sand to granule size; average size is about 3 mm. Nearly 100% of particles are crinoid columnals. Other fossil grains compose less than 1% but may range up to 5% in places. These other fossils, in decreasing order of abundance, are brachiopods and their shell fragments, rugose corals, bryozoan fragments, unidentifiable fossil fragments, gastropods, and rarely, trilobites, blastoids and echinoid spines. The upper 4.5 m contains lenses of brown to orange, bryozoan-rich, crinoidal grainstones and crinoidal packstones; packstones tend to be silty. In these lenses, fenestrate bryozoans compose up to 15% of rock's constituent particles; bryozoans are especially conspicuous on bedding plane surfaces. White to occasionally pink or flesh tone chert nodules are present throughout this unit's thickness. Nodules range up to 1.5 m long and 12-15 cm thick.

Contact with unit below is gradual; underlying crinoidal packstones grade into crinoidal grainstones above.

9 Alternating crinoidal packstones, shales, lime mudstones and clastic mudstones. This is the stratigraphic level at which the "silver pipe" occurs in the Magdalena Mountains sections. Crinoidal packstones are light to medium gray on weathered surfaces; fresh surfaces are medium gray. Shales, clastic mudstones and lime mudstones are light brown and tan on both weathered and fresh surfaces. Beds are tabular. Lime mudstones are wavy, thinly to thickly laminated. Crinoidal packstones are wavy, thinly to medium bedded. Unit is a slope former due to clastic mudstones and shales weathering easily. Crinoid columnals compose 98-100% of constituent grains in packstones; size ranges up to 10 mm (pebble size). The remaining 1-2% are composed of brachiopod shells, rugose corals, 250

unidentifiable fossil fragments, and bryozoan fragments. White chert nodules are present in crinoidal packstones and range up to 40 cm long, 4-5 cm thick.

Contact with unit below is gradual; crinoidal grainstones below grade into crinoidal packstones above.

8 Crinoidal grainstone. Weathered surface is light gray to light medium gray; fresh surface is medium gray. Unit is tabular; wavy, thinly to thickly bedded; a cliff former. Crinoid columnals compose up to 98-100% of total grains. At the base the unit one may find, in places, up to 5% rounded, coarse quartz sand. The matrix is finely to medium crystalline calcite spar. Other fossil grains which account for 1-2% (in decreasing order of abundance) broken brachiopod shells, rugose corals, bryozoan fragments, and unidentifiable fossil fragments. White chert nodules, up to 1 m long and 10 cm 250

thick are parallel to subparallel to bedding.

Contact with the unit below, the Caloso Member, is sharp and planar to wavy (wavelength = 32-40 cm; amplitude = 6 cm). Chert nodules in the unit above (base of the Ladron Member) help mark this as the contact.

7 Alternating shales, lime mudstones, and crinoidal grainstone. Weathered surfaces are tan or medium gray; fresh surfaces are medium or dark gray. Units are tabular; wavy, thinly laminated to thickly bedded; lower 135 cm is slope forming due to shales and nodular silty lime mudstone; upper 150 cm is a fossiliferous crinoidal grainstone which is a cliff former. Upper 150 cm are composed of 95-99% crinoid columnals of medium sand to granule size; 1-5%, in decreasing order of abundance, is composed of unidentifiable fossil fragments, broken brachiopod shells, and bryozoan fragments. In this interval, fossil 285

grains are medium sand size towards the bottom and gradually increase in size towards the top.

Contact with the unit below is abrupt and slightly undulating.

6 Lime mudstone and intraclastic packstone. 288
Weathered surface is tan to light brown; fresh surface is brown. Unit is tabular; thinly to thickly laminated; a slope former. Intraclastic packstone occurs within the 110-180 cm interval. Intraclasts are thinly laminated lime mudstone particles which range up to 75 mm in size; average size is 40-50 mm (pebble size). Particles are randomly oriented in a lime mudstone matrix which occasionally may grade into silty lime mudstone. Where lime mudstones grade into silty lime mudstones and nodular lime mudstones, the unit is easily weathered. Nodules range up to 10 cm long. Contacts between these three subunits are abrupt and irregular to planar.

	Contact with unit below is abrupt and planar to irregular.	
5	Crystalline limestone. Weathered surface is very light brownish gray; fresh surface is medium to dark gray. Unit is tabular; very thinly to thinly bedded; a cliff former. In places, unit weathers to spheroidal masses up to 50 cm in diameter. Calcite spar is finely to medium crystalline.	221
	Contact with unit below is abrupt and planar.	
4	Fossiliferous arenaceous lime mudstone. Weathered surface is light brown (tan); fresh surface is grayish brown. Unit is tabular; very thinly laminated to medium bedded; a cliff former. Quartz grains are fine to medium sand; they constitute up to 20% of rock. Grain shape is subrounded. Fossils are about 1-2% of rock's composition, and include broken brachiopod shells, crinoid columnals, unidentifiable fossil fragments, and fragments of fenestrate	140

bryozoans (in decreasing order of abundance). Stylolites are laterally continuous for up to 56 cm and are replaced by silica; veins of silica and calcite also are observed in this unit.

Contact with unit below is abrupt and planar to slightly undulatory.

3 Nodular lime mudstone. Weathered surface is very light gray; fresh surface is light gray. Unit is tabular; a cliff former. Nodules are a product of weathering; range in size is 2.5-18 cm in length. Nodules are more abundant and larger towards the top of the unit. Dendrites are evident on fractured surfaces. 57

Contact with unit below is abrupt and planar.

2 Fossiliferous arenaceous lime mudstone. Weathered surface is either medium gray or light brown; fresh surface is medium gray. Unit is tabular; wavy medium bedded; a cliff former. Quartz grains 213

are fine to medium sand with an occasional greenstone or quartz pebble. Quartz may be as high as 20% of rock's composition in places. Grain shape is subrounded. Fossils are 1-5% of rock's constituents. In decreasing order of abundance, these are broken brachiopod shells, crinoid columnals, unidentifiable fossil fragments, echinoid spines and fragments of fenestrate bryozoans. Occasional gray to brown chert nodules are observed in the lower portion of unit ranging up to 1 m long, 10 cm thick; parallel or subparallel to bedding.

Contact with underlying unit is abrupt and planar; may be irregular in places.

1 Shale and quartz arenite. Weathered 94
surface is light brown (tan); fresh surface is white to light tan. Unit is tabular; a slope former. Lower third is a green shale with small Precambrian greenstone pebbles at the base. The upper two thirds is friable (calcium carbonate cement); medium-grained sand

(occasional greenstone pebbles); subangular to subrounded grains; 98% quartz with the remainder composed of feldspar and lithic fragments; well sorted.

3448

Contact with the Precambrian basement is abrupt and irregular. Precambrian lithology is metamorphic greenstones.

Cerro de Colorado Section (Ladron Mountains)

Location: Riley Quadrangle
E 1/2 sec. 30, T. 2 N., R. 3 W.

Outcrop Photo: The Kelly Limestone caps a series of hogback ridges south of Ladron Peak. This is the type locality for the Caloso Member of the Kelly. The Caloso is darker than the overlying Ladron.

Eighteen miles (29 km) north of Socorro, the Kelly Limestone occurs north of Rio Salado in the southern Ladron Mountains immediately west of Cerro de Colorado. The Kelly is exposed along Arroyo Caloso for about four miles (6.4 km) in a north-south strip through the middle of secs. 18, 19, 30, and 31, T. 2 N., R. 3 W. This is the type locality for the Caloso Member. The Kelly disappears toward the northern end of the arroyo, with the Pennsylvanian Sandia Formation eventually overlying Precambrian basement. Access to this locality is extremely difficult. It lies in U. S. Bureau of Land Management proposed wilderness area. Travel in this area is restricted to hiking and horseback. The western approach from the town of Riley is no longer feasible because the northern bank of Rio Salado is too high and steep. One must traverse Sevilleta National Wildlife Refuge from the east, off the Mountainair exit of I-25. Because of its refuge status, gates are locked to unauthorized personnel. Permission must be obtained from U. S. Fish and Wildlife Service for admittance.

An improved dirt road, maintained for access to a telephone company microwave tower, parallels the northern fence line. Head south along the second north-south power line. The road eventually deteriorates. A four-wheel drive vehicle is necessary to travel through the western reaches of the refuge. When there is standing water in the roadbed, it is impassable. This road gradually becomes a jeep trail. The trail ends at the western end of the refuge at an abandoned line camp and fresh-water spring. Access to the Kelly Limestone is on foot, a mile or two south through some of the more rugged wilderness terrain in New Mexico (personal communication, Rousseau Flower, 1987).

Notes: The Kelly Limestone occurs along a series of hogback ridges at Arroyo Caloso, from the northern end of Cerro de Colorado south to Rio Salado. The Caloso Member forms the western wall of the arroyo. The Caloso is a cliff face here. It is easiest to measure the lower portions of section in the tributary gullies dissecting the hogbacks. The Ladron Member is not as steep and can be measured in a direct, up-dip, straight-line traverse using the Jacob staff.

The southern Ladron Mountains are among the most rugged wilderness areas in New Mexico. Hogback ridges composed of Mississippian and Pennsylvanian limestone strata, and hills composed of Precambrian igneous and metamorphic crystalline rocks, are steep and covered with talus. This makes hiking difficult and strenuous. Rattlesnakes take up residence in talus, and are found basking in the sun on boulders and in stream beds, making any hike potentially dangerous. During the summer months temperatures exceed 100 degrees F in gullies and arroyos so one needs to safeguard against dehydration and sun stroke.

Field Unit	Lithologic Description	Thickness (cm)
	The Mississippian-Pennsylvanian contact is abrupt and irregular. The Pennsylvanian Sandia Formation consists of dark brown, hematitic, quartz arenite. The Ladron member erosional surface is irregular with up to 1 m of relief; typically 30 cm of relief. Along this horizon one may observe cut-	

	and-fill structures in the Ladron erosional surface.	
10	Alternating crinoidal grainstones and silty bryozoan crinoidal packstones. Weathered surfaces are light to medium gray (grainstones) and orange to brown (packstones); fresh surfaces are medium gray (grainstones) and orange to brown (packstones). Unit is tabular; wavy, thinly to thickly bedded; a cliff former. Crinoidal grainstones contain columnals of coarse sand to granule size; average grain size is about 3 mm. Nearly 100% of particles are crinoid ossicles. Other fossil grains compose less than 1%, but in places may be 5% of rock's composition. Other fossils in decreasing order of abundance are bryozoans, brachiopods, rugose corals, unidentifiable fossil fragments, and gastropods. Packstones may contain up to 15% bryozoans, conspicuous on bedding plane surfaces. Packstones may also be replaced by silica in places. Chert nodules are present throughout the thickness of this unit. Nodules	182

	are brown to pink or white; ranging up to 70-80 cm long and 7-8 cm thick.	
9	Crinoidal grainstone. Weathered and fresh surfaces are light to medium gray. Unit is tabular; wavy, thinly to thickly bedded; a cliff former. Crinoid columnals range from medium sand to pebble size; average size is the lower limit of pebble size (about 5-6 mm). Nearly 100% of particles are crinoid columnals. Other fossil grains compose less than 1%, but may range up to 5% in places. These other fossils in decreasing order of abundance are bryozoans, brachiopods and their shell fragments, rugose corals, unidentifiable fossil fragments, gastropods, and rarely, trilobites and echinoid spines. Occasionally crinoid grainstones grade into crinoidal packstones, or more rarely, into fossiliferous wackestones. White chert nodules are present throughout the unit's thickness. Nodules range up to 1.5 m in length and 12-15 cm in thickness.	1200

Contact with the Caloso Member below is abrupt and undulatory to irregular. Upper 30 cm of field unit 8 is pinkish gray and contains disseminated silica.

8 Fossiliferous wackestones and packstones. 545
Weathered surface is medium gray to brownish gray; fresh surface is brownish gray. Unit is tabular; thickly laminated to thinly bedded; a cliff former. Grains are very fine to fine sand. Unidentifiable fossil fragments range in abundance from 10% to 90% of rock's composition. Other fossils, rugose corals and brachiopods, were found in a 3-5 cm zone about 3 m from the base of field unit 8.

Contact with unit below is abrupt and undulating.

7 Lime mudstone. Weathered and fresh 61
surfaces are mottled medium gray and brownish gray. Unit is tabular; wavy, thinly to thickly laminated; a cliff former. At the base of this unit,

fine-grained quartz sand, similar to that found in field unit 6, composes less than 10% of the rock.

Contact with unit below is abrupt and irregular.

6 Quartz arenite. Weathered and fresh surfaces are very light brown (tan) to white. Unit is tabular; thickly laminated to very thinly bedded; a slope former. Quartz grains are nearly 100% of particles; much less than 1% is lithic fragments and feldspar. Particles are rounded, very fine sand; well sorted; poorly indurated; calcium carbonate cement. Elliptical concretions up to 10 cm long are observed on weathered surfaces. 88

Contact with unit below is gradual.

5 Subarkosic quartz arenite. Weathered surface is grayish tan to brown; fresh surface is brown to medium gray. Unit is tabular; wavy (upper 50 cm) or planar (lower 120 cm); very thinly to 170

thickly bedded; a cliff former. Constituent grains are fine to medium sand ranging up to coarse sand in places. Quartz composes 80-85%; feldspars 15-20%; and, lithic fragments less than 1%. Grains are angular (coarse sand is rounded); well sorted to moderately sorted; well indurated; calcium carbonate cement. Thinly bedded units occasionally grade laterally into arenaceous lime mudstone.

Contact with unit below is gradual.

4 Subarkosic quartz arenite. Weathered surface pink to brown; fresh surface is brown to medium gray. Unit is tabular; wavy to irregular, very thinly to thickly bedded; lower 70 cm is a cliff former; upper 62 cm is a slope former. Constituent grains are fine to medium sand with an occasional quartz pebble. Quartz composes 80-85%; feldspars 15-20%; and, lithic fragments less than 1%. Grains are angular; well sorted; calcium carbonate cement. Upper 62 cm 141

	are poorly indurated with nearly spherical cavities up to 16 cm across. The lower 79 cm are well indurated.	
	Contact with the unit below is gradual.	
3	Calcareous nodular arenaceous shale. Weathered and fresh surfaces are grayish brown. Unit is tabular; wavy, thinly laminated to thickly laminated; a slope former. Angular, medium-grained quartz makes up about 10% of rock. Nodules (concretions) are arenaceous lime mudstones. Nodules are almost spherical, ranging up to 16 cm across. Largest nodules are located in the middle third of the unit, gradually decreasing in size towards the top and bottom.	96
	Contact with the unit below is gradual.	
2	Calcareous arenaceous shale. Weathered surface is light brown (tan); fresh surface is tan to brown. Unit is tabular; a cliff former. Angular,	14

	medium-grained, quartz sand composes less than 10% of rock. Contact with unit below is gradual.	
1	Subarkosic quartz arenite. Weathered surface is pink to brown; fresh surface is brown, sometimes medium gray. Unit is tabular; occasionally wavy (oscillation ripples are evident on bedding plane surfaces), very thinly to thickly bedded; a cliff former. Constituent grains are fine to medium sand ranging up to pebble size at the base. Quartz composes 80-85%; feldspars 15-20%; and, lithic fragments less than 1%. Grains are angular; well sorted; well indurated; calcium carbonate cement.	109
		2606

The Precambrian-Mississippian nonconformity is abrupt and irregular. Up to 1 m of relief may be observed along the Precambrian erosional surface, but 30 cm of relief is typical. Precambrian rocks here are composed of foliated crystalline metamorphic rocks (schists and gneisses) that weather into platy slabs. The very basal Caloso Member is a lithic pebble conglomerate including fragments of these schists and gneisses.

APPENDIX II: PETROGRAPHIC DATA

Description of terms used in petrographic study.

Carbonate Rock Classification based on Folk's (1959) classification system:

					Limestones, partly dolomitized limestones, and primary dolomites (see Notes 1 to 6)						Replacement dolomites[7] (V)		
					>10% Allochems Allochemical rocks (I and II)		<10% Allochems Microcrystalline rocks (III)						
					Sparry calcite cement > microcrystalline ooze matrix	Microcrystalline ooze matrix > sparry calcite cement	1–10% Allochems		<1% Allochems	Undisturbed bioherm rocks (IV)	Allochem ghosts		No allochem ghosts
					Sparry allochemical rocks (I)	Microcrystalline allochemical rocks (II)							
Volumetric allochem composition				>25% Intraclasts (i)	Intrasparrudite (Ii:Lr) Intrasparite (Ii:La)	Intramicrudite* (IIi:Lr) Intramicrite* (IIi:La)	Most abundant allochem	Intraclasts: intraclast-bearing micrite* (IIIi:Lr or La)	Micrite (IIIm:L); if disturbed, dismicrite (IIImX:L); if primary dolomite, dolomicrite (IIIm:D)	Biolithite (IV:L)	Evident allochem	Finely crystalline intraclastic dolomite (Vi:D3) etc.	Medium crystalline dolomite (V:D4)
	<25% Intraclasts			>25% Oölites (o)	Oösparrudite (Io:Lr) Oösparite (Io:La)	Oömicrudite* (IIo:Lr) Oömicrite* (IIo:La)		Oölites: oölite-bearing micrite* (IIIo:Lr or La)				Coarsely crystalline oölitic dolomite (Vo:D5) etc.	Finely crystalline dolomite (V:D3)
		<25% Oölites	Volume ratio of fossils to pellets	>3:1 (b)	Biosparrudite (Ib:Lr) Biosparite (Ib:La)	Biomicrudite (IIb:Lr) Biomicrite (IIb:La)		Fossils: fossiliferous micrite (IIIb: Lr, La, or L1)				Aphanocrystalline biogenic dolomite (Vb:D1) etc.	
				3:1–1:3 (bp)	Biopelsparite (Ibp:La)	Biopelmicrite (IIbp:La)		Pellets: pelletiferous micrite (IIIp:La)				Very finely crystalline pellet dolomite (Vp:D2) etc	etc.
				<1:3 (p)	Pelsparite (Ip:La)	Pelmicrite (IIp:La)							

*Designates rare rock types.

[1] Names and symbols in the body of the table refer to limestones. If the rock contains more than 10 percent replacement dolomite, prefix the term "dolomitized" to the rock name, and use DLr or DLa for the symbol (e.g., dolomitized intrasparite, Li:DLa). If the rock contains more than 10 percent dolomite of uncertain origin, prefix the term "dolomitic" to the rock name, and use dLr or dLa for the symbol (e.g., dolomitic pelsparite, Ip:dLa). If the rock consists of primary (directly deposited) dolomite, prefix the term "primary dolomite" to the rock name, and use Dr or Da for the symbol (e.g., primary dolomite intramicrite, IIi:Da). Instead of "primary dolomite micrite" (IIIm:D) the term "dolomicrite" may be used.

[2] Upper name in each box refers to calcirudites (median allochem size larger than 1.0 mm); lower name refers to all rocks with median allochem size smaller than 1.0 mm. Grain size and quantity of ooze matrix, cements, or terrigenous grains are ignored.

[3] If the rock contains more than 10 percent terrigenous material, prefix "sandy," "silty," or "clayey" to the rock name and "Ts," "Tz," or "Tc" to the symbol, depending on which is dominant (e.g., sandy biosparite, TsIb:La, or silty dolomitized pelmicrite, TzIIp:DLa). Glauconite, collophane, chert, pyrite, or other modifiers may also be prefixed.

[4] If the rock contains other allochems in significant quantities that are not mentioned in the main rock name, these should be prefixed as qualifiers proceeding the main rock name (e.g., fossiliferous intrasparite, oölitic pelmicrite, pelletiferous oösparite, or intraclastic biomicrudite). This can be shown symbolically as Ii(b), Io(p), IIb(i), respectively.

[5] If the fossils are of rather uniform type or one type is dominant, this fact should be shown in the rock name (e.g., pelecypod biosparrudite, crinoid biomicrite).

[6] If the rock was originally microcrystalline and can be shown to have recrystallized to microspar (5–15 microns, clear calcite) the terms "microsparite," "biomicrosparite," etc., can be used instead of "micrite" or "biomicrite."

[7] Specify crystal size as shown in the examples.

Source: Folk, R. L., 1962, Spectral subdivision of limestone types, *in* W. E. Ham (ed.), Classification of carbonate rocks: Am. Assoc. Petroleum Geologists Mem. 1. Table 1, p. 70, reprinted by permission of AAPG, Tulsa, Okla.

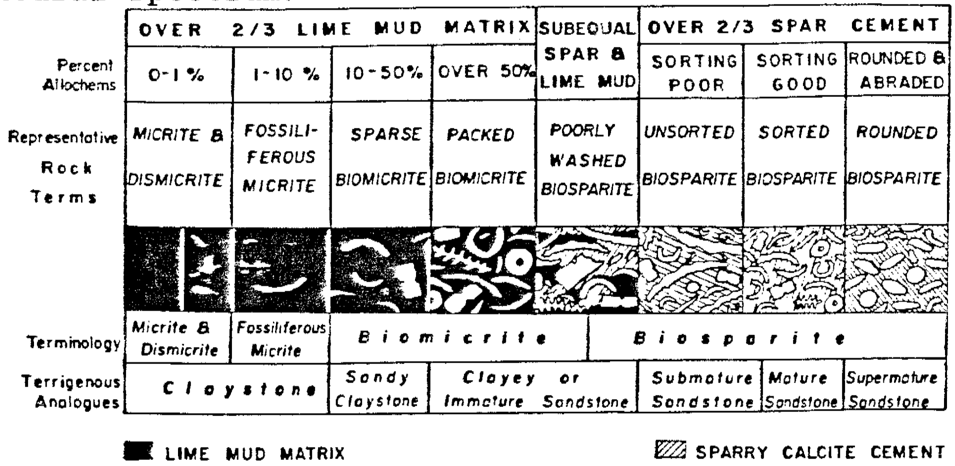
Average Grain Size based on Wentworth's (1922) particle grade scale:

Grain Size	Diameter of Grain (mm)
pb = pebble	greater than 4
g = granule	2 - 4
cs = coarse sand	0.5 - 2
ms = medium sand	0.25 - 0.50
fs = fine sand	0.0625 - 0.25
st = silt	0.0039 - 0.0625
cl = clay	less than 0.0039

Semiquantitative Frequency Estimates based on comparison images/ charts of Flugel (1982) after Baccelle and Bosellini (1965):

Relative Abundances of Sedimentary Particles	Percentages (%)
ea = extremely abundant	greater than 40
va = very abundant	26 - 39
a = abundant	16 - 25
la = less abundant	6 - 15
c = common	1 - 5
r = rare	less than 1
t = trace	much less than 1

Carbonate Textural Scheme based on Folk's (1959) carbonate textural spectrum:



	OVER 2/3 LIME MUD MATRIX				SUBEQUAL SPAR & LIME MUD	OVER 2/3 SPAR CEMENT		
Percent Allochems	0-1 %	1-10 %	10-50%	OVER 50%		SORTING POOR	SORTING GOOD	ROUNDED & ABRADED
Representative Rock Terms	MICRITE & DISMICRITE	FOSSILIFEROUS MICRITE	SPARSE BIOMICRITE	PACKED BIOMICRITE	POORLY WASHED BIOSPARITE	UNSORTED BIOSPARITE	SORTED BIOSPARITE	ROUNDED BIOSPARITE
Terminology	Micrite & Dismicrite	Fossiliferous Micrite	Biomicrite			Biosparite		
Terrigenous Analogues	Claystone		Sandy Claystone	Clayey or Immature Sandstone		Submature Sandstone	Mature Sandstone	Supermature Sandstone

■ LIME MUD MATRIX

▨ SPARRY CALCITE CEMENT

m = micrite
d = dismicrite
fm = fossiliferous micrite
sp = sparse
p = packed
pw = poorly washed
u = unsorted
s = sorted
rd = rounded

Rock Names are from Folk's (1959) carbonate classification system:

bl = biolithite
bm = biomicrite
bmr = biomicrudite
bpm = biopelmicrite
bs = biosparite
bsr = biosparudite
dm = dismicrite
imr = intramicrudite
m = micrite
pm = pelmicrite
ps = pelsparite

Chupadera Peak; Caloso Member

Sample Number	CH3a	CH3b	CH3c	CH4c
Distance from base (m)	2.3	4.6	4.6	7.2
Matrix (%)				
Micrite	62	99	95	5
Spar	1	-	3	55
Texture	sp	m	m	sp
Allochems	X	-	X	X
Average Grain Size	cs	-	ms	ms
Fossils:	X	-	X	X
Algae	-	-	-	-
Brachiopods	r	-	-	r
Bryozoans	-	-	-	c
Calcispheres	-	-	-	-
Corals	-	-	-	-
Crinoids	r	-	?*	c
Foraminifers	-	-	-	t
Gastropods	-	-	-	-
Mollusks	-	-	-	-
Ostracods	-	-	-	t
Trilobites	r	-	-	t
Other: UFF**	va	-	t	-
Intraclasts	-	-	-	c
Peloids	-	-	-	va
Pellets	-	-	-	-
Other:	-	-	-	-
Terrigenous Grains	X	X	X	-
Average Grain Size	st	st	st	-
Feldspar	-	-	-	-
Mica	-	-	-	-
Quartz	c	c	c	-
Rock Fragments	-	-	-	-
Other:	-	-	-	-
Neomorphism				
Aggrading	X	X	X	-
Degrading	X	-	-	X
Diagenesis				
Dolomitization	X	X	X	-
Replacement by Quartz	X	X	-	X
Rock Name	bm	m	m	ps

*indeterminant

**UFF = Unidentified Fossil Fragment

Chihuahua Gulch; Caloso Member

Sample Number	CG3b	CG5a	CG9b	CG10	CG11a
Distance from base (m)	1.0	2.1	5.7	7.0	8.9
Matrix (%)					
Micrite	-	85	85	95	60
Spar	57	3	15	-	-
Texture	sp	sp	m	m	sp
Allochems	X	X	X	-	X
Average Grain Size	ms	fs	fs	-	cs
Fossils:	X	X	X	-	-
Algae	-	-	?[*]	-	-
Brachiopods	c	-	-	-	-
Bryozoans	r	-	-	-	-
Calcispheres	-	-	-	-	-
Corals	-	-	-	-	-
Crinoids	va	-	-	-	-
Foraminifers	-	-	-	-	-
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	-	-	-	-	-
Trilobites	-	-	-	-	-
Other: UFF[**]	-	la	t	-	-
Intraclasts	t	-	-	-	la
Peloids	-	-	c	-	-
Pellets	-	-	-	-	-
Other:	-	-	-	-	-
Terrigenous Grains	X	X	X	X	X
Average Grain Size	ms	st	st	st	st
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	c	r	t	c	a
Rock Fragments	t	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	-	-	-	X	-
Degrading	X	-	-	-	-
Diagenesis					
Dolomitization	-	X	-	-	-
Replacement by Quartz	X	X	-	-	-
Rock Name	bs	d	bl	m	m

[*] indeterminant

[**] UFF = Unidentifiable Fossil Grain

North Peak; Caloso Member

Sample Number	FT1	FT2	KG10a	KG11a	FT3
Distance from base (m)	5.4	6.9	8.1	10.5	11.6
Matrix (%)					
Micrite	2	2	95	-	3
Spar	38	41	-	60	35
Texture	rd	rd	m	s	p
Allochems	X	X	-	X	X
Average Grain Size	fs	fs	-	ms	ms
Fossils:	X	X	-	X	X
Algae	-	-	-	-	-
Brachiopods		r		r	c
Bryozoans	-	-	-	t	-
Calcispheres	-	-	-	-	-
Corals	-	-	-	-	-
Crinoids	r	la	-	ea	a
Foraminifers	-	-	-	-	-
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	-	-	-	-	-
Trilobites	-	-	-	-	-
Other:	-	-	-	-	-
Intraclasts	r	-	-	-	c
Peloids	ea	va	-	-	a
Pellets	-	-	-	-	-
Other: UFF*	r	-	-	-	c
Terrigenous Grains	X	X	-	-	X
Average Grain Size	fs	fs	-	-	ms
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	a	la	-	-	c
Rock Fragments	-	-	-	-	-
Other: Clay	-	-	-	t	-
Neomorphism					
Aggrading	X	X	-	-	X
Degrading	X	X	-	X	-
Diagenesis					
Dolomitization	-	-	-	-	-
Replacement by Quartz	X	X	X	X	X
Rock Name	ps	ps	m	bs	bm

*UFF = Unidentifiable Fossil Fragments

North Peak; Ladron Member

Sample Number	KG13a	KG14a	FT4	KG15a	FT5
Distance from base (m)	-	0.9	4.6	5.1	8.3
Matrix (%)					
Micrite	-	10	-	100	5
Spar	25	25	30	-	30
Texture	u	pw	s	m	u
Allochems	X	X	X	-	X
Average Grain Size	ms	cs	cs	-	ms
Fossils:	X	X	X	-	X
Algae	-	-	-	-	-
Brachiopods	-	-	t	-	c
Bryozoans	r	-	-	-	a
Calcispheres	-	-	-	-	r
Corals	-	-	-	-	-
Crinoids	-	ea	ea	-	a
Foraminifers	-	-	-	-	r
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	-	-	-	-	-
Trilobites	-	-	-	-	-
Other: UFF[*]	-	-	-	-	t
Intraclasts	-	-	-	-	-
Peloids	-	-	-	-	la
Pellets	-	-	-	-	-
Other	-	-	-	-	-
Terrigenous Grains	X	X	-	X	-
Average Grain Size	ms	cs	-	st	-
Feldspar	-	-	-	-	-
Mica	-	-	-	t	-
Quartz	t	t	-	t	-
Rock Fragments	-	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	-	-	-	-	X
Degrading	X	X	-	-	X
Diagenesis					
Dolomitization	-	-	-	?[**]	-
Replacement by Quartz	X	X	X	X	-
Rock Name	bsr	bsr	bs	m	bs

[*] UFF = Unidentified Fossil Fragment

[**] indeterminant

North Peak; Ladron Member (cont'd)

Sample Number	FT6-1	FT6-2	KG16a	KG16c
Distance from base (m)	8.7	8.7	11.2	12.7
Matrix (%)				
Micrite	55	30	30	7
Spar	-	1	3	25
Texture	sp	p	p	u
Allochems	X	X	X	X
Average Grain Size	ms	ms	ms	ms
Fossils:	X	X	X	X
Algae	-	-	-	-
Brachiopods	r	t	r	r
Bryozoans	la	ea	ea	c
Calcispheres	t	t	-	-
Corals	?	?	-	-
Crinoids	va	a	va	ea
Foraminifers	-	-	r	r
Gastropods	-	-	-	-
Mollusks	-	-	r	-
Ostracods	-	-	r	-
Trilobites	-	-	-	-
Other: UFF*	-	t	-	-
Intraclasts	-	-	-	-
Peloids	-	-	c	c
Pellets	-	-	-	-
Other:	-	-	-	-
Terrigenous Grains	-	-	-	-
Average Grain Size	-	-	-	-
Feldspar	-	-	-	-
Mica	-	-	-	-
Quartz	-	-	-	-
Rock Fragments	-	-	-	-
Other:	-	-	-	-
Neomorphism				
Aggrading	-	X	X	-
Degrading	-	-	X	X
Diagenesis				
Dolomitization	-	-	-	-
Replacement by Quartz	X	-	-	X
Rock Name	bm	bm	bm	bs

*UFF = Unidentified Fossil Fragment

North Peak; Ladron Member (cont'd)

Sample Number	KG17b	FT7	KG19a	KG19b
Distance from base (m)	18.7	21.1	22.0	22.0+
Matrix (%)				
Micrite	-	30	5	15
Spar	20	2	15	r
Texture	u	p	r	u
Allochems	X	X	X	X
Average Grain Size	ms	ms	cs	ms
Fossils:	X	X	X	X
Algae	-	-	-	-
Brachiopods	a	c	r	r
Bryozoans	ea	ea	c	ea
Calcispheres	-	?*	t	-
Corals	-	-	-	-
Crinoids	a	la	ea	va
Foraminifers	r	r	-	r
Gastropods	-	-	-	-
Mollusks	-	-	-	-
Ostracods	-	-	-	-
Trilobites	-	-	-	-
Other: UFF**	t	-	t	r
Intraclasts	-	-	c	r
Peloids	c	-	-	-
Pellets	-	-	-	-
Other:	-	-	-	-
Terrigenous Grains	X	-	-	-
Average Grain Size	fs	-	-	-
Feldspar	-	-	-	-
Mica	-	-	-	-
Quartz	r	-	-	-
Rock Fragments	-	-	-	-
Other:	-	-	-	-
Neomorphism				
Aggrading	-	X	-	-
Degrading	X	-	-	X
Diagenesis				
Dolomitization	-	-	-	-
Replacement by Quartz	X	X	X	X
Rock Name	bs	bm	bsr	bmr

*indeterminant

**UFF = Unidentified Fossil Fragment

Corkscrew Canyon; Caloso Member

Sample Number	LM2b	LM2c	LM3a	LM4a	LM6a
Distance from base (m)	1.5	3.0	3.4	4.3	8.7
Matrix (%)					
Micrite	65	80	99	92	25
Spar	1	15	r	t	-
Texture	fm	fm	m	fm	p
Allochems	X	X	-	X	X
Average Grain Size	cs	st	-	fs	pb
Fossils:	X	-	-	X	-
Algae	-	-	-	-	-
Brachiopods	r	-	-	-	-
Bryozoans	t	-	-	-	-
Calcispheres	-	-	-	-	-
Corals	-	-	-	-	-
Crinoids	c	-	-	c	-
Foraminifers	-	-	-	-	-
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	-	-	-	-	-
Trilobites	-	-	-	-	-
Other: UFF*	-	-	-	t	-
Intraclasts	-	-	-	-	ea
Peloids	t	c	-	-	-
Pellets	-	-	-	-	-
Other:	-	-	-	-	-
Terrigenous Grains	X	-	X	X	X
Average Grain Size	st	-	st	st	st
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	a	-	c	c	c
Rock Fragments	c	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	-	X	X	X	-
Degrading	-	-	-	X	-
Diagenesis					
Dolomitization	-	-	-	X	-
Replacement by Quartz	X	-	-	-	X
Rock Name	m	m	m	m	lmr

*UFF = Unidentified Fossil Fragment

Corkscrew Canyon; Caloso Member (cont'd)

Sample Number	FT8	LM7a	LM7b
Distance from base (m)	10.6	11.2	12.9
Matrix (%)			
Micrite	50	90	-
Spar	3	10	35
Texture	p	m	rd,s
Allochems	X	-	X
Average Grain Size	ms	-	ms
Fossils:	X	-	X
Algae	-	-	-
Brachiopods	la	-	-
Bryozoans	-	-	va
Calcispheres	-	-	-
Corals	-	-	-
Crinoids	-	-	va
Foraminifers	-	-	r
Gastropods	-	-	-
Mollusks	-	-	-
Ostracods	-	-	-
Trilobites	-	-	t
Other:	-	-	-
Intraclasts	-	-	-
Peloids	ea	-	-
Pellets	la	-	-
Other:	-	-	-
Terrigenous Grains	-	-	-
Average Grain Size	-	-	-
Feldspar	-	-	-
Mica	-	-	-
Quartz	-	-	-
Rock Fragments	-	-	-
Other:	-	-	-
Neomorphism			
Aggrading	X	-	-
Degrading	X	-	X
Diagenesis			
Dolomitization	-	-	-
Replacement by Quartz	-	-	-
Rock Name	pm	m	bs

Corkscrew Canyon; Ladron Member

Sample Number	LM8a	LM10a	FT9	FT10	FT11
Distance from base (m)	-	5.1	6.6	8.7	9.0
Matrix (%)					
Micrite	25	-	42	-	20
Spar	25	7	3	40	r
Texture	pw	u	p	u	p
Allochems	X	X	X	X	X
Average Grain Size	ms	cs	cs	cs	fs
Fossils:	X	X	X	X	X
Algae	-	-	-	-	-
Brachiopods	r	r	c	t	t
Bryozoans	-	c	a	t	ea
Calcispheres	a	-	t	-	t
Corals	-	r	-	-	-
Crinoids	c	ea	va	ea	la
Foraminifers	a	r	-	-	t
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	r	-	-	-	-
Trilobites	-	-	-	-	-
Other: UFF*	-	-	t	-	t
Intraclasts	c	t	-	-	-
Peloids	la	t	-	-	-
Pellets	-	-	-	-	-
Other:	-	-	-	-	-
Terrigenous Grains	-	-	-	-	-
Average Grain Size	-	-	-	-	-
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	-	-	-	-	-
Rock Fragments	-	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	X	-	-	-	-
Degrading	X	X	-	X	-
Diagenesis					
Dolomitization	-	-	-	-	-
Replacement by Quartz	X	X	X	X	X
Rock Name	bm	bsr	bmr	bsr	bm

*UFF = Unidentified Fossil Fragment

Corkscrew Canyon; Ladron Member (cont'd)

Sample Number	LM10b'	LM10d-1	LM10d-2
Distance from base (m)	16.3	19.3	19.3
Matrix (%)			
Micrite	-	58	20
Spar	20	2	r
Texture	u	s	p
Allochems	X	X	X
Average Grain Size	cs	fs	cs
Fossils:	-	X	X
Algae	-	-	-
Brachiopods	la	c	r
Bryozoans	ea	-	ea
Calcispheres	t	-	r
Corals	-	-	-
Crinoids	va	r	c
Foraminifers	r	-	-
Gastropods	-	-	-
Mollusks	-	-	-
Ostracods	-	c	c
Trilobites	r	-	-
Other: UFF*	-	ea	-
Intraclasts	-	-	-
Peloids	-	-	-
Pellets	-	-	-
Other:	-	-	-
Terrigenous Grains	-	-	-
Average Grain Size	-	-	-
Feldspar	-	-	-
Mica	-	-	-
Quartz	-	-	-
Rock Fragments	-	-	-
Other:	-	-	-
Neomorphism			
Aggrading	-	-	-
Degrading	X	-	-
Diagenesis			
Dolomitization	-	-	-
Replacement by Quartz	X	-	X
Rock Name	bsr	bm	bm

*UFF = Unidentified Fossil Fragment

Cerro de Colorado; Caloso Member

Sample Number	CC7a	CC7b	CC8a	CC	FT12
Distance from base (m)	5.8	6.3	10.9	9.1	6.9
Matrix (%)					
Micrite	92	98	25	25	60
Spar	r	t	25	25	t
Texture	m	m	pw	pw	s
Allochems	-	-	X	X	-
Average Grain Size	-	-	fs	fs	-
Fossils:	-	-	X	X	X
Algae	-	-	-	-	-
Brachiopods	-	-	r	r	-
Bryozoans	-	-	-	r	r
Calcispheres	-	-	va	c	la
Corals	-	-	-	-	-
Crinoids	-	-	r	r	-
Foraminifers	-	-	c	c	la
Gastropods	-	-	-	-	-
Mollusks	-	-	-	-	-
Ostracods	-	-	r	r	-
Trilobites	-	-	-	-	-
Other: UFF*	-	-	c	a	c
Intraclasts	-	-	c	la	-
Peloids	-	-	c	c	-
Pellets	-	-	-	-	-
Other:	-	-	-	-	-
Terrigenous Grains	X	X	-	-	-
Average Grain Size	ms	st	-	-	-
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	la	c	-	-	-
Rock Fragments	-	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	X	X	-	-	-
Degrading	-	-	X	X	-
Diagenesis					
Dolomitization	-	-	-	-	X
Replacement by Quartz	-	X	X	X	-
Rock Name	m	m	bm/bs	bm/bs	bm

*UFF = Unidentified Fossil Fragment

Cerro de Colorado; Caloso Member (cont'd)

Sample Number	FT14	FT15	FT16	FT17	FT19
Distance from base (m)	8.4	9.0	9.6	10.3	11.8
Matrix (%)					
Micrite	85	50	90	75	15
Spar	t	1	1	t	20
Texture	s	s	s	s	pw
Allochems	X	X	X	X	X
Average Grain Size	fs	fs	fs	ms	ms
Fossils:	X	X	X	X	X
Algae	-	-	-	-	-
Brachiopods	-	c	-	c	-
Bryozoans	t	r	?*	r	-
Calcispheres	c	c	t	la	a
Corals	-	-	-	-	-
Crinoids	?	-	t	r	-
Foraminifers	?	-	t	c	la
Gastropods	-	va	-	-	-
Mollusks	-	c	-	-	-
Ostracods	-	r	c	c	c
Trilobites	-	-	-	-	-
Other: UFF**	c	c	c	-	-
Intraclasts	-	-	-	-	c
Peloids	-	-	-	-	va
Pellets	-	-	-	-	-
Other:	-	-	-	-	-
Terrigenous Grains	-	-	-	-	-
Average Grain Size	-	-	-	-	-
Feldspar	-	-	-	-	-
Mica	-	-	-	-	-
Quartz	-	-	-	-	-
Rock Fragments	-	-	-	-	-
Other:	-	-	-	-	-
Neomorphism					
Aggrading	-	-	-	X	X
Degrading	-	-	-	-	X
Diagenesis					
Dolomitization	-	-	X	X	-
Replacement by Quartz	X	-	-	-	-
Rock Name	bm	bm	bm	bm	bpm/bps

*indeterminant

**UFF = Unidentified Fossil Fragment

<u>Cerro de Colorado; Caloso Member</u> (cont'd)

Sample Number	ClLa	K15-86
Distance from base (m)	11.8	1.0 m (from top)
Matrix (%)		
Micrite	25	60
Spar	15	r
Texture	pw	s
Allochems	X	X
Average Grain Size	ms	cs
Fossils:	X	X
Algae	-	-
Brachiopods	r	r
Bryozoans	t	-
Calcispheres	c	la
Corals	-	-
Crinoids	-	?*
Foraminifers	c	c
Gastropods	-	-
Mollusks	-	-
Ostracods	r	r
Trilobites	-	-
Other: UFF**	ea	-
Intraclasts	la	-
Peloids	c	a
Pellets	-	-
Other:	-	-
Terrigenous Grains	-	-
Average Grain Size	-	-
Feldspar	-	-
Mica	-	-
Quartz	-	-
Rock Fragments	-	-
Other:	-	-
Neomorphism		
Aggrading	-	X
Degrading	-	X
Diagenesis		
Dolomitization	-	-
Replacement by Quartz	X	-
Rock Name	bm	bpm

*indeterminant

**UFF = Unidentified Fossil Fragment

Cerro de Colorado; Ladron Member

Sample Number	CC9c	CC9h	CC10a
Distance from base (m)	7.5	10.2	13.5
Matrix (%)			
Micrite	r	49	30
Spar	15	2	2
Texture	rd	s	p
Allochems	X	X	X
Average Grain Size	cs	fs	fs
Fossils:	X	X	X
Algae	-	-	-
Brachiopods	c	r	t
Bryozoans	a	a	ea
Calcispheres	-	t	-
Corals	r	-	-
Crinoids	ea	c	t
Foraminifers	t	r	-
Gastropods	-	-	-
Mollusks	t	t	t
Ostracods	t	t	t
Trilobites	-	-	-
Other: UFF*	-	a	-
Intraclasts	-	-	-
Peloids	-	-	-
Pellets	-	-	-
Other:	-	-	-
Terrigenous Grains	-	-	-
Average Grain Size	-	-	-
Feldspar	-	-	-
Mica	-	-	-
Quartz	-	-	-
Rock Fragments	-	-	-
Other:	-	-	-
Neomorphism			
Aggrading	-	-	-
Degrading	X	-	-
Diagenesis			
Dolomitization	-	-	-
Replacement by Quartz	X	X	-
Rock Name	bsr	bm	bm

*UFF = Unidentified Fossil Fragment

APPENDIX III: FORAMINIFER DATA TABLES

Foraminifers in North Peak Section

Sample Number:	FT5	KG16a	KG16c	KG17b
Foraminifers[*]				
indet. multilocular foram.	X	-	-	X
indet. Aoujgaliaceae	-	-	-	-
Earlandia moderata grp.	X	X	X	X
Earlandia clavatula grp.	X	X	-	X
Palaeospinoplectammina sp.	-	-	-	-
Calcisphaera sp.	-	-	-	-
Radiosphaerids	-	-	-	-
Septaglomospiranella sp.	-	-	-	-
Tuberculate foram.	-	-	-	-
Laxoendothyra parakosvensis grp.	-	-	-	-
Septaglomospiranella dainae	-	-	-	-
Spinoendothyra costifera	-	-	-	-
Inflatoendothyra sp.	-	-	-	-
Earlandia elegans grp.	X	X	-	-
Spinoendothyra sp.	-	-	-	-
Tuberendothyra sp.	-	-	-	-
Parathuraminna sp.	-	-	-	-
Spinotournayella sp.	-	-	-	-
Issinella sp.	-	-	-	-
Diplosphaerina inaequalis	-	-	-	-
"Priscella" sp.	-	?	X	-
Earlandia vulgaris grp.	-	-	-	-
Asphaltina ? macadami	-	?	-	-
Pseudoammodiscus - Viscidiscus	-	-	-	-
Endotaxis sp.	-	-	?	-
Septatournayella pseudocamerata	-	-	-	-
Calligellid	-	-	-	-
Earlandianella sp.	-	-	-	-
Kamaena sp.	-	-	-	-
Tuberendothyra tuberculata	-	-	-	-
indet. Tournayellidae	-	-	-	-
"forschiid"	-	-	-	-
Spinoendothyra tenniseptata	-	-	-	-
Soloenoporid	-	-	-	-
Stacheoides sp.	-	X	-	-
Tetrataxis sp.	-	X	-	-
Endothyra sp.	-	?	-	-
Planoarchaediscus sp.	-	-	-	?
Paraarchaediscus sp.	-	-	-	-
Girvanella sp.	-	-	-	-

[*] other calcareous microfossils are listed under "Foraminifers"

Foraminifers in North Peak Section (cont'd)

Sample Number:	FT7	KG19b	KG
Foraminifers			
indet. multilocular foram.	X	X	X
indet. Aoujgaliaceae	-	-	-
Earlandia moderata grp.	X	-	X
Earlandia clavatula grp.	X	X	-
Palaeospinoplectammina sp.	-	-	-
Calcisphaera sp.	-	-	-
Radiosphaerids	-	-	-
Septaglomospiranella sp.	-	-	-
Tuberculate foram.	-	-	-
Laxoendothyra parakosvensis grp.	-	-	-
Septaglomospiranella dainae	-	-	-
Spinoendothyra costifera	-	-	-
Inflatoendothyra sp.	-	-	-
Earlandia elegans grp.	X	-	X
Spinoendothyra sp.	-	-	-
Tuberendothyra sp.	-	-	-
Parathuraminna sp.	-	-	-
Spinotournayella sp.	-	-	-
Issinella sp.	-	-	-
Diplosphaerina inequalis	-	X	-
"Priscella" sp.	X	-	?
Earlandia vulgaris grp.	-	-	-
Asphaltina ? macadami	?	X	-
Pseudoammodiscus - Viscidiscus	?	-	-
Endotaxis sp.	-	-	-
Septatournayella pseudocamerata	-	-	-
Calligellid	-	-	-
Earlandianella sp.	-	-	-
Kamaena sp.	-	-	-
Tuberendothyra tuberculata	-	-	-
indet. Tournayellidae	-	-	-
"forschiid"	-	-	-
Spinoendothyra tenniseptata	-	-	-
Soloenoporid	-	-	-
Stacheoides sp.	-	-	-
Tetrataxis sp.	-	-	-
Endothyra sp.	-	?	-
Planoarchaediscus sp.	-	-	-
Paraarchaediscus sp.	-	X	-
Girvanella sp.	-	-	-

Foraminifers in Corkscrew Canyon Section

Sample Number:	LM7b	LM8a	LM10a	FT11
Foraminifers				
indet. multilocular foram.	X	-	X	X
indet. Aoujgaliaceae	?	-	X	-
Earlandia moderata grp.	X	X	X	X
Earlandia clavatula grp.	X	-	-	-
Palaeospinoplectammina sp.	X	-	-	-
Calcisphaera sp.	-	X	-	-
Radiosphaerids	-	X	-	-
Septaglomospiranella sp.	-	X	-	-
Tuberculate foram.	-	X	-	-
Laxoendothyra parakosvensis grp.	-	?	-	-
Septaglomospiranella dainae	-	X	-	-
Spinoendothyra costifera	-	?	-	-
Inflatoendothyra sp.	-	X	-	-
Earlandia elegans grp.	-	X	X	X
Spinoendothyra sp.	-	X	-	-
Tuberendothyra sp.	-	X	-	-
Parathuraminna sp.	-	X	-	-
Spinotournayella sp.	-	X	-	-
Issinella sp.	-	X	-	-
Diplosphaerina inequalis	-	X	-	-
"Priscella" sp.	-	-	X	?
Earlandia vulgaris grp.	-	-	?	-
Asphaltina ? macadami	-	-	-	-
Pseudoammodiscus - Viscidiscus	-	-	-	-
Endotaxis sp.	-	-	-	?
Septatournayella pseudocamerata	-	-	-	-
Calligellid	-	-	-	-
Earlandianella sp.	-	?	-	-
Kamaena sp.	-	-	-	-
Tuberendothyra tuberculata	-	-	-	-
indet. Tournayellidae	-	-	-	-
"forschiid"	-	-	-	-
Spinoendothyra tenniseptata	-	X	-	-
Soloenoporid	-	-	-	-
Stacheoides sp.	-	-	-	-
Tetrataxis sp.	-	-	-	-
Endothyra sp.	-	-	-	-
Planoarchaediscus sp.	-	-	-	-
Paraarchaediscus sp.	-	-	-	-
Girvanella sp.	-	-	-	-

Foraminifers in Corkscrew Canyon Section (cont'd)

Sample Number:	LM10b'
Foraminifers	
indet. multilocular foram.	X
indet. Aoujgaliaceae	X
Earlandia moderata grp.	X
Earlandia clavatula grp.	X
Palaeospinoplectammina sp.	-
Calcisphaera sp.	-
Radiosphaerids	-
Septaglomospiranella sp.	-
Tuberculate foram.	-
Laxoendothyra parakosvensis grp.	-
Septaglomospiranella dainae	-
Spinoendothyra costifera	-
Inflatoendothyra sp.	-
Earlandia elegans grp.	-
Spinoendothyra sp.	-
Tuberendothyra sp.	-
Parathuraminna sp.	-
Spinotournayella sp.	-
Issinella sp.	-
Diplosphaerina inequalis	-
"Priscella" sp.	-
Earlandia vulgaris grp.	-
Asphaltina ? macadami	-
Pseudoammodiscus - Viscidiscus	-
Endotaxis sp.	-
Septatournayella pseudocamerata	-
Calligellid	-
Earlandianella sp.	-
Kamaena sp.	-
Tuberendothyra tuberculata	-
indet. Tournayellidae	-
"forschiid"	-
Spinoendothyra tenniseptata	-
Soloenoporid	-
Stacheoides sp.	-
Tetrataxis sp.	-
Endothyra sp.	-
Planoarchaediscus sp.	-
Paraarchaediscus sp.	-
Girvanella sp.	-

Foraminifers in Cerro de Colorado Section

Sample Number:	CC8a	CC	K1586	ClLa
Foraminifers				
indet. multilocular foram.	X	X	-	-
indet. Aoujgaliaceae	-	-	-	-
Earlandia moderata grp.	X	X	X	X
Earlandia clavatula grp.	-	X	X	-
Palaeospinoplectammina sp.	-	-	-	-
Calcisphaera sp.	X	X	X	X
Radiosphaerids	X	X	X	X
Septaglomospiranella sp.	-	-	X	X
Tuberculate foram.	X	X	X	X
Laxoendothyra parakosvensis grp.	-	-	-	-
Septaglomospiranella dainae	X	X	X	X
Spinoendothyra costifera	-	-	-	X
Inflatoendothyra sp.	?	?	?	?
Earlandia elegans grp.	-	-	-	X
Spinoendothyra sp.	-	X	X	-
Tuberendothyra sp.	-	?	-	X
Parathuraminna sp.	X	X	X	X
Spinotournayella sp.	-	-	-	-
Issinella sp.	-	-	-	X
Diplosphaerina inequalis	X	X	X	X
"Priscella" sp.	-	-	-	-
Earlandia vulgaris grp.	-	-	-	-
Asphaltina ? macadami	-	-	-	-
Pseudoammodiscus - Viscidiscus	-	-	-	-
Endotaxis sp.	-	-	-	-
Septatournayella pseudocamerata	-	-	-	-
Calligellid	-	-	-	-
Earlandianella sp.	-	-	?	-
Kamaena sp.	?	?	X	-
Tuberendothyra tuberculata	-	-	X	-
indet. Tournayellidae	-	-	X	-
"forschiid"	-	-	?	-
Spinoendothyra tenniseptata	-	X	X	X
Soloenoporid	-	X	-	X
Stacheoides sp.	-	-	-	-
Tetrataxis sp.	-	-	-	-
Endothyra sp.	-	-	-	-
Planoarchaediscus sp.	-	-	-	-
Paraarchaediscus sp.	-	-	-	-
Girvanella sp.	-	X	-	-

Foraminifers in Cerro de Colorado Section (cont'd)

Sample Number:	FT19	CC9c	CC9h
Foraminifers			
indet. multilocular foram.	-	X	X
indet. Aoujgaliaceae	-	-	-
Earlandia moderata grp.	X	X	X
Earlandia clavatula grp.	-	-	X
Palaeospinoplectammina sp.	-	-	-
Calcisphaera sp.	X	-	-
Radiosphaerids	X	-	-
Septaglomospiranella sp.	-	-	-
Tuberculate foram.	X	-	-
Laxoendothyra parakosvensis grp.	-	-	-
Septaglomospiranella dainae	X	-	-
Spinoendothyra costifera	-	-	-
Inflatoendothyra sp.	?	-	-
Earlandia elegans grp.	X	-	X
Spinoendothyra sp.	X	-	-
Tuberendothyra sp.	-	-	-
Parathuraminna sp.	X	-	-
Spinotournayella sp.	-	-	-
Issinella sp.	?	-	-
Diplosphaerina inequalis	X	-	X
"Priscella" sp.	-	X	X
Earlandia vulgaris grp.	-	-	-
Asphaltina ? macadami	-	-	X
Pseudoammodiscus - Viscidiscus	-	-	-
Endotaxis sp.	-	-	X
Septatournayella pseudocamerata	X	-	-
Calligellid	?	-	-
Earlandianella sp.	-	-	-
Kamaena sp.	-	-	-
Tuberendothyra tuberculata	-	-	-
indet. Tournayellidae	-	-	-
"forschiid"	-	-	-
Spinoendothyra tenniseptata	-	-	-
Soloenoporid	-	-	-
Stacheoides sp.	-	-	-
Tetrataxis sp.	-	-	-
Endothyra sp.	-	-	?
Planoarchaediscus sp.	-	-	-
Paraarchaediscus sp.	-	-	-
Girvanella sp.	-	-	-

APPENDIX IV: CONODONT DATA TABLES

Chupadera Peak Section

Stratigraphic Position*	2.3	3.3	4.4	4.9
Sample Number	CH3a	CH3c	CH3b	CH4a
Sample Weight (kg)	2.0	2.1	3.0	4.5
Conodonts				
Anchignathodus peniscitula	-	-	-	-
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	-	-	-
Bispathodus aculeatus plumulus	15	11	-	8
Bispathodus stabilis	-	-	-	-
Cavusgnathus altus	-	-	-	-
Cavusgnathus charactus	-	-	-	-
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	-
Cavusgnathus unicornis	-	-	-	-
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	-	-	-	-
Cloghergnathus sp.	-	-	-	-
Cudotaxis pricelingi	-	-	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	-	-	-
Gnathodus pseudosemiglaber	-	-	-	-
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	-	-
Gnathodus texanus	-	-	-	-
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	-	-
Patrognathus variabilis	1	7	4	6
Polygnathus cf. P. bischoffi	-	-	-	-
Polygnathus communis communis	-	-	-	-
Polygnathus inornatus inornatus	9	4	3	8
Polygnathus inornatus lobatus	-	-	-	2
Protognathodus praedelicatus	-	-	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	-	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	-	-	-
"Spathognathodus" n. sp.	-	-	-	-
Taphrognathus varians	-	-	-	-
Taphrognathus-Cavusgnathus trans.	-	-	-	-
TOTALS	25	22	7	24

* meters above Precambrian/Mississippian nonconformity

CHUPADERA PEAK SECTION (cont'd)

Stratigraphic Position*	7.3	
Sample Number	CH4c	
Sample Weight (kg)	1.5	
Conodonts		TOTAL
Anchignathodus peniscitula	-	
Apatognathus geminus	-	
Apatognathus porcatus	-	
Bispathodus aculeatus plumulus	1	35
Bispathodus stabilis	-	
Cavusgnathus altus	-	
Cavusgnathus charactus	-	
Cavusgnathus convexus	-	
Cavusgnathus regularis	-	
Cavusgnathus unicornis	-	
Cavusgnathus sp.	-	
Cloghergnathus carinatus	-	
Cloghergnathus sp.	-	
Cudotaxis pricelingi	-	
Gnathodus cuneiformis	-	
Gnathodus delicatus	-	
Gnathodus pseudosemiglaber	-	
Gnathodus cf. G. punctatus	-	
Gnathodus semiglaber	-	
Gnathodus texanus	-	
Gnathodus typicus M1	-	
Gnathodus typicus M2	-	
Hindeodus cristulus	-	
Hindeodus scitulus	-	
Patrognathus variabilis	6	24
Polygnathus cf. P. bischoffi	-	
Polygnathus communis communis	-	
Polygnathus inornatus inornatus	1	25
Polygnathus inornatus lobatus	-	2
Protognathodus praedelicatus	-	
Pseudopolygnathus oxypageous M1	-	
Pseudopolygnathus oxypageous M3	-	
"Spathognathodus" abbreviatus	-	
"Spathognathodus" deflexus	-	
"Spathognathodus" n. sp.	-	
Taphrognathus varians	-	
Taphrognathus-Cavusgnathus trans.	-	
TOTALS	8	86

* meters above Precambrian/Mississippian nonconformity

Chihuahua Gulch Section; Caloso Member

Stratigraphic Position*	0.8	1.0	1.7	
Sample Number	CG3b	CG3a	CG4	
Sample Weight (kg)	1.0	1.0	3.6	
Conodonts				TOTAL
Anchignathodus penescitula	-	-	-	
Apatognathus geminus	-	-	-	
Apatognathus porcatus	-	-	-	
Bispathodus aculeatus plumulus	2	1	-	3
Bispathodus stabilis	-	-	-	
Cavusgnathus altus	-	-	-	
Cavusgnathus charactus	-	-	-	
Cavusgnathus convexus	-	-	-	
Cavusgnathus regularis	-	-	-	
Cavusgnathus unicornis	-	-	-	
Cavusgnathus sp.	-	-	-	
Cloghergnathus carinatus	-	-	-	
Cloghergnathus sp.	-	-	-	
Cudotaxis pricelingi	-	-	-	
Gnathodus cuneiformis	-	-	-	
Gnathodus delicatus	-	-	-	
Gnathodus pseudosemiglab	-	-	-	
Gnathodus cf. G. punctus	-	-	-	
Gnathodus semiglaber	-	-	-	
Gnathodus texanus	-	-	-	
Gnathodus typicus M1	-	-	-	
Gnathodus typicus M2	-	-	-	
Hindeodus cristulus	-	-	-	
Hindeodus scitulus	-	-	-	
Patrognathus variabilis	5	4	3	12
Polygnathus cf. P. bischoffi	-	-	-	
Polygnathus communis communis	-	-	-	
Polygnathus inornatus inornatus	1	-	1	2
Polygnathus inornatus lobatus	-	-	-	
Protognathodus praedelicatus	-	-	-	
Pseudopolygnathus oxypageous M1	-	-	-	
Pseudopolygnathus oxypageous M3	-	-	-	
"Spathognathodus" abbreviatus	-	-	-	
"Spathognathodus" deflexus	-	-	-	
"Spathognathodus" n. sp.	-	-	-	
Taphrognathus varians	-	-	-	
Taphrognathus-Cavusgnathus trans.	-	-	-	
TOTALS	8	5	4	17

* meters above Precambrian/Mississippian nonconformity

Chihuahua Gulch Section; Ladron Member

Stratigraphic Position*	12.7	13.1	14.9	15.9
Sample Number**	13d	14b	14a	14c
Sample Weight (kg)	5.0	5.0	1.0	0.5
Conodonts				
Anchignathodus penescitula	-	-	-	-
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	-	-	-
Bispathodus aculeatus plumulus	-	-	-	-
Bispathodus stabilis	15	12	-	-
Cavusgnathus altus	-	-	-	-
Cavusgnathus charactus	-	-	-	-
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	-
Cavusgnathus unicornis	-	-	-	-
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	-	-	-	-
Cloghergnathus sp.	-	-	-	-
Cudotaxis pricelingi	5	2	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	1	1	-
Gnathodus pseudosemiglaber	-	-	-	-
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	-	-
Gnathodus texanus	-	-	-	-
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	-	-
Patrognathus variabilis	-	-	-	-
Polygnathus cf. P. bischoffi	1	-	-	-
Polygnathus communis communis	4	18	-	4
Polygnathus inornatus inornatus	-	-	-	-
Polygnathus inornatus lobatus	-	-	-	-
Protognathodus praedelicatus	-	1	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	1	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	-	-	-
"Spathognathodus" n. sp.	5	1	-	-
Taphrognathus varians	-	-	-	-
Taphrognathus-Cavusgnathus trans.	-	-	-	-
TOTALS	30	36	1	4

* meters above Precambrian/Mississippian nonconformity
** sample prefix is CG-

Chihuahua Gulch Section; Ladron Member (cont'd)

Stratigraphic Position*	17.7	22.0	
Sample Number**	16a	16b	
Sample Weight (kg)	5.5	1.0	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	-	
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	-	-	
Cavusgnathus altus	-	-	
Cavusgnathus charactus	-	-	
Cavusgnathus convexus	-	-	
Cavusgnathus regularis	-	-	
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	-	
Cloghergnathus sp.	-	-	
Cudotaxis pricelingi	-	-	7
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	2
Gnathodus pseudosemiglaber	-	-	
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	
Gnathodus texanus	41	2	43
Gnathodus typicus M1	-	-	
Gnathodus typicus M2	-	-	
Hindeodus cristulus	-	-	
Hindeodus scitulus	-	-	
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	1
Polygnathus communis communis	-	-	26
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	1
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	1
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	3	-	3
"Spathognathodus" n. sp.	-	-	6
Taphrognathus varians	2	-	2
Taphrognathus-Cavusgnathus trans.	-	-	
TOTALS	46	3	120

* meters above Precambrian/Mississippian nonconformity

** sample prefix is CG-

North Peak Section; Ladron Member
(below dolomitic mudstone)

Stratigraphic Position*	12.7	14.8	15.7	
Sample Number**	KG11a	KG13a	KG14a	
Sample Weight (kg)	5.5	5.5	5.5	
Conodonts				TOTAL
Anchignathodus penescitula	-	-	-	
Apatognathus geminus	-	-	-	
Apatognathus porcatus	-	-	-	
Bispathodus aculeatus plumulus	-	-	-	
Bispathodus stabilis	-	12	10	22
Cavusgnathus altus	-	-	-	
Cavusgnathus charactus	-	-	-	
Cavusgnathus convexus	-	-	-	
Cavusgnathus regularis	-	-	-	
Cavusgnathus unicornis	-	-	-	
Cavusgnathus sp.	-	-	-	
Cloghergnathus carinatus	-	-	-	
Cloghergnathus sp.	-	-	-	
Cudotaxis pricelingi	-	8	2	10
Gnathodus cuneiformis	-	6	-	6
Gnathodus delicatus	-	13	1	14
Gnathodus pseudosemiglaber	-	-	-	
Gnathodus cf. G. punctatus	-	-	-	
Gnathodus semiglaber	-	-	-	
Gnathodus texanus	-	-	-	
Gnathodus typicus M1	-	-	-	
Gnathodus typicus M2	-	-	-	
Hindeodus cristulus	-	-	-	
Hindeodus scitulus	-	-	-	
Patrognathus variabilis	9	-	-	9
Polygnathus cf. P. bischoffi	-	-	-	
Polygnathus communis communis	3	135	-	138
Polygnathus inornatus inornatus	-	-	-	
Polygnathus inornatus lobatus	-	-	-	
Protognathodus praedelicatus	-	-	-	
Pseudopolygnathus oxypageous M1	-	-	-	
Pseudopolygnathus oxypageous M3	-	-	-	
"Spathognathodus" abbreviatus	-	-	-	
"Spathognathodus" deflexus	-	-	-	
"Spathognathodus" n. sp.	-	-	-	
Taphrognathus varians	-	-	-	
Taphrognathus-Cavusgnathus trans.	-	-	-	
TOTALS	12	174	11	197

* meters above Precambrian/Mississippian nonconformity

North Peak Section; Ladron Member
(above dolomitic mudstone)

Stratigraphic Position*	25.9	27.6	29.2	30.2
Sample Number**	16a	16c	17a	16b
Sample Weight (kg)	1.0	3.5	1.0	1.0
Conodonts				
Anchignathodus penescitula	-	-	-	-
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	1	4	-
Bispathodus aculeatus plumulus	-	-	-	-
Bispathodus stabilis	-	-	-	-
Cavusgnathus altus	-	-	-	-
Cavusgnathus charactus	-	-	-	-
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	-
Cavusgnathus unicornis	-	-	-	-
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	2	-	-	-
Cloghergnathus sp.	-	-	-	1
Cudotaxis pricelingi	-	-	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	-	-	-
Gnathodus pseudosemiglaber	-	-	-	-
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	-	-
Gnathodus texanus	4	4	-	2
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	3	-
Patrognathus variabilis	-	-	-	-
Polygnathus cf. P. bischoffi	-	-	-	-
Polygnathus communis communis	-	-	-	-
Polygnathus inornatus inornatus	-	-	-	-
Polygnathus inornatus lobatus	-	-	-	-
Protognathodus praedelicatus	-	-	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	-	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	-	-	-
"Spathognathodus" n. sp.	-	-	-	-
Taphrognathus varians	-	-	-	1
Taphrognathus-Cavusgnathus trans.	-	-	-	1
TOTALS	6	5	7	5

* meters above Precambrian/Mississippian nonconformity
** sample prefix is KG-

North Peak Section; Ladron Member
(above dolomitic mudstone; cont'd)

Stratigraphic Position*	34.9	36.5	
Sample Number**	17b	19a	
Sample Weight (kg)	4.0	1.5	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	2	2
Apatognathus porcatus	-	-	5
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	-	-	
Cavusgnathus altus	4	-	4
Cavusgnathus charactus	3	-	3
Cavusgnathus convexus	1	-	1
Cavusgnathus regularis	-	2	2
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	2	2
Cloghergnathus carinatus	-	-	2
Cloghergnathus sp.	2	-	3
Cudotaxis pricelingi	-	-	
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	
Gnathodus pseudosemiglaber	-	-	
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	
Gnathodus texanus	2	-	12
Gnathodus typicus M1	-	-	
Gnathodus typicus M2	-	-	
Hindeodus cristulus	2	-	2
Hindeodus scitulus	-	4	7
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	1	-	1
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	-	
Taphrognathus varians	5	-	6
Taphrognathus-Cavusgnathus trans.	3	-	4
TOTALS	23	10	56

* meters above Precambrian/Mississippian nonconformity
** sample prefix is KG-

Corkscrew Canyon Section; Caloso Member

Stratigraphic Position*	0.5	11.6	
Sample Number	LM2a	LM7b	
Sample Weight (kg)	5.0	6.5	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	-	
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	1	68	69
Cavusgnathus altus	-	-	
Cavusgnathus charactus	-	-	
Cavusgnathus convexus	-	-	
Cavusgnathus regularis	-	-	
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	-	
Cloghergnathus sp.	-	-	
Cudotaxis pricelingi	-	7	7
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	2	2
Gnathodus pseudosemiglaber	-	-	
Gnathodus cf. G. punctatus	-	1	1
Gnathodus semiglaber	-	-	
Gnathodus texanus	-	-	
Gnathodus typicus M1	-	2	2
Gnathodus typicus M2	-	1	1
Hindeodus cristulus	-	-	
Hindeodus scitulus	-	-	
Patrognathus variabilis	12	-	12
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	-	146	146
Polygnathus inornatus inornatus	5	-	5
Polygnathus inornatus lobatus	1	-	1
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	1	1
Pseudopolygnathus oxypageous M3	-	1	1
"Spathognathodus" abbreviatus	-	3	3
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	2	2
Taphrognathus varians	-	-	
Taphrognathus-Cavusgnathus trans.	-	-	
TOTALS	19	234	253

* meters above Precambrian/Mississippian nonconformity

Corkscrew Canyon Section; Ladron Member
(below dolomitic mudstone)

Stratigraphic Position*	12.6	14.0	
Sample Number	LM8a	LM8b	
Sample Weight (kg)	2.5	3.5	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	-	
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	6	17	23
Cavusgnathus altus	-	-	
Cavusgnathus charactus	-	-	
Cavusgnathus convexus	-	-	
Cavusgnathus regularis	-	-	
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	-	
Cloghergnathus sp.	-	-	
Cudotaxis pricelingi	-	-	
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	
Gnathodus pseudosemiglaber	-	-	
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	
Gnathodus texanus	-	-	
Gnathodus typicus M1	2	9	11
Gnathodus typicus M2	-	3	3
Hindeodus cristulus	-	-	
Hindeodus scitulus	-	-	
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	15	-	15
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	-	
Taphrognathus varians	-	-	
Taphrognathus-Cavusgnathus trans.	-	-	
TOTALS	23	29	52

* meters above Precambrian/Mississippian nonconformity

Corkscrew Canyon Section; Ladron Member
(above dolomitic mudstone)

Stratigraphic Position*	17.0	19.8	24.1	26.8
Sample Number**	10a	10a′	10b	10d
Sample Weight (kg)	1.5	3.0	4.5	7.5
Conodonts				
Anchignathodus penescitula	-	-	-	3
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	-	-	-
Bispathodus aculeatus plumulus	-	-	-	-
Bispathodus stabilis	-	2	-	-
Cavusgnathus altus	-	-	-	1
Cavusgnathus charactus	-	-	-	4
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	2
Cavusgnathus unicornis	-	-	-	1
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	-	-	1	-
Cloghergnathus sp.	-	1	9	2
Cudotaxis pricelingi	-	-	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	-	-	-
Gnathodus pseudosemiglaber	-	5	-	-
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	-	-
Gnathodus texanus	15	8	79	1
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	-	7
Patrognathus variabilis	-	-	-	-
Polygnathus cf. P. bischoffi	-	-	-	-
Polygnathus communis communis	-	-	-	-
Polygnathus inornatus inornatus	-	-	-	-
Polygnathus inornatus lobatus	-	-	-	-
Protognathodus praedelicatus	-	-	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	-	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	-	-	-
"Spathognathodus" n. sp.	-	-	-	-
Taphrognathus varians	-	1	-	1
Taphrognathus-Cavusgnathus trans.	-	1	1	-
TOTALS	15	18	90	22

* meters above Precambrian/Mississippian nonconformity
** sample prefix is LM-

Corkscrew Canyon Section; Ladron Member
(above dolomitic mudstone; cont'd)

Stratigraphic Position*	27.6	28.8	
Sample Number**	10c	10b′	
Sample Weight (kg)	1.0	4.0	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	3
Apatognathus geminus	-	-	
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	-	2	2
Cavusgnathus altus	-	-	1
Cavusgnathus charactus	1	-	5
Cavusgnathus convexus	-	-	
Cavusgnathus regularis	-	-	2
Cavusgnathus unicornis	-	-	1
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	8	9
Cloghergnathus sp.	1	7	20
Cudotaxis pricelingi	-	-	
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	
Gnathodus pseudosemiglaber	-	5	5
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	
Gnathodus texanus	-	17	120
Gnathodus typicus M1	-	-	
Gnathodus typicus M2	-	-	
Hindeodus cristulus	-	-	
Hindeodus scitulus	1	-	8
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	-	-	
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	-	
Taphrognathus varians	-	2	4
Taphrognathus-Cavusgnathus trans.	-	3	5
TOTALS	3	37	185

* meters above Precambrian/Mississippian nonconformity
** sample prefix is LM-

Cerro de Colorado Section; Caloso Member

Stratigraphic Position*	8.2	12.3	
Sample Number	CC8b	CLLA	
Sample Weight (kg)+	3.0	3.0	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	-	
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	-	-	
Cavusgnathus altus	-	-	
Cavusgnathus charactus	-	-	
Cavusgnathus convexus	-	-	
Cavusgnathus regularis	-	-	
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	-	
Cloghergnathus sp.	-	-	
Cudotaxis pricelingi	-	-	
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	
Gnathodus pseudosemiglaber	-	-	
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	
Gnathodus texanus	-	-	
Gnathodus typicus M1	-	-	
Gnathodus typicus M2	1	-	1
Hindeodus cristulus	-	-	
Hindeodus scitulus	-	-	
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	-	1	1
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	-	
Taphrognathus varians	-	-	
Taphrognathus-Cavusgnathus transition	-	-	
TOTALS	1	1	2

* meters above Precambrian/Mississippian nonconformity

\+ sample wts. CC8b and CLLA are minimum estimated values

Cerro de Colorado Section; Ladron Member

Stratigraphic Position*	12.5	14.3	14.4	16.9
Sample Number**	9a	9d	9e	9b
Sample Weight (kg)$^+$	3.0	2.5	3.5	3.0
Conodonts				
Anchignathodus penescitula	-	-	-	-
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	-	-	-
Bispathodus aculeatus plumulus	-	-	-	-
Bispathodus stabilis	-	-	-	-
Cavusgnathus altus	-	-	-	-
Cavusgnathus charactus	-	-	-	-
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	-
Cavusgnathus unicornis	-	-	-	-
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	-	1	-	-
Cloghergnathus sp.	-	-	-	3
Cudotaxis pricelingi	-	-	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	-	-	-
Gnathodus pseudosemiglaber	-	-	-	13
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	3	-
Gnathodus texanus	-	22	66	-
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	-	-
Patrognathus variabilis	-	-	-	-
Polygnathus cf. P. bischoffi	-	-	-	-
Polygnathus communis communis	1	-	-	-
Polygnathus inornatus inornatus	-	-	-	-
Polygnathus inornatus lobatus	-	-	-	-
Protognathodus praedelicatus	-	-	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	-	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	3	8	-
"Spathognathodus" n. sp.	-	-	-	-
Taphrognathus varians	-	1	-	-
Taphrognathus-Cavusgnathus trans.	-	-	-	-
	1	27	77	26

* meters above Precambrian/Mississippian nonconformity
** sample prefix is CC-

$^+$Samples 9a and 9b are minimum estimated values

Cerro de Colorado Section; Ladron Member (cont'd)

Stratigraphic Position*	19.3	19.4	19.6	22.3
Sample Number**	9c	9f	9g	9h
Sample Weight (kg)$^{+}$	3.0	2.5	2.5	3.0
Conodonts				
Anchignathodus penescitula	-	-	-	-
Apatognathus geminus	-	-	-	-
Apatognathus porcatus	-	-	-	-
Bispathodus aculeatus plumulus	-	-	-	-
Bispathodus stabilis	-	-	-	-
Cavusgnathus altus	-	-	-	-
Cavusgnathus charactus	-	-	-	-
Cavusgnathus convexus	-	-	-	-
Cavusgnathus regularis	-	-	-	-
Cavusgnathus unicornis	-	-	-	-
Cavusgnathus sp.	-	-	-	-
Cloghergnathus carinatus	-	4	-	-
Cloghergnathus sp.	4	1	-	1
Cudotaxis pricelingi	-	-	-	-
Gnathodus cuneiformis	-	-	-	-
Gnathodus delicatus	-	-	-	-
Gnathodus pseudosemiglaber	-	1	-	-
Gnathodus cf. G. punctatus	-	-	-	-
Gnathodus semiglaber	-	-	1	-
Gnathodus texanus	39	-	3	6
Gnathodus typicus M1	-	-	-	-
Gnathodus typicus M2	-	-	-	-
Hindeodus cristulus	-	-	-	-
Hindeodus scitulus	-	-	-	-
Patrognathus variabilis	-	-	-	-
Polygnathus cf. P. bischoffi	-	-	-	-
Polygnathus communis communis	-	-	-	-
Polygnathus inornatus inornatus	-	-	-	-
Polygnathus inornatus lobatus	-	-	-	-
Protognathodus praedelicatus	-	-	-	-
Pseudopolygnathus oxypageous M1	-	-	-	-
Pseudopolygnathus oxypageous M3	-	-	-	-
"Spathognathodus" abbreviatus	-	-	-	-
"Spathognathodus" deflexus	-	-	-	-
"Spathognathodus" n. sp.	-	-	-	-
Taphrognathus varians	-	-	-	-
Taphrognathus-Cavusgnathus trans.	-	-	-	1
TOTALS	43	6	4	8

* meters above Precambrian/Mississippian nonconformity

** samples prefix is CC-

$^{+}$ sample wts. for 9c, 9g and 9h are minimum estimated values

Cerro de Colorado Section; Ladron Member (cont'd)

Stratigraphic Position*	24.3	25.9	
Sample Number**	9i	10a	
Sample Weight (kg)+	4.0	3.0	
Conodonts			TOTAL
Anchignathodus penescitula	-	-	
Apatognathus geminus	-	3	3
Apatognathus porcatus	-	-	
Bispathodus aculeatus plumulus	-	-	
Bispathodus stabilis	-	-	
Cavusgnathus altus	-	-	
Cavusgnathus charactus	-	-	
Cavusgnathus convexus	-	1	1
Cavusgnathus regularis	-	-	
Cavusgnathus unicornis	-	-	
Cavusgnathus sp.	-	-	
Cloghergnathus carinatus	-	24	
Cloghergnathus sp.	27	-	28
Cudotaxis pricelingi	-	-	
Gnathodus cuneiformis	-	-	
Gnathodus delicatus	-	-	
Gnathodus pseudosemiglaber	2	-	2
Gnathodus cf. G. punctatus	-	-	
Gnathodus semiglaber	-	-	1
Gnathodus texanus	10	-	19
Gnathodus typicus M1	-	-	
Gnathodus typicus M2	-	-	
Hindeodus cristulus	-	1	1
Hindeodus scitulus	-	-	
Patrognathus variabilis	-	-	
Polygnathus cf. P. bischoffi	-	-	
Polygnathus communis communis	-	-	
Polygnathus inornatus inornatus	-	-	
Polygnathus inornatus lobatus	-	-	
Protognathodus praedelicatus	-	-	
Pseudopolygnathus oxypageous M1	-	-	
Pseudopolygnathus oxypageous M3	-	-	
"Spathognathodus" abbreviatus	-	-	
"Spathognathodus" deflexus	-	-	
"Spathognathodus" n. sp.	-	-	
Taphrognathus varians	1	-	1
Taphrognathus-Cavusgnathus trans.	1	-	2
TOTALS	65	5	82

* meters above Precambrian/Mississippian nonconformity
** samples prefix is CC-

+ sample wts. for 10a are minimum estimated values

Total Number of Conodont Specimens

Anchignathodus penescitula	3
Apatognathus geminus	5
Apatognathus porcatus	5
Bispathodus aculeatus plumulus	38
Bispathodus stabilis	144
Cavusgnathus altus	5
Cavusgnathus charactus	8
Cavusgnathus convexus	2
Cavusgnathus regularis	4
Cavusgnathus unicornis	1
Cavusgnathus sp.	2
Cloghergnathus carinatus	40
Cloghergnathus sp.	59
Cudotaxis pricelingi	24
Gnathodus cuneiformis	6
Gnathodus delicatus	18
Gnathodus pseudosemiglaber	21
Gnathodus cf. G. punctatus	1
Gnathodus semiglaber	4
Gnathodus texanus	321
Gnathodus typicus M1	13
Gnathodus typicus M2	5
Hindeodus cristulus	3
Hindeodus scitulus	15
Patrognathus variabilis	57
Polygnathus cf. P. bischoffi	1
Polygnathus communis communis	328
Polygnathus inornatus inornatus	32
Polygnathus inornatus lobatus	3
Protognathodus praedelicatus	1
Pseudopolygnathus oxypageous M1	1
Pseudopolygnathus oxypageous M3	2
"Spathognathodus" abbreviatus	3
"Spathognathodus" deflexus	14
"Spathognathodus" n. sp.	8
Taphrognathus varians	14
Taphrognathus-Cavusgnathus transition .	11

1220 TOTAL

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