CIRCULAR 39

PRELIMINARY OBSERVATIONS ON THE MISSISSIPPIAN SYSTEM OF NORTHERN NEW MEXICO

by

Augustus K. Armstrong

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

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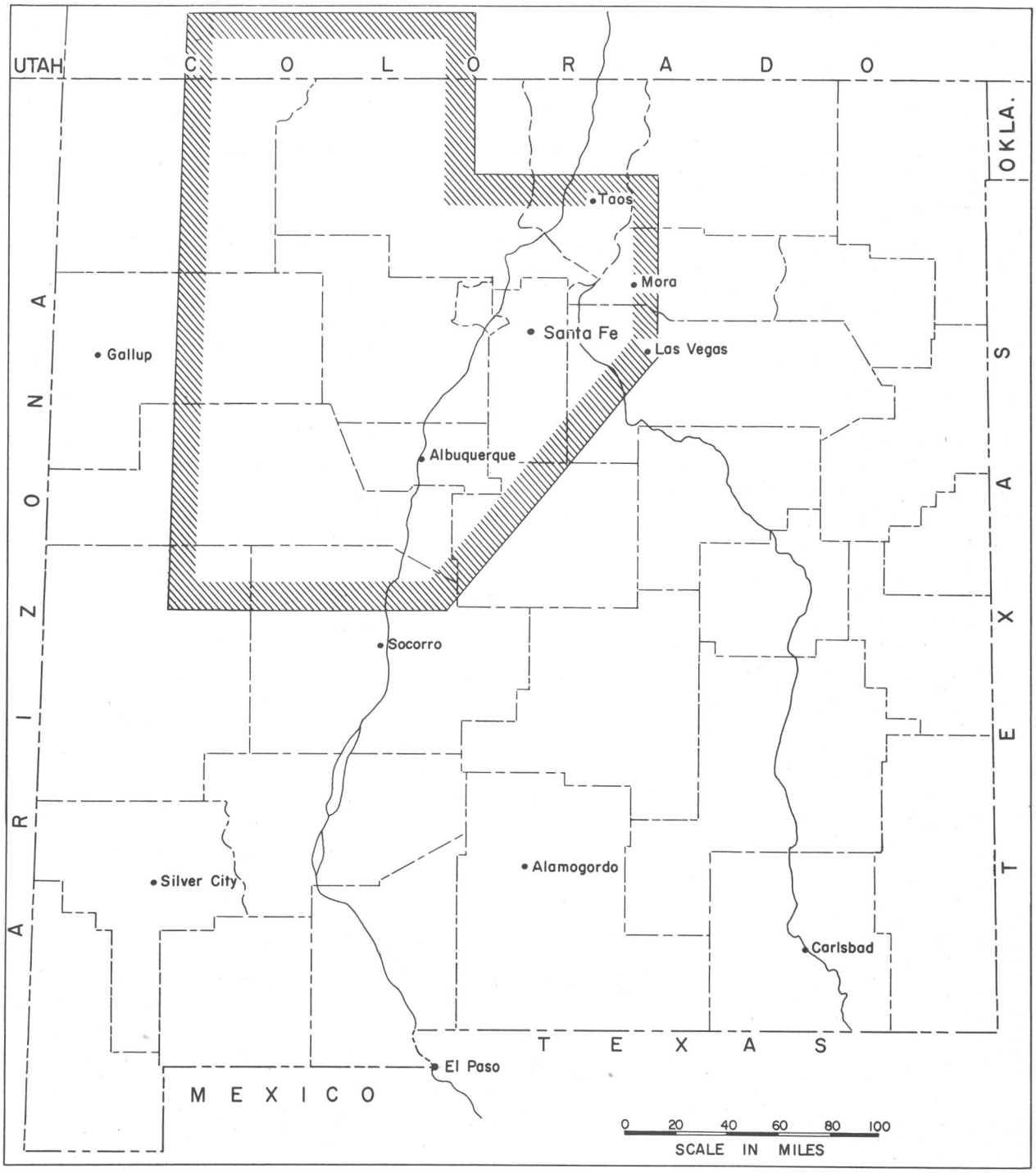

Figure 1. Index of area under consideration in this report.

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By AUGUSTUS K. ARMSTRONG
Graduate Student
University of Cincinnati

1955

NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
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SOCORRO, NEW MEXICO

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COVER DESIGN

Typical Endothyra of the Arroyo Penasco formation.
Microphotograph. X 50.

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ABSTRACT

Study of fossil collections from the lower limestone member of the Sandia formation in northern New Mexico, which hitherto has been regarded as Pennsylvanian, shows that this part of the section is actually Mississippian. In the Sangre de Cristo Mountains, the Meramec only may be represented, but in the San Pedro, Nacimiento, Jemez, and Sandia Mountains, the lower barren portions of the limestone section may be of an earlier Mississippian age.

INTRODUCTION

This paper is primarily a survey of the Mississippian strata of northern and central New Mexico and treats associated rocks of Lower Pennsylvanian age only incidentally. (See fig 1.) Mississippian sections have been studied and measured in the Ladron, Manzano, Sandia, Jemez, Nacimiento, San Pedro, and Sangre de Cristo Mountains. The Mississippian Leadville limestone was studied in the San Juan Mountains of southwestern Colorado.

A series of beds at the base of the Pennsylvanian consisting of 0-47 feet of sandstone and shale, followed by 15-135 feet of dense, semilithographic, relatively unfossiliferous gray limestone, occurs sporadically in northern and central New Mexico. In the spring of 1951, the writer found in Penasco Canyon of the Nacimiento Mountains a Mississippian fauna in this series of beds which had been regarded as the lower limestone member of the Sandia formation.

The summers of 1951, 1952, and 1955 and the month of June 1954 were spent in the field in an attempt to find new outcrops of this Mississippian limestone and to collect fossils therefrom. The search was moderately successful. The fauna was studied at the University of Cincinnati in the spring of 1955 and at the State Bureau of Mines and Mineral Resources, Socorro, New Mexico, in the summer of the same year.

PREVIOUS WORK

Thompson (1942) studied the outcrops of the lower limestone member of the Sandia formation in the Sandia Mountains and in Gallinas Canyon of the Sangre de Cristo Mountains and reported that, on a lithologic basis, they were of "Lower Paleozoic" age.

The first paleontologic study was made on the exposure in the Sandia Mountains by Henbest (1946). He wrote as follows: "In the northwestern Sandia Mountains the lower limestone member of the Sandia formation (Pennsylvanian) contains a foraminifer characteristic of the Leadville limestone of the San Juan Mountains." He concluded that the San Juan Mountains facies of the Leadville limestone (Lower Mississippian) extended 150 miles southeastward into New Mexico.

Numerous other workers, e.g., Read et al. (1944) and Moore et al. (1949), regarded these limestones as the lower limestone member of the Sandia formation, which they considered to be of Pennsylvanian age.

Loudon and Bowsher (1949), in their extensive study of the Mississippian of southern New Mexico, were of the opinion that Mississippian seas did not extend north of the Ladron Mountains.

ACKNOWLEDGMENT

Sincere appreciation is due the New Mexico Bureau of Mines and Mineral Resources for continued support of this project. I cannot express adequately my thanks to my respected friend, Dr. Rousseau Flower, for guidance in conducting the field work and advice in paleontologic matters.

The writer is grateful to Professor K. E. Caster and Professor H. K. Brooks, of the University of Cincinnati, for assistance and guidance in the paleontologic studies. Assistance was given by Dr. M. L. Thompson, of the University of Kansas, who examined microfossils and furnished valuable information. Dr. E. Zeller, of the University of Wisconsin, studied microphotographs of foraminifera and supplied information regarding their age.

CLASSIFICATION OF MISSISSIPPIAN ROCKS OF NORTHERN AND CENTRAL NEW MEXICO

Rocks of Kinderhook Age

Caloso formation: The name Caloso formation was suggested by Noble (1950, p 37; published reference, Kelley and Silver, 1952) for the 86 feet of Mississippian strata in T. 2 N., R. 2 W., Ladron Mountains. The term Caloso formation, as used in this paper, is restricted to the lower 28 feet of sandstones, shales, and dense gray limestones which contains a small Kinderhook fauna characterized by Dielasma chouteauensis Weller and Spirifer centronatus Winchell (fig 24). The Caloso formation rests unconformably on Precambrian gneiss and schist and is overlain disconformably by the Kelly formation.

Leadville limestone: In the San Juan Mountains of southwestern Colorado, the massive, fine-grained, gray Leadville limestone (fig 10) contains a fauna originally described by Girty (1903) which appears to be of Kinderhook age. These beds are not known to crop out in New Mexico.

Rocks of Osage Age

Kelly formation: The name Kelly formation was given to the Mississippian limestone of the Magdalena mining district (Herrick, 1904, p 310). The formation also is exposed in the southern Ladron Mountains, where it consists of 33 feet of slabby crinoidal limestone containing a rich megafauna characteristic of Osage rocks (fig 24). The Kelly formation is not known to occur north of Ladron Peak.

Rocks of Meramec Age

Arroyo Penasco formation: The name Arroyo Penasco formation is proposed for the 20-150 feet of gray, dense, fine-grained to oolitic, massive- to medium-bedded limestone occurring in Pinos and Penasco Canyons in the Nacimiento Mountains, SW¼ SE¼ sec. 5, T. 16 N., R. 1 E. (fig 5). The Arroyo Penasco formation named for the arroyo of that name one mile southeast of the type section, rests unconformably on Precambrian gneiss and is overlain unconformably by red shales and sandstones of the Pennsylvanian Log Springs formation.

This formation, which is consistent in lithology over a wide area, is exposed in the San Pedro, NaCimiento, Jemez, Sandia, and Sangre de Cristo Mountains. In certain zones it contains a rich Meramec microfauna characterized by Endothyra sp. and Plectogyra sp. The rare megafauna consists of Eumetria vera Hall and Eumetria verneuiliana Hall, Spirifer beckenridgensis? Weller, and Linoproductus sp.

Mississippian Rocks of Uncertain Age

Along the front of the Manzano mountains between Tijeras Canyon and Bosque Peak, are a few isolated remnants of dense, fine-grained, gray to brown fossiliferous limestone generally 20-30 feet thick. These rocks cannot be dated definitely, but are either a northward extension of the Kinderhookianloso formation or a southward facies of the Meramecian Arroyo Penasco formation.

The lower 35-40 feet of Mississippian strata in the northern Sandia, Jemez, Nacimiento, and San Pedro Mountains is not fossiliferous; its age also is probably Meramec. It is conceivable that these unfossiliferous lower beds may be of Kinderhook age.

CLASSIFICATION OF PENNSYLVANIAN MORROW ROCKS OF NORTHERN NEW MEXICO

It has been stated that rocks of Lower Pennsylvanian are restricted to southern New Mexico. In the course of this study, Pennsylvanian strata of Morrow age were found in association with Mississippian strata in the northern part of the state.

Log Springs formation: The name Log Springs formation is proposed herewith for the 10-75 feet of ferruginous, deep-red shales and sandstones lying unconforrnably on Mississippian strata in the Sandia, Jemez, Nacimiento, and San Pedro Mountains. The Log Springs formation is similar Lithologically, and probably in origin, to the Molas formation of Colorado (Cross and Howe, 1905) and the lowest part of the Naco formation of southeastern Arizona (Ransome, 1904). The type section is in Penasco Canyon, Nacimiento Mountains (fig 6), NW ¼ SE¼ sec. 5, T. 16 N., R. 1 E. The name is derived from Log Springs in Penasco Canyon.

Some 40 feet of arenaceous limestone, containing numerous Schizophoria oklahomae Dunbar and Condra and Millerella of Morrow age) occurs above the Log Spring formation. The Schizophoria oklahomae strata are in turn deeply channelled and truncated by the overlying Middle Pennsylvanian strata. The Schizophoria oklahomae strata were found in Penasco Canyon; the only other known occurrence, first described by Northrop and Wood (1945), is in Guadalupe Box Canyon, Jemez Mountains. As the Log Springs formation is below beds of undoubted Morrow age and is unconformable on the Mississippian, it is, though unfossiliferous, assigned to the Morrow.

STRATIGRAPHIC DISCUSSION OF LOCAL AREAS

Penasco Canyon, Nacimiento Mountains (figs 5, 6)

The thickest, most fossiliferous section of Mississippian strata known in northern New Mexico is in Penasco Canyon, Nacimiento Mountains.

The Arroyo Penasco formation is exposed due east of Warm Springs Resort in Penasco and Pinos Canyon, T. 16 N., R. 1 E., east of the Nacimiento thrust on the flanks of a syncline which is faulted to the east against Precambrian gneiss by the Penasco Canyon fault (fig. 2). The syncline is complicated further by a series of east-west, north-south trending normal faults (fig 3).

Arroyo Penasco formation: The measured section is 110-140 feet thick. It is exposed on a dip slope, but numerous small faults complicate its accurate measurement. On the Precambrian gneiss is 18-20 feet of clean, calcareous sandstone with interbedded shales which are fine- to coarse-grained, and gray limestone beds up to 3 feet thick in the upper 10 feet. These limestone and clastic beds grade laterally into each other and are overlain by 31 feet of fine- to coarse-grained, gray to brown ledge-forming limestone. Conformably above this is some 70 feet of lithographic to oolitic, light-gray, medium-bedded limestone. The highest 10-15 feet of this limestone has been replaced by white chert of varying color.

The Arroyo Penasco formation in Penasco Canyon has yielded most of the megascopic Mississippian fossils known from northern New Mexico. These have come almost entirely from the upper chert zone, some 15-20 feet thick, just below the contact with the Pennsylvanian Log Springs formation. Fossils from this formation generally are difficult to extract, are poorly preserved, and are mostly internal molds of single shells of brachiopods, which occur as disassociated valves and abraded and broken material.

Thus far, the following forms have been identified:

Eumetria verneuiliana Hall
Eumetria vera Hall
Linoproductus ovatus Hall
Linoproductus sp.
Composita aff. C. lewisensis Weller
Spirifer sp.
Straparolus sp.
Leptodesma sp.
Fenestrel I ina sp.
Archimedes? sp.
Endothyra sp.
Plectogyra sp.

The majority of Eumetrias from Penasco Canyon have from 30-40 plications; thus, they are placed in the species Eumetria vera. A few specimens have 50 to 55 plications,

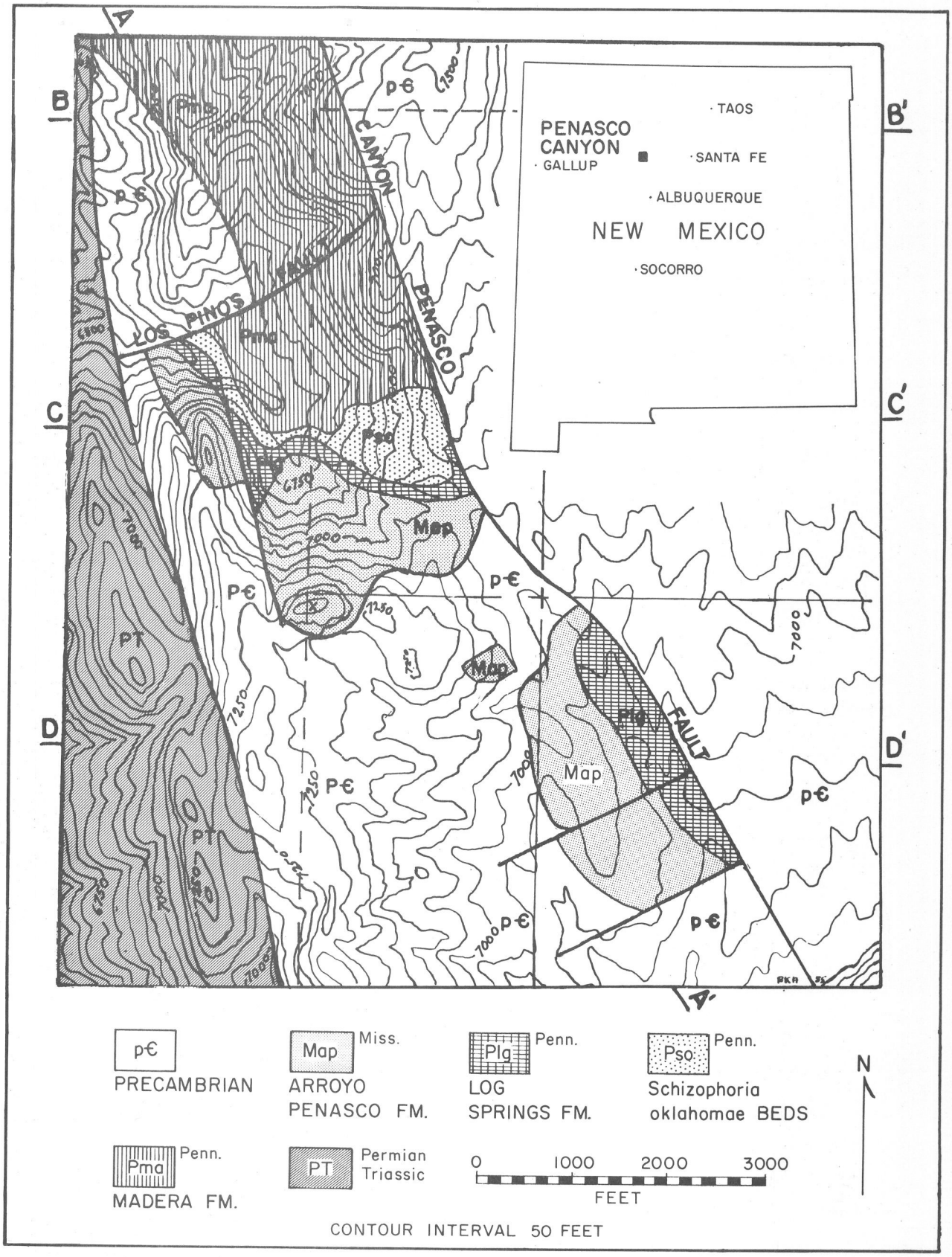


Figure 2. Geologic map of Los Pinos and Penasco Canyon, Nacimiento Mts.

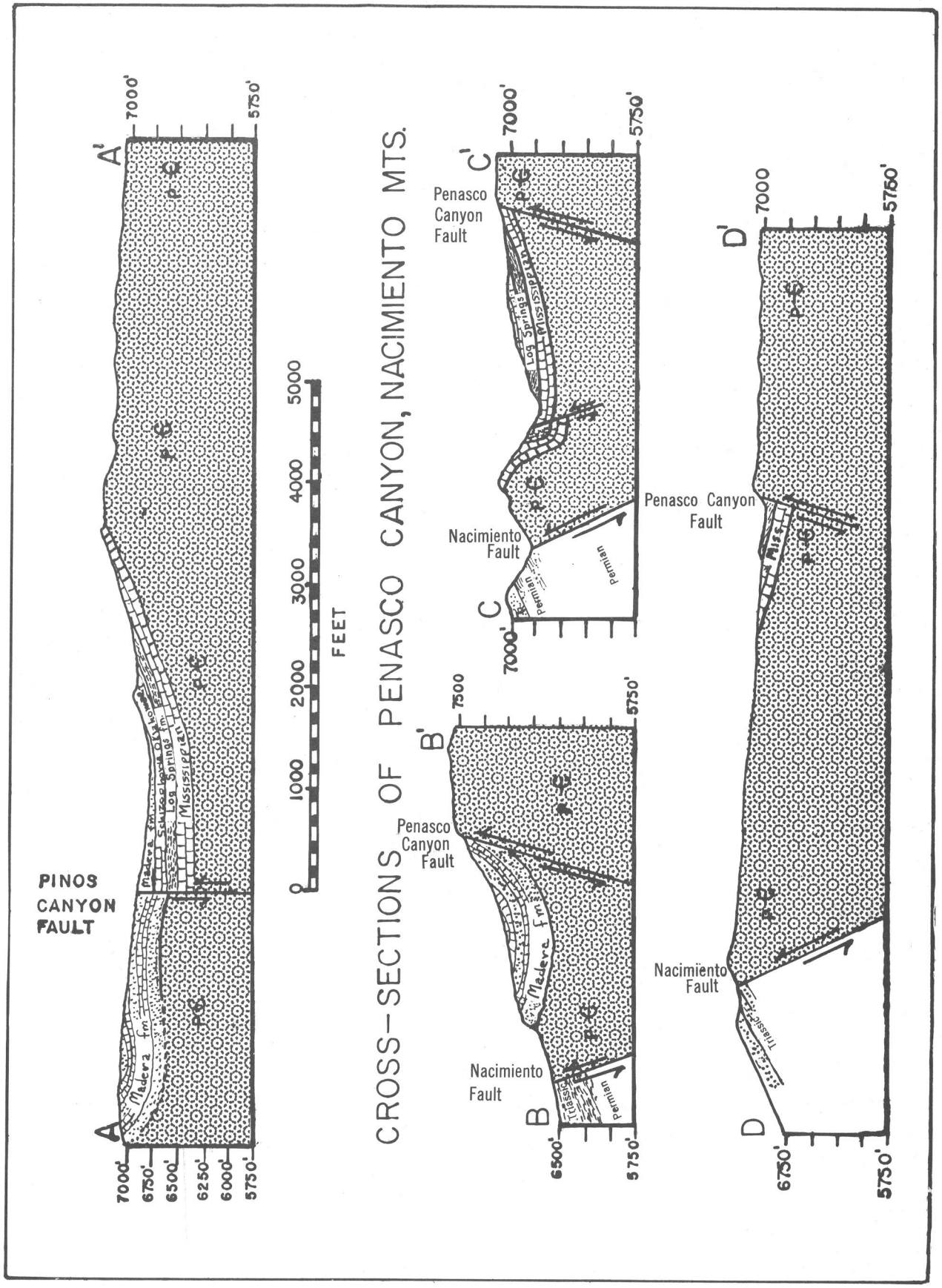


Figure 3. Geologic cross-sections of Los Pinos and Penasco Canyon, Nacimiento Mts.

which places them as Eumetria verneuiliana. The general contour of Eumetrias from Penasco Canyon compares with those illustrated by Weller (1914) from the Mississippi Valley. Numerous Endothyra and Plectogyra range from 50 feet above the Precambrian to the top of the formation. The megafauna is definitely Mississippian and suggestive of Meramec rocks. The microfauna, both Endothyra and Plectogyra, is of the type found in Meramec rocks of the Mississippi Valley.

Log Springs formation: The Log Springs formation, which lies unconformably on the Arroyo Penasco formation consists of 60-75 feet of ferruginous shales, sandstones, and conglomerates. The immediately underlying part of the Arroyo Penasco formation is brecciated and contains numerous solution cavities that are filled with the basal ferruginous shales from the overlying Log Springs formation. The basal shale of the Log Springs formation is highly ferruginous, with numerous oolites of hematite, and is followed by a medium-bedded series of deep-red shales, sandstones, and conglomerates. The sandstones tend to form small prominent ledges. It is interesting to note that the lower beds of this formation contain sporadic rounded pebbles of Mississippian chert; but the higher, conglomerate beds contain angular pebbles of Mississippian chert and limestone as well as of Precambrian gneiss and green schist. No fossils have been found in the Log Springs formation.

Schizophoria oklahomae zone: Some 25-40 feet of arenaceous limestone containing a fauna characterized by SchizopTc7.7-ici oklahomae Dunbar and Condra occurs above the Log Springs formation. Northrop and Wood (1945) called attention to the occurrence in Guadalupe Box Canyon, Jemez Mountains, of beds in the base of the Pennsylvanian containing this fossil, which is a characteristic Morrow species. Thus far, these two occurrences provide the only record of beds of definite Morrow age in northern New Mexico.

The Schizophoria oklahomae beds overlie the Log Springs formation in Penasco Canyon with an angular unconformity of 14-16 degrees. The Log Springs surface shows channels 2-3 feet deep and up to 5 feet across. In Penasco Canyon the Schizophoria oklahomae beds are separated from the overlying upper arkosic limestone member of the Madera formation (Middle Pennsylvanian) by a marked unconformity. Channeling occurred in the top of the Morrow sediments prior to the beginning of Madera deposition. The angle of unconformity is from 4 to 6 degrees, but the channeling is not so marked as that at the base of the Schizophoria oklahomae strata.

The brachiopod fauna is large, and a detailed study of it would be rewarding. The most common forms observed are:

Schizophoria oklahomae Dunbar and Condra
Meekel la sp.
Hustedia sp.
Composita subtilita Hall
Spirifer sp. (several species)
Dictyoclostus sp. (several species)
Linoproductus sp.
Millerella sp.

A large pelecypod and bryozoan assemblage is present, as well as several thoracic segments and pygidia of trilobites. Numerous Millerella were found in thinsections representing various horizons in the limestone sequence. No fusulinids of a higher evolutionary stage than Millerella were observed.

Pre-Madera faulting in Penasco Canyon: North of the east-west trending Los Pinos Canyon fault, the Arroyo Penasco and Log Springs formations and Schizophoria oklahomae zone are completely absent, the upper arkosic limestone member of the Madera formation resting directly upon the Precambrian (figs 3, 4). A detailed study of the contact of the upper arkosic limestone member of the Madera formation with Precambrian gneiss north of the Los Pinos Canyon fault failed to show evidence of post-Madera faulting as an explanation. Conclusive evidence was found for post-Morrow, pre-Madera faulting, which permitted the preservation of a small area of Meramec and Morrow rocks in this locality.

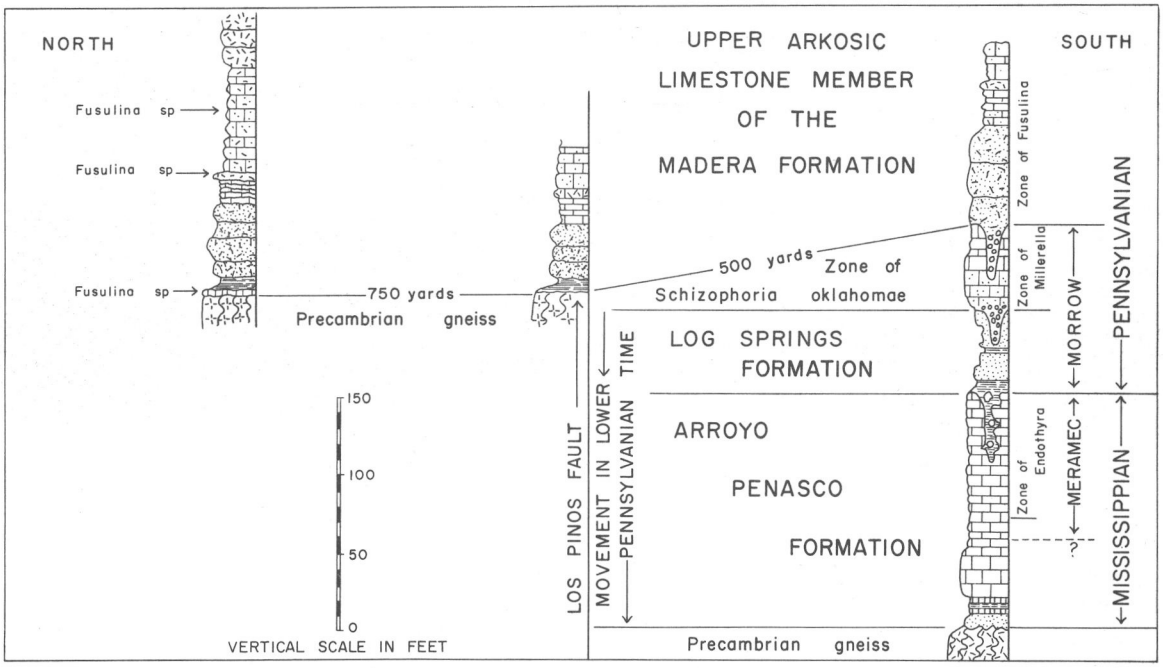
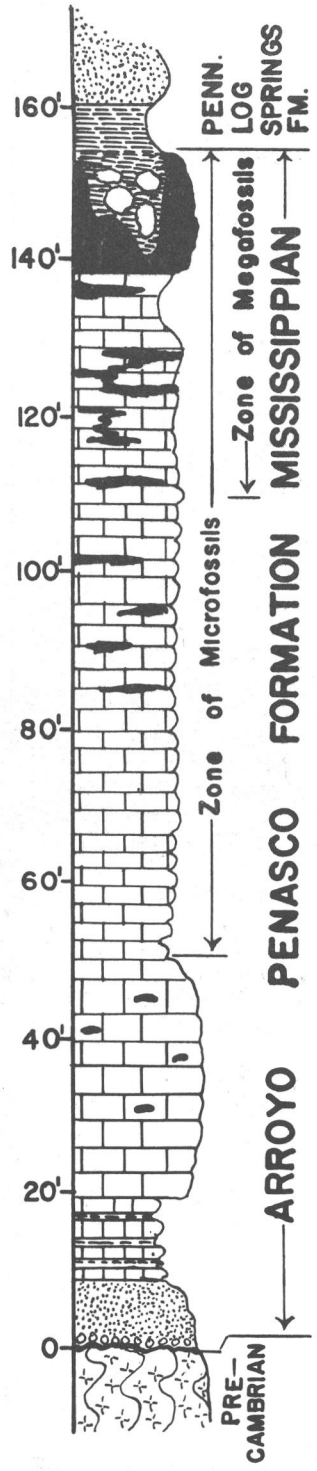


Figure 4. Stratigraphic sections across Los Pinos Canyon.

These conclusions are based on the following evidence:

On the south side of the Los Pinos fault, the Arroyo Penasco and Log Springs formations and Schizophoria oklahomae zone, which total some 250 feet, are present between the Precambrian gneiss and the basal beds of the upper arkosic limestone member of the Madera formation. On the north side of the Los Pinos fault, however, 1-3 feet of light-gray, fossiliferous limestone rests upon the Precambrian. Some 2-3 feet below the limestone, the Precambrian gneiss is weathered, and the limestone contains numerous rounded and weathered fragments of feldspar. Thinsections of the limestone disclosed the presence of abundant Fusulina sp., a Middle Pennsylvanian index fossil.



Pennsylvanian
Log Springs formation, Morrow

Unconformity
Mississippian

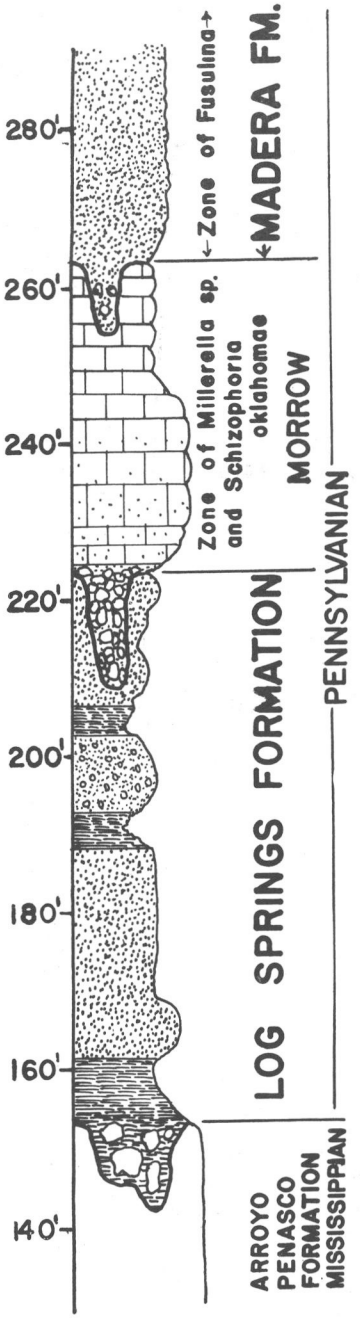
Arroyo Penasco formation, Meramec

Chert, white with iron oxide staining, massive fossiliferous, thin brown shale zone present at base.	14.0
Calcarenite, coarse-grained, brown to gray	8.0
Limestone, dense fine-grained, granular to oolitic, bedding plains every three to five feet, dove-gray, abundant Endothyra sp.	50-80.0
Limestone, massive, dense, fine-grained, in zones granular, gray to brownish-gray, resistant	31.0
Sandstone, fine- to medium-grained, a few limestone gragments up to two inches present, small thin shales in zones; laterly this unit grades into limestone	10.0
Sandstone, quartz grains, medium- to coarse-grained with pebbles up to an inch in diameter in lower portion, slightly cross-bedded, calcite cement, white	8.0

Unconformity
Precambrian

Gneiss, very coarse-grained, iron rich, pink to red

Figure 5. Penasco Canyon section (part 1).



Pennsylvanian

Madera formation, upper arkosic member

Sandstone, quartz, coarse, subrounded grains, massive, brown

Unconformity

Schizophoria oklahomae zone, Morrow

Limestone, arenaceous, light-brown to gray color, thin shale bed present, very fossiliferous, abundant Schizophoria oklahomae, Millerella sp. 30-40.0

Unconformity

Log Springs formation, Morrow

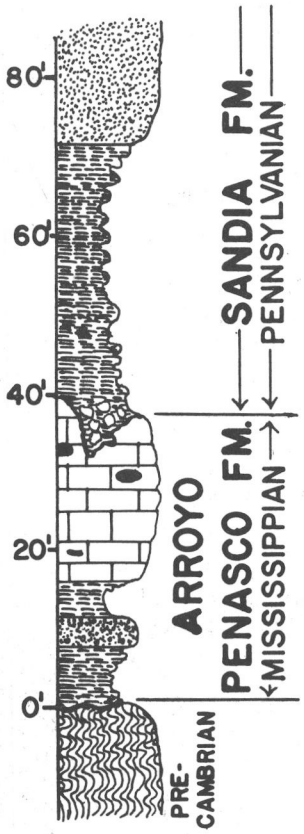
Sandstone, fine-grained, interbedded shale, very ferruginous, numerous angular pebbles of Arroyo Penasco limestone and chert, and Precambrian gneiss	14.0
Shale, deep brownish-red color, very ferruginous, numerous oolites of hematite	6.0
Conglomerate, pebbles up to 13 inches in diameter, mostly of Precambrian quartzite and gneiss	8.0
Shale, brownish-red, thin fine-grained sandstone beds present	4.0
Sandstone, fine-grained, slightly cross-bedded, hematite cement, deep-red	20.0
Sandstone, fine-grained, hematite cement, hematite "oolites", small flakes of biotite, deep-red	7.0
Shale, brownish-red, streaked with gray, highly ferruginous with numerous hematite "oolitic"	9.0

Unconformity

Mississippian

Arroyo Penasco formation

Figure 6. Penasco Canyon section (part 2).



Pennsylvanian
Madera formation
Sandstone, coarse-grained, cross-bedded, massive, brown

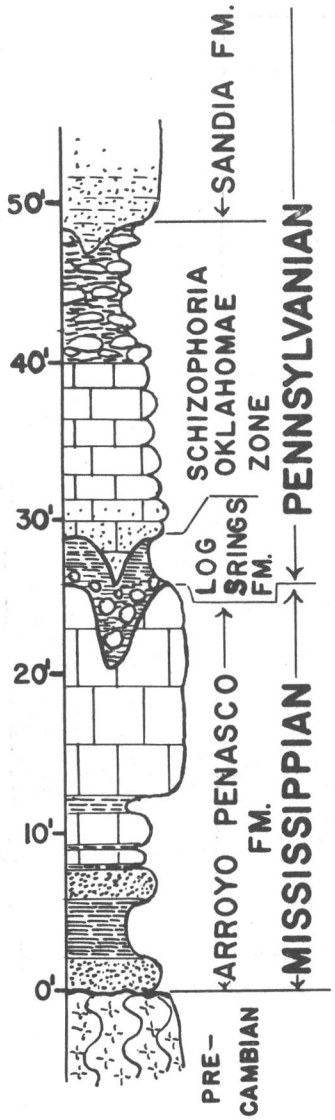
Mudstone and shales, gray, maroon, blue, contains rounded boulders and pebbles of Mississippian chert 35.0

Unconformity

Mississippian
Arroyo Penasco formation
Limestone, fine-grained, dense, light dove-gray, banded nodular chert present 20.0
Shale, light grayish-green 5.0
Limestone, dense, fine-grained, dark steel-gray 4.0
Mudstone, large amount of muscovite present, light-green 8.0
Unconformity

Precambrian
Schist, high percentage silica, pinkish-white, pre-Arroyo Penasco weathering extended some twelve to sixteen feet below unconformity

Figure 7. Soda Dam section.



Pennsylvanian

Shales and mudstone, gray to olive green, numerous flakes of muscovite

Unconformity

Schizophoria oklahomae zone, Morrow

Shale, calcareous, sparcely fossiliferous, gray to purple	6.0
Limestone, coarse-grained, bedded every 6 to 10 inches, numerous shell fragments, light-gray to brown, highly fossiliferous	13.0

Unconformity

Log Springs formation, Morrow

Shale, ferruginous, deep-red, numerous rounded pebbles of Arroyo Penasco fm.	3.0

Unconformity

Arroyo Penasco formation, Meramec

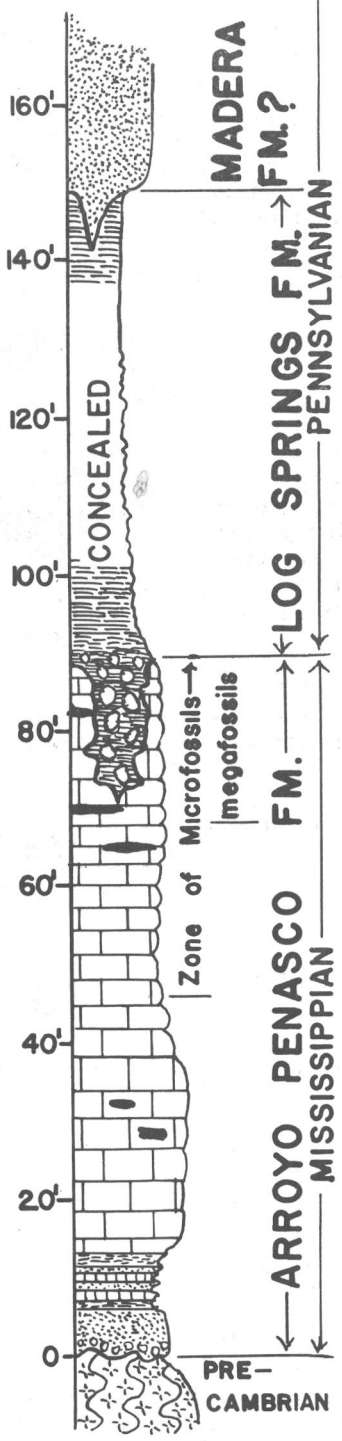
Limestone, fine-grained, dense, massive, brownish-gray, upper portions brecciated and filled with ferruginous Log Springs shale	14.0
Shale, calcareous, light-gray	1.0
Limestone, arenaceous, fine-grained, gray	2.0
Shale, calcareous, gray	0.2
Limestone, siliceous, gray	0.4
Shale, calcareous, gray	0.2
Sandstone, medium-grained, silica cement, gray	2.0
Shale, calcareous, light-gray	4.0
Sandstone, medium-grained, calcite cement, white color	2.0

Unconformity

Precambrian

Gneiss, coarse-grained, pink to red

Figure 8. Guadalupe Box Canyon section.



Pennsylvanian
Madera formation
Sandstone, coarse-grained, cross-bedded, brown

Unconformity

Pennsylvanian
Log Springs formation
Shale, sandstones, and mudstones, deep brownish-red, highly ferruginous 40-60.0

Unconformity

Mississippian

Arroyo Penasco formation, Meramec
Limestone, very fine-grained, dense, oolitic to crinoidal in zones, white chert, dove-gray, upper portion highly broken and filled with red shale 33-40.0

Limestone, dense, fine- to medium-grained, nodular brown to black chert, massive, gray 23.0

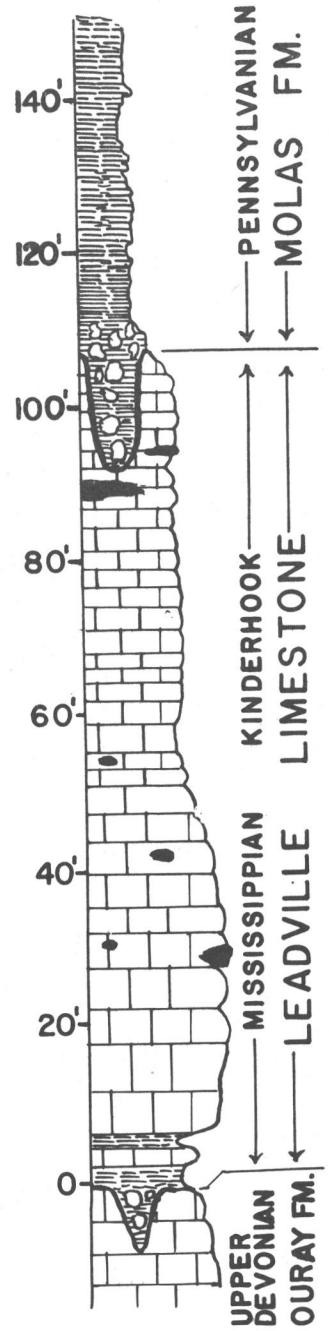
Sandstone, shale, and limestone, all thin-bedded, light-gray, covered 8.0

Sandstone, quartz, medium-to coarse-grained, calcite cement, white 5.0

Unconformity

Precambrian
Gneiss, coarse, pink to red, with numerous green schist dikes

Figure 9. San Pedro Mts. section.



Pennsylvanian
Molas formation
Shales, very ferruginous, basal units contain large fragments of reworked Leadville limestone, red — 60–90.0

Unconformity

Mississippian
Leadville formation, Kinderhook
Limestone, dense, fine-grained, absence of sand grains, massive and resistant, contains bedding plains in upper half, chert present, very abundant towards top of section, member varies in thickness because of pre-Molas erosion, gray — 59.0

Limestone, dense, very fine-grained, absence of any clastic material, very resistant, light brownish-gray color — 42.0

Limestone, massive, dense, fine-grained, dark-gray — 2.2

Shale, contains bands and nodules of limestone, deep-red — 2.0

Unconformity

Devonian
Limestone, dense, massive, gray, very fossiliferous

Figure 10. Rockwood Quarry section, San Juan Mts., Colorado.

Jemez Mountains

Soda Dam (fig 7): The Arroyo Penasco formation is exposed in NW¼ SW¼ sec.13, T. 18 N., R. 2 E., a mile and a half north of Jemez Springs, to the west of Soda Dam. A lenticular remnant, up to 37 feet thick, of the characteristic Arroyo Penasco formation lies beneath the basal clastics of the Sandia formation. No fossils are known from this site. The Mississippian is overlain unconformably by red, yellow, green, and olive shales of the Sandia formation.

Guadalupe Box Canyon (fig 8): The Arroyo Penasco formation is exposed on the east and west sides of Guadalupe Box Canyon, NE1/4 sec. 6, T. 17 N., R. 2 E. The maximum thickness of Mississippian strata is 25 feet. A 3-foot remnant of the typical, ferruginous Log Springs formation rests unconformably on the Arroyo Penasco formation, and is overlain unconformably by 19 feet of the Schizophoria oklahomae zone. No fossils have been collected from the Mississippian rocks here.

San Pedro Mountains (fig 9)

The Arroyo Penasco formation.is exposed on the northwest side of San Pedro Mountains, sections 25 and 26, R. 1 W., T. 23 N., 3-1/2 miles due east of Regina, New Mexico, but is absent elsewhere in the San Pedros. The Arroyo Penasco formation and the Log Springs formation of the San Pedro Mountains are similar lithologically to the type sections in Penasco Canyon. The fauna recovered in the San Pedro Mountains consists of one excellent Eumetria vera Hall, a Spirifer sp., and some poorly preserved bryozoans. Excellent specimens of Endothyra and Plectogyra were found within 45 feet of the Precambrian

San Juan Mountains, Colorado

The Mississippian Leadville limestone is exposed widely in the San Juan Mountains, particularly along the Animas River. This formation, which is deceptively similar lithologically to the Arroyo Penasco formation of the San Pedro and Nacimiento Mountains, is a series of massive- to medium-bedded, fine-grained to crinoidal gray limestones with black to white chert, and averages about 100 feet in thickness. It rests unconformably upon the channeled and weathered, fossiliferous Upper Devonian Ouray limestone. About 2-4 feet of reworked, deep-red, conglomeratic soil zone separates the two formations.

The Leadville limestone is overlain unconformably by the ferruginous Molas formation f Pennsylvanian age. The red shales of the Molas formation fill and slump into the numerous solution cavities in the upper portion of the Leadville limestone.

Rockwood Quarry (fig 10): The Leadville limestone was examined at Rockwood quarry, which is 100 yards north of the first intersection of the narrow gage railroad with U. S. Highway 550, 15 miles north of Durango, Colorado.

Plectogyra and an unnamed foraminifer were observed in thinsections. The Plectogyras from Rockwood quarry were small, the chambers few and large in proportion

to size and very much enlarged between sutures. They are similar to forms found in Kinderhookian beds of the Mississippi Valley.

The megafauna of the Leadville was studied carefully by Girty (1903), who described 32 species of invertebrate fossils from the San Juan Mountains, 13 of which were brachiopods. He concluded that the Leadville limestone of the San Juan Mountains was equivalent to the Chouteau limestone of Missouri and the Waverly group of Ohio. Studies made by the writer on a megafauna collected from Rockwood quarry in 1952 and 1954 failed to reveal any fossils which Girty did not describe, or to modify his age assignment for the Leadville limestone.

Piedra River (fig 11): Mississippian strata crop out in Piedra River Canyon below the mouth of Sandy Creek. The section was first described and correlated by lithology with the Leadville limestone by Read et al.(1949). This section is the nearest (81 miles distant) outcrop of Mississippian in Colorado to exposures of the Meramec Arroyo Penasco formation of New Mexico. It overlies unconformably the Upper Devonian Ouray formation, and is overlain unconformably by the Molas formation. This Mississippian is similar lithologically to the Leadville limestone of the Rockwood quarry.

From a fauna collected in 1952, the following identifications have been made:

Spiriferina solidirostris ? White
Spirifer cf. S. biplicoides Weller
Straparol us sp.
Plectogyra sp.
Foraminifer, unidentified

Spiriferina solidirostris ? White

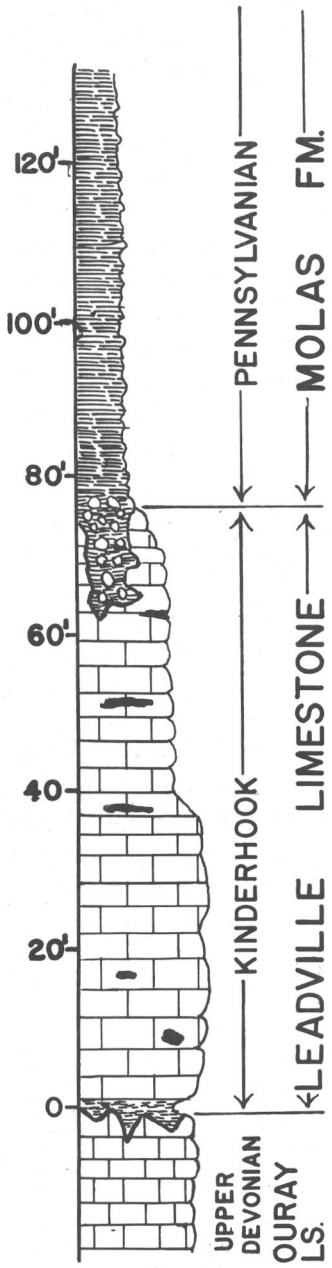
The megafauna which was taken from the top of the section could be matched with specimens collected from Rockwood quarry. Both Spiriferina solidirostris ? and Spirifer biplicoides are known only from Kinderhookian beds.

The microfauna consisted of numerous Plectogyra conspecific with those collected from the Rockwood quarry. The species of Plectogyra from the Leadville limestone of the Rockwood quarry and the Piedra River has never been observed in thinsections made from the Arroyo Penasco formation.

Sangre de Cristo Mountains

The Meramec Arroyo Penasco formation is exposed in an almost continuous outcrop along the east front of the Sangre de Cristo Mountains from the Rincon Range, in Mora County, to the Pecos River Canyon. The only known exposure of the Arroyo Penasco formation on the west side of the Sangre de Cristo Mountains is about 5 miles south of Taos, a few hundred feet east of Ponce de Leon Springs. Pennsylvanian sediments rest directly on the Precambrian from Picuris to north of Cowles (A. Montgomery and J. R. Miller, personal communication, August 1955).

Mississippian rocks apparently once covered the whole Sangre de Cristo region, but were stripped off the central and western areas in Pennsylvanian time.



Pennsylvanian
Mosas formation, Morrow?
Shales, mudstones, highly ferruginous, deep-red, reworked Mississippian chert in basal beds

Unconformity

Mississippian
Leadville limestone, Kinderhook
Limestone, dense, fine-grained, oolitic in upper third, dove-gray, upper half contains numerous solution cavities filled with Molas shale 30-40.0

Limestone, dense-to coarse-grained, oolitic in bands, massive, gray 30-35.0

Shales, thin-bedded limestone, red to gray 0.5

Unconformity

Devonian
Ouray formation
Limestone, dense, fine-to coarse-grained, fossiliferous, gray

Figure 11. Piedra River section, San Juan Mts., Colorado.

Rancho de Rio Grande Canyon (fig 12): The Arroyo Penasco formation crops out on the west ridge bordering Rancho de Rio Grande Canyon. The Mississippian strata can be followed from Ponce de Leon 2-1/2 miles south along the crest of the ridge. The basal sandstone unit, 25-45 feet thick, which is assigned to the Mississippian, is barren and possibly may be pre-Mississippian. It is best exposed on the crest of the ridge. The overlying limestone unit is beautifully exposed east of Ponce de Leon Springs next to Arroyo Miranda.

In the upper limestone beds, numerous silicified corals were found, tentatively identified as Lithostrotion sp. of the whitneyi type. With these corals were a few beautifully preserved specimens of an undescribed species of Spirifer. Sponges and echinoid plates also were collected. The microfauna consists of abundant Endothyra and Plectogyra.

Lujan Canyon, Rincon Range (fig 13): The Arroyo Penasco formation, about 100 feet thick, is exposed 4-1/2 miles above Chacon, Mora County, on the west wall of Lujan Canyon. The lower 46 feet consists of massive, fine- to coarse-grained sandstones; the upper 54 feet is limestone and thin-bedded argillaceous limestones. The limestone is fine-grained to oolitic, dense, and gray to buff, and contains both black nodular chert in the lower beds and white banded chert in the higher beds.

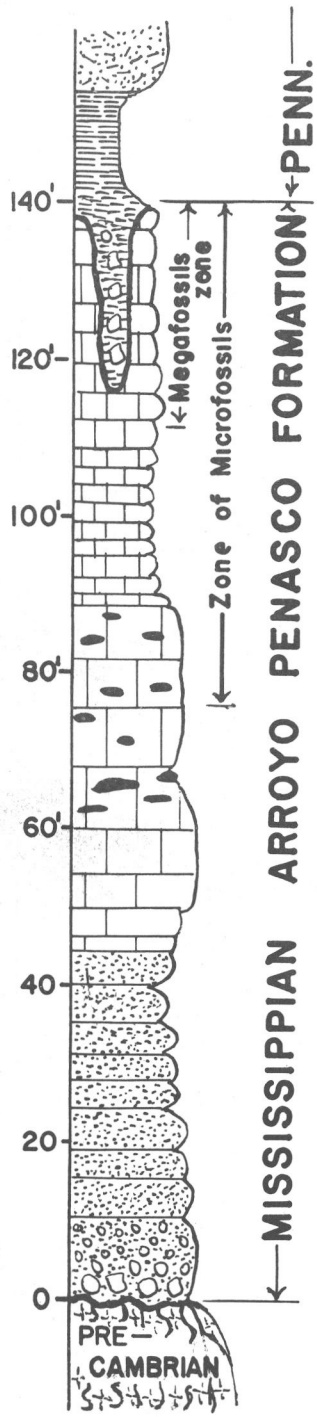
One megafossil, Triplophyllites sp., was collected in the upper 20 feet of the section. The microfauna consists of typical Endothyra sp. and Plectogyra sp.,which occur throughout the limestone sequence. No fossils were found in the thick basal sandstone, which may be of pre-Mississippian age.

Manuelita Creek (fig 14): About 1.2 miles east of the village of Lower Rociada, on the north side of Manuelita Creek, NW1/4 sec. 30, T. 19 N., R. 15 E., the Arroyo Penasc formation is beautifully exposed. The thick basal clastic unit, which is 47 feet thick some 22 miles to the north, in Lujan Canyon, Rincon Range, is only 5 feet thick in the section on Manuelita Creek. The bedding of the lower half of the limestone is very irregular. The limestone is fine-grained to oolitic, dense, siliceous in zones, and light gray to greenish brown. The chert is composed of brown or black nodules.

No megascopic fossils were found in this section, but Endothyra and Plectogyra occur throughout the limestone.

Gallinas Canyon (fig 15): The Arroyo Penasco formation was studied about 3 miles west of Montezuma on the north side of State Highway 65. The section is 80-90 feet thick, with 1-2 feet of basal sandstone. The limestone is fine-grained, locally oolitic, dense, light gray to brown, massive, and poorly bedded with nodular white and black chert. The Mississippian strata generally form a prominent ledge between the less resistant gneiss and overlying basal Pennsylvanian clastics.

Though no megascopic fossils were seen in this section, abundant Endothyra and Plectogyra were found throughout the limestone.



Pennsylvanian

Arkose, medium-grained, angular

Mudstone, brown — 20.0

Unconformity

Mississippian

Arroyo Penasco formation, Meramec

Limestone, dense, fine-grained, bedding every foot, gray to buff — 30.0

Limestone, dense, fine-grained, thin-bedded, weak, gray to buff — 20.0

Limestone, fine-grained, dark-gray, massive, black chert — 22.0

Limestone, dense, fine-grained, light-gray, nodular black chert in upper half — 15.0

Limestone, dense, fine-grained, light-brown — 3.5

Limestone, fine-grained, light-gray on weathered surface, black on fresh — 2.0

Sandstone, quartz, rounded to subrounded, fine- to medium-grained, silica cement, white to light-brown — 34.0

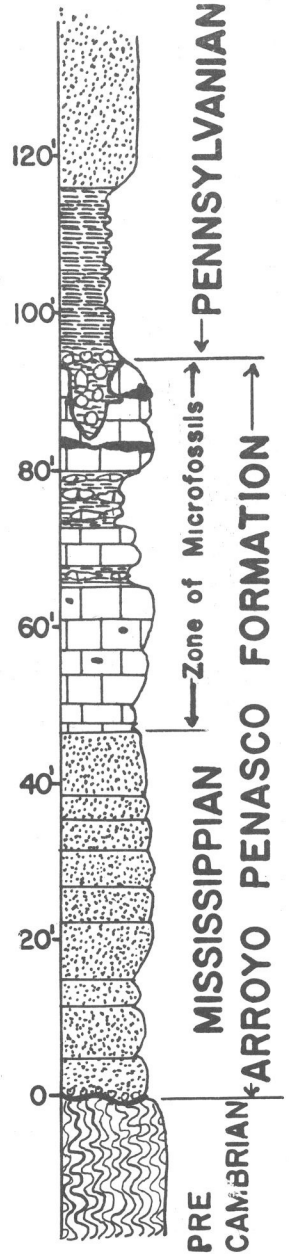
Conglomerate, quartz pebbles up to 8 inches in diameter, clean sand grains, silica cement, white to light-brown — 13.0

Unconformity

Precambrian

Granite, fine- to medium-grained, light-buff to pink

Figure 12. Rancho de Rio Grande Canyon section.



Pennsylvanian

Shales, black	16.0
Conglomerate, very ferruginous, black to deep-red, pebbles of Precambrian quartz and Mississippian chert and limestone	6.0

Unconformity

Mississippian, Meramec

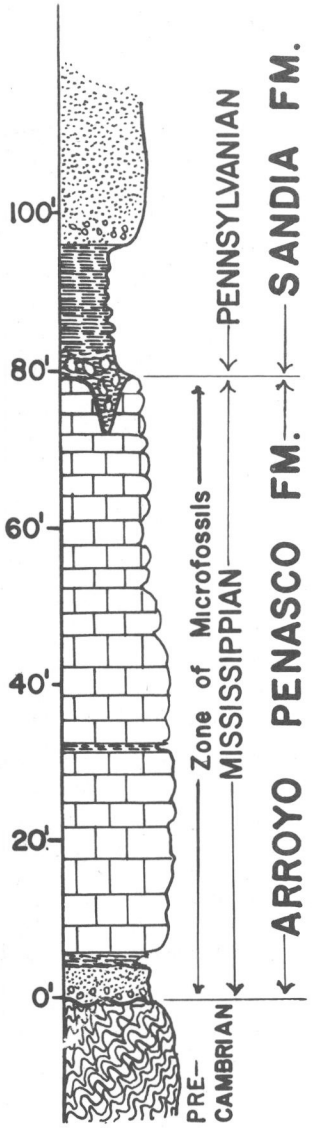
Limestone, fine-grained, dense siliceous, tan, bedding every 2 inches or less, white chert	7.0
Limestone, dense, very siliceous, tan on weathered surface, gray on fresh, massive white chert	6.0
Marl, limestone nodules very fine-grained, shale, light-gray	7.0
Limestone, fine-grained, light-tan	2.0
Marl, nodular limestone, fine-grained, light-gray to tan	0.5
Limestone, fine-grained, light-brown weathered, gray on fresh surface	3.0
Marl, nodular limestone, gray to tan, grades into limestone laterally	2.0
Limestone, dense fine-grained, gray color, lenticular bodies of chert present, limestone oolitic in places	8.0
Limestone, thin-bedded with shale parting, gray	7.0
Limestone, dense fine-grained, siliceous, brown weathering	2.0
Sandstone, fine-grained quartz, siliceous cement, light-tan, iron stain, bedding planes every one to three feet	33.0
Sandstone, fine-grained quartz, siliceous cement, light-tan to brown	2.5
Sandstone; medium-grained quartz, pebbles up to inch in diameter in upper half, calcite and silica cement, white, spherical weathering	7.0
Sandstone, medium-to fine-grained, silica and hematite cement, brown	4.5

Unconformity

Precambrian

Schist, muscovite, large bodies of green schist and quartzite present

Figure 13. Lujan Canyon section, Rincon Range.



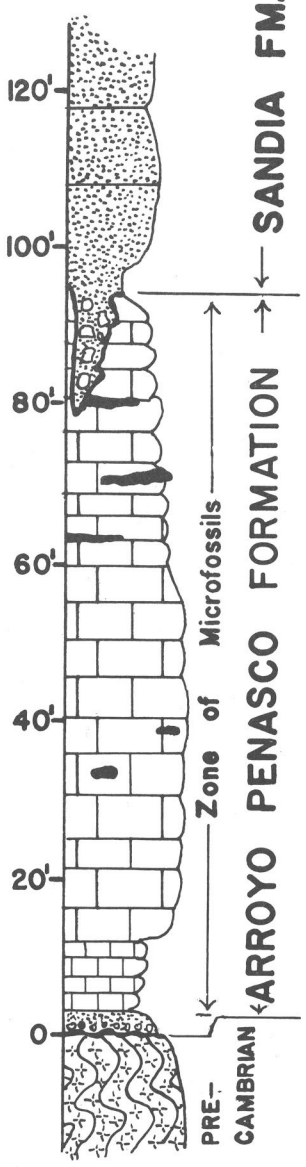
Pennsylvanian
Sandia formation
Mudstone, slabby, red to black

Unconformity
Mississippian
Arroyo Penasco formation, Meramec

Limestone, dense to oolitic, medium-bedded, siliceous in zones, light greenish-brown	26.0
Limestone, dense, fine-grained, light-gray	3.0
Limestone, thin-bedded, fine-grained, light greenish-brown	4.0
Limestone, fine-grained to oolitic, siliceous in zones, massive, light-brown	14.0
Shale and nodular limestone, gray	1.0
Limestone, fine- to medium-grained, broken and somewhat nodular bedding, contains fine quartz grains, banded white chert, buff to light-gray	25.0
Shale, calcareous, light-gray	2.0
Sandstone, quartz, coarse- to fine-grained	2-4.0

Unconformity
Precambrian
Muscovite schist

Figure 14. Manuelita Creek section.



Pennsylvanian

Sandia formation
Sandstone, coarse-grained, cross-bedded, numerous large imprints of Lepidodendron, brown

Unconformity

Mississippian
Arroyo Penasco formation, Meramec
Limestone, dense, fine-grained, oolitic, light-brown to gray color, bedding every 12 to 24 inches 35.0

Limestone, massive, dense, fine-grained to oolitic, dark-gray 45.0

Limestone, dense, fine-grained, dark-gray 4.0

Limestone, crystals up to 2 inches in diameter, dark-gray 2.0

Limestone, dark-gray, dense, fine-grained 3.0

Sandstone, grains up to 1/2 inch in diameter 1.5

Unconformity

Precambrian
Granitic gneiss, red

Figure 15. Gallinas Canyon section.

Tecolote Creek (fig 16): The Tecolote Creek section is on State Highway 103, 1.6 miles west of Aqua Zarca. The portion which was studied is about 2-1/2 miles north of Tecolote Creek. Fossils were collected 120 yards north of the highway. The Arroyo Penasco formation is 90-100 feet thick, with the lower 5-10 feet composed of crossbedded sandstone, shales, and limestones. The main body of limestone is massive, poorly bedded, fine-grained and locally oolitic, and gray to brown. Numerous nodules of black chert occur in the lower half; white chert is present in the upper half.

Most of the megascopic fossils were taken from a zone 65 feet above the Precambrian.

Spirifer cf. Spirifer beckenridgensis ? Weller
Spirifer sp.
Conularia sp.

Eight very excellently preserved Spirifer beckenridgensis ? were obtained from this exposure. They compare in their general contour with those illustrated by Weller (1914, v 2, p 105), except that the mesial fold is not so strongly developed.

The microfauna consists of Endathyra and Plectogyra. The upper 30 feet of limestone contains a high percentage of oolites composed largely of the tests of these foraminifera.

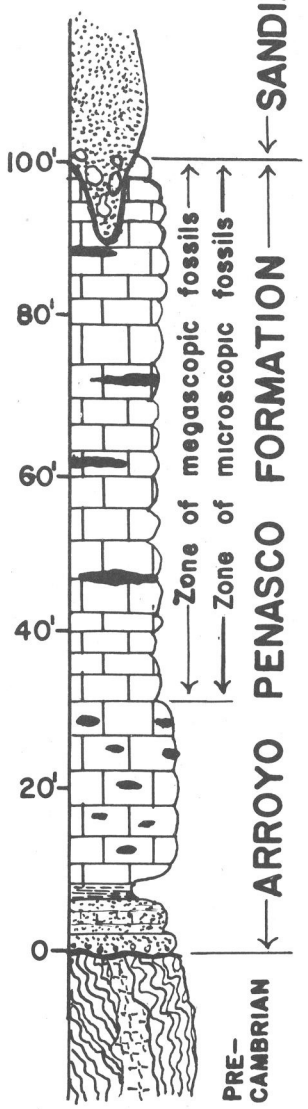
El Macho, Pecos River Canyon (fig 17): The Arroyo Penasco formation was studied a mile below the village of El Macho, on the west side of Pecos River, in NE1/4NE1/ sec. 5, T. 16 N., R. 12 E., where it is 90-100 feet thick. The Precambrian green schist was deeply weathered prior to Mississippian deposition; consequently, the basal beds contain a large amount of chlorite and have iron oxides as a cement. The limestone is fine-grained, locally oolitic, light gray to greenish brown, and irregularly bedded. It forms a prominent ledge on both sides of Pecos Canyon. The Log Springs formation is absent here, as elsewhere in the Sangre de Cristo Mountains. The basal clastic beds of the Sandia formation fill the irregular surface depressions in the Mississippian.

No megascopic fossils are known; the upper 30-35 feet of limestone contains numerous Endothyra and Plectogyra.

Sandia Mountains

Placitas, Northern Sandia Mountains (fig 18): A series of pure limestones of pre-PennsylvTirTiciT36eITenile east and south of Placitas, in SE1/4 sec. 34, T. 13 N., R. 5 E. and SE1/4 sec. 5, T. 13 N.,R. 5 E. These limestones, which total 100 feet in thickness, are lithologically very similar to the type Arroyo Penasco formation. Some 9 feet of hematitic oolitic shales of the Log Springs formation rest unconformably upon the channeled and uneven Mississippian surface.

Intensive, but almost fruitless, searches have been made of this section to find a megascopic fauna. Henbest (1946) found foraminifera from the northern Sandia Mountains,



Pennsylvanian
Sandia formation
Sandstone, quartz, coarse-grained, numerous flakes of muscovite, iron-stained, brown

Unconformity

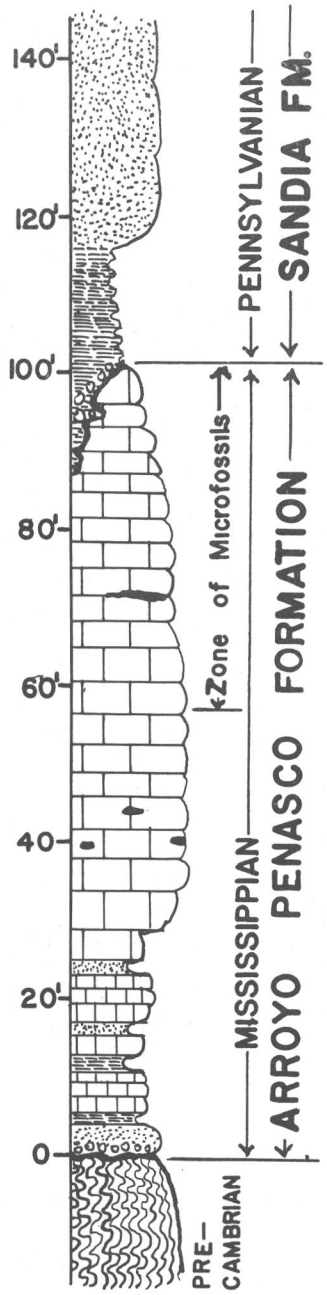
Mississippian
Arroyo Penasco formation, Meramec

Limestone, dense, fine-grained, buff on weathered surface, light-gray on fresh	27.0
Limestone, dense, fine-grained to oolitic, medium-bedded, light- to dark-gray, occasional thin stringers of fine quartz grains, banded white chert	41.0
Limestone, coarse to fine-grained, gray on weathered surface, dark-gray on fresh, numerous black chert nodules a foot in diameter, massive	23.0
Shale, thin-bedded limestone, light-gray to brown	2.0
Sandstone, calcareous, gray, numerous mud cracks and trails present	5.0
Sandstone, coarse, quartz, silica and calcite cement, cross-bedded	2.0

Unconformity

Precambrian
Green schist, numerous granite dikes

Figure 16. Tecolote Creek section.



Pennsylvanian
Sandia formation
Shales and mudstones, olive-green, rounded pebbles of Mississippian present in lower 4 feet

Unconformity

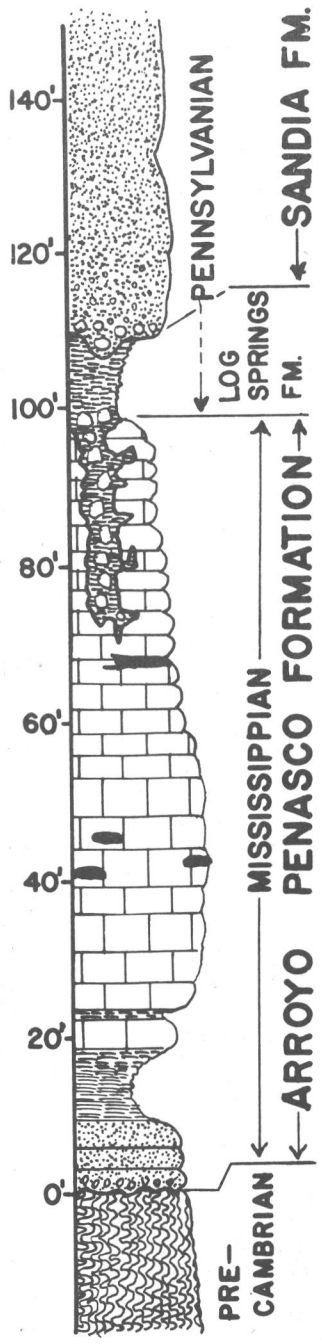
Mississippian
Arroyo Penasco formation, Meramec

Limestone, fine-grained to oolitic, white chert, light-gray on fresh surface, light-tan on weathered surface	31.0
Limestone, dense, fine- to granular-grained, black nodular chert, massive, prominent cliff-former, gray	41.0
Limestone, massive, dark-gray euhedral crystals 3/4 inch across	4.0
Sandstone, quartz, fine-grained, slightly cross-bedded, light-brown	2.0
Limestone, medium-grained, very flaggy bedding with thin shale partings, gray	6.0
Sandstone, quartz, medium-grained, calcite cement, light-brown	1.5
Limestone, medium-grained, gray	3.0
Shales, sandstone, thin-bedded, light-gray	2.0
Limestone, very fine-grained, light-brown	1.0
Limestone, shales, light-gray	2.5
Siltstone, 30% or less sand, light-brown, numerous worm burrows	2.0
Sandstone, quartz, calcite cement, cross-bedded, brown	3.0

Unconformity

Precambrian
Green schist, deep-green, upper 20 or so feet were deeply weathered previous to deposition of Mississippian sediments

Figure 17. El Macho section, Pecos River Canyon.



Pennsylvanian
Sandia formation
Sandstones, coarse-grained, massive, cross-bedded, brown color, contains numerous Lepidodendron imprints

Unconformity
Log Springs formation, Morrow
Shale, highly ferruginous, small nodules of hematite, deep-red color 9.0

Unconformity

Mississippian
Arroyo Penasco formation, Meramec
Limestone, dense, fine-grained, dove-gray to light-brown, bedding every 3 or 4 feet 40.0
Limestone, fine-grained to granular, massive, light-brown weathered surface, banded chert nodules up to 6 inches in diameter 35.0

Shale, light brownish-gray 0.5
Limestone and sandstone, thin-bedded, light-brown 4.5
Shale, arenaceous, varied from white, green to purple 9.0
Sandstone, medium-grained, quartz, subrounded, calcite cement, white 2.0
Sandstone, medium-grained quartz, few pebbles up to inch in diameter 3.0
Sandstone, medium-grained, quartz, subrounded, calcite cement 2.0
Conglomerate, quartz sand, pebbles up to three inches in diameter, calcite cement, white with slight greenish tint due to presence of small amount of clay 2.5

Unconformity

Precambrian
Muscovite schist, greenish-gray

Figure 18. Placitas section.

which he recognized as characteristic of the Leadvil le limestone of southwestern Colorado. Unfortunately, Henbest did not document his conclusions. In the light of the better understood regional stratigraphic picture today, his identification and correlation, therefore, are open to some doubt.

The megascopic fauna consists of some very poorly preserved Goniatites, one very poorly preserved gastropod resembling Stegocoelia, and a fragment of a whorl of a large gastropod similar to Straparolus.

Owing to extensive recrystal I ization of the limestone of the northern Sandia Mountains, numerous thinsections failed to reveal a microfauna. The results were disappointing.

Several fragments of Plectogyra, strongly reminiscent of the form found in the Arroyo Penasco formation in the Sangre de Cristo Mountains, were found 45-50 feet above the Precambrian.

Tijeras Canyon (fig 19): On the south side of Tijeras Canyon, NW¼ SE¼ sec. 21, T. 10 N., R. 5 E., unfossiliferous Mississippian strata are exposed, but have been reduced by pre-Pennsylvanian erosion to 16 feet. The Mississippian is overlain by 23 feet of ferruginous red shales tentatively assigned to the Log Springs formation. The latter is followed by typical sandstones of the Sandia formation.

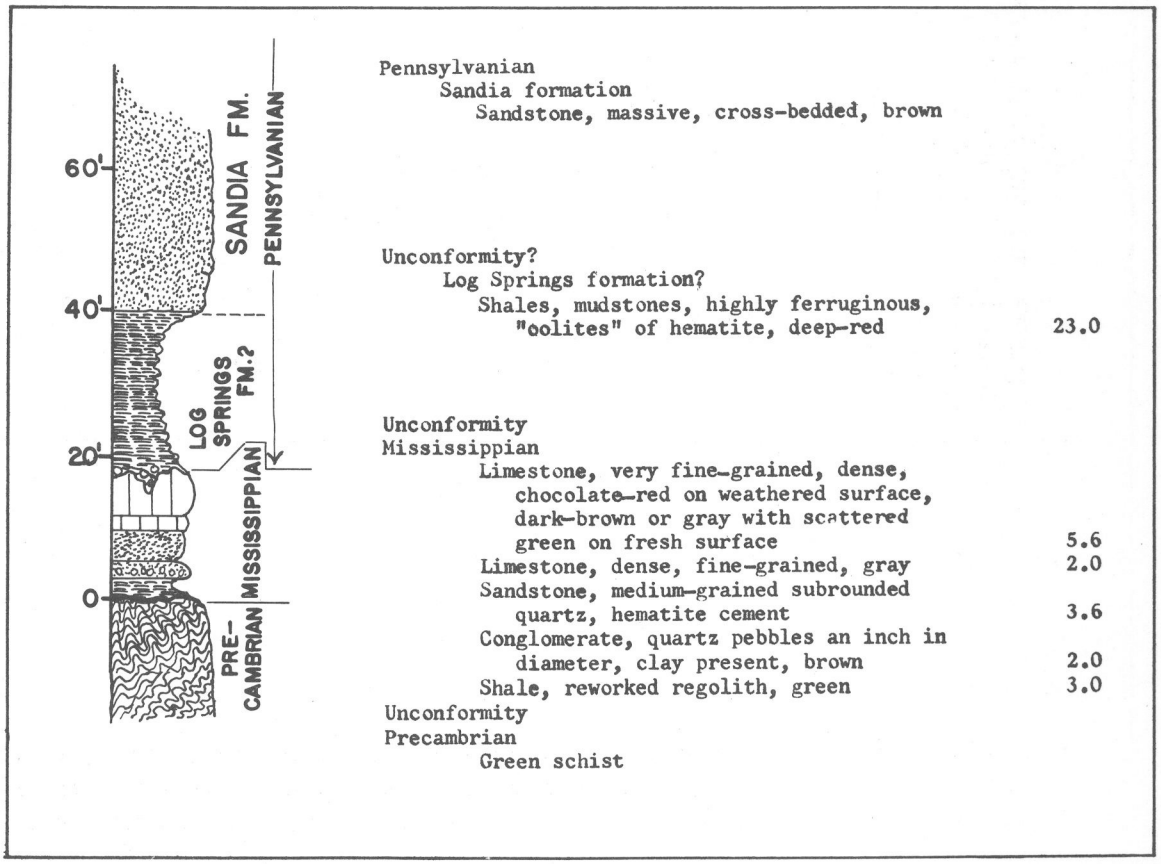


Figure 19. Tijeras Canyon section.

Manzano Mountains

Bosque Peak (fig 20): On the north side of Bosque Peak, NW¼ NE¼ sec. 4, T. 6 N., R. 5 E., 22 feet of dense, fine-grained, siliceous, brown to gray, unfossiliferous limestone rests on the Precambrian granitic gneiss. The remarkable feature of this limestone is that it rests directly on the Precambrian without an intervening basal sandstone. The lower 3-5 inches of limestone contains a few rounded quartz pebbles and grains. Coarse-grained sandstone of the Sandia formation rests unconformably on the weathered and channeled Mississippian limestone. As fossil data are completely lacking, definite correlation with other known Mississippian sections is impossible. This limestone, from a Lithologic standpoint, could be either a northward extension of the Caloso formation of Kinderhook age or a southern extension of the Arroyo Penasco formation.

At both Hell's Canyon and Capillo Peak, the Pennsylvanian Sandia formation rests upon the Precambrian. The area south of Capilla Peak extending to Abo Pass was not surveyed because of the Montosa thrust, which obscures the Precambrian-Paleozoic contact.

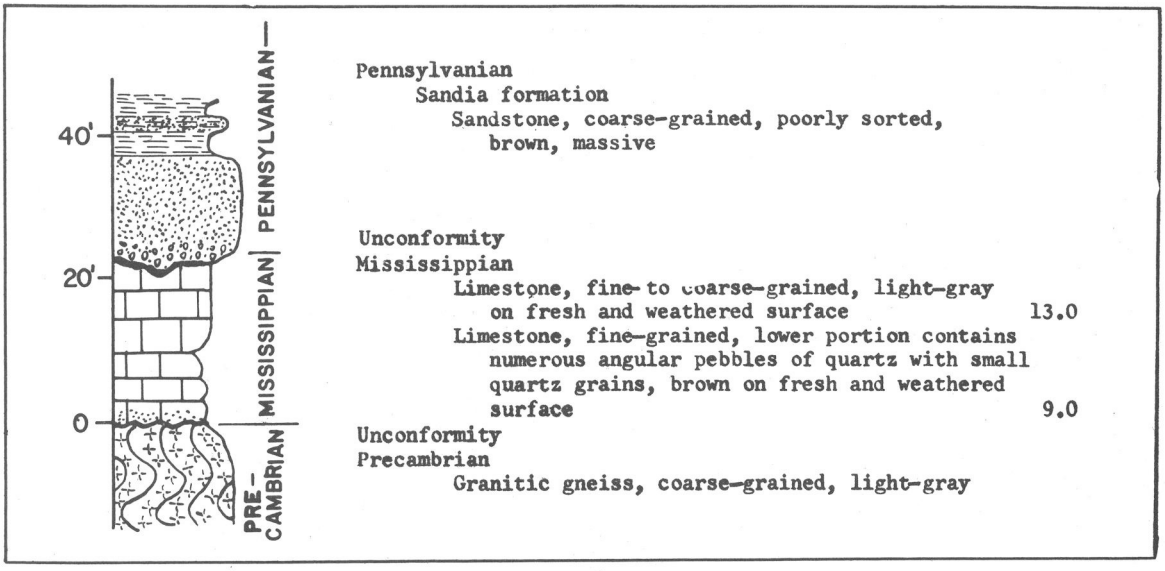


Figure 20. Bosque Peak section.

Ladron Mountains (figs 23,24)

Mississippian strata are exposed in a continuous north-south outcrop 4.4 miles long in the southern Ladron Mountains. The Mississippian is well exposed north of the Rio Salado (fig 21) northward to where it is faulted against Pennsylvanian strata near Ladron Peak. The

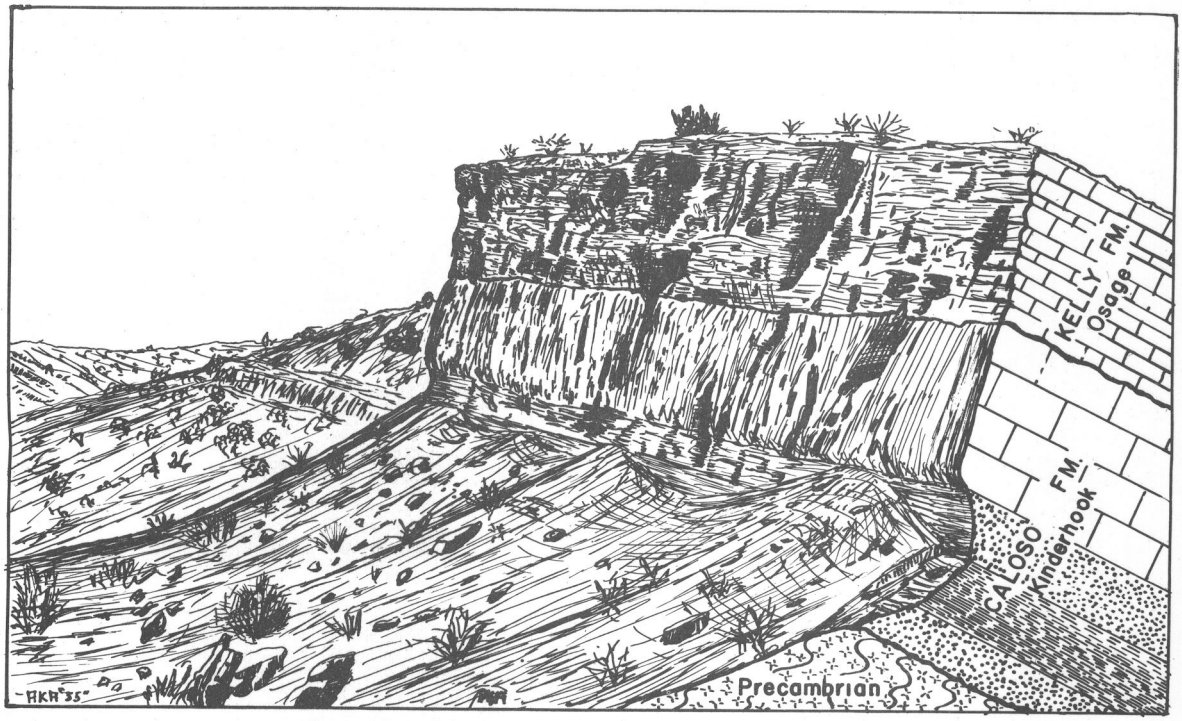


Figure 21. Sketch of the Mississippian, one mile north of the Rio Salado.

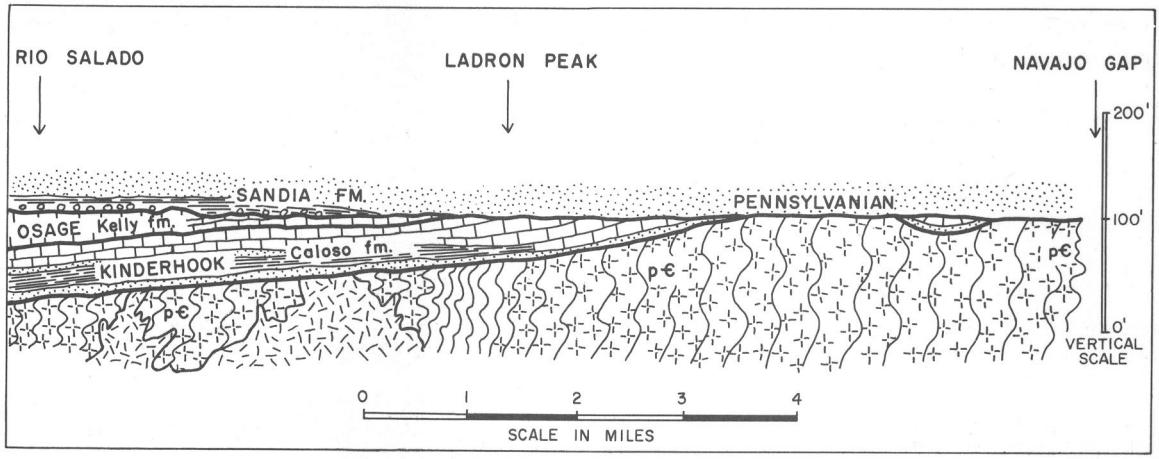


Figure 22. Restored cross-section from the Rio Salado to Navajo Gap, Ladron Mts.

most northerly known exposure of Lower Mississippian rocks in New Mexico is 2 miles north of Ladron Peak, or 2 miles south of Navajo Gap (fig 22). A small synclinal erosional remnant of the Caloso formation is preserved between Precambrian granitic gneiss and the basal beds of the Pennsylvanian Sandia formation.

The Mississippian strata at the southernmost exposure near the Rio Salado are about 90 feet thick. They were beveled progressively northward by pre-Sandia erosion. Near Ladron Peak, some 45 feet escaped erosion, whereas, a mile north of Ladron Peak, it is absent, except for the synclinal remnant 2 miles south of Navajo Gap (fig 22).

The Mississippian system is represented in the Ladron Mountains by two formations:

Caloso formation: The Caloso formation was named by Noble (1950; published reference, Kelley and Silver, 1952) for the exposure of Mississippian rock in Caloso Arroyo, T. 2 N., R. 2 W. The term Caloso formation is here restricted to the Kinderhook part of the section. The maximum thickness of the Caloso formation is 45-50 feet. The lower 20-28 feet consists of sandstones, shales, and thin-bedded, fine-grain, gray limestone. In the exposures near the Rio Salado, the basal sandstone is arkosic and contains considerable chlorite and feldspar, whereas in the exposures near Ladron Peak the basal sandstone is a fine-grained, clean, white quartz. South of Navajo Gap, the basal sandstone is a quartz conglomerate with silica cement. The limestone unit is 17-23 feet thick, massive, dark gray, and dense to granular, containing stringers of chert, 5-18 inches thick and 40-60 feet long. These chert bands are dark brown or black, and in places are very fossiliferous.

The Caloso formation is separated by an unconformity from the overlying Kelly formation.

The fauna is small in the number of species but contains an abundance of individuals. The fossils are found almost entirely in the long black-chert stringers. North of Cerro Colorado, on the south flank of the Ladron Mountains, the chert is extremely fossiliferous, being composed almost entirely of beautifully preserved brachiopods. An extensive attempt to enlarge the fauna listed by Kelley and Silver (1952, p 86) met with little success. The only new species is a pelecypod.

Dielasma chouteauensis Weller
Spirifer centronatus Winchell
Straparolus luxus (White)
Conocardium sp.

None of the species from the Caloso formation are known in the overlying Kelly formation. Both Dielasma chouteauensis Weller and Spirifer centronatus Winchell are known only in Kinderhook rocks.

Kelly formation: The Kelly formation, named by Herrick (1904, p 310) from exposures in the Magdalena Mountains, is well exposed in the southern Ladron Mountains, where it attains a maximum thickness of 35 feet of crinoidal, slabby, light-buff to light-gray, richly fossiliferous limestone, with nodular, white, fossiliferous chert. The maximum thickness of the Kelly formation is in the southern part of the mountains near the Rio Salado.

Northward from the Rio Salado, the Kelly formation is beveled progressively by pre-Sandia erosion, which completely removed it 3 miles north of the Rio Salado. The Kelly is not known north of this point in New Mexico.

The Kelly formation of the southern Ladron Mountains provides a rich and diversified fauna. Many crinoids are present, but their identification is complicated by exfoliation of the plates. The fauna also includes abundant cup corals and bryozoans.

The brachiopod assemblage is very large and contains numerous new species. It is of definite Osage age and shows strong early Osage affinities.

Thus far, the following forms have been identified tentatively from the Kelly formation of the southern Ladron Mountains:

Brachiopoda

Spirifer grimesi Hall
Spirifer rowleyi Weller
Spirifer sp.
Rhynchopora persinuata (Winchell)
Cleiothyridina obmaxima (McChesney)
Cleiothyridina tenuilineata (Rowley)
Rhipidomel la diminutive Rowley
Athyris lamellosa (Leveill6)
Brachythyris suborbicularis (Hall)
Chonetes illinoisensis Worthen
Linoproductus
Rowleyel la cf. fabulites (Rowley)
Syringothyris ? sp.

Gastropoda

Platyceras sp.

Blastoidea

Cryptoblastus cf. granulosus Meek and Worthen

Crinoidea

Paltycrinites sp.

Vertebrata

Shark tooth

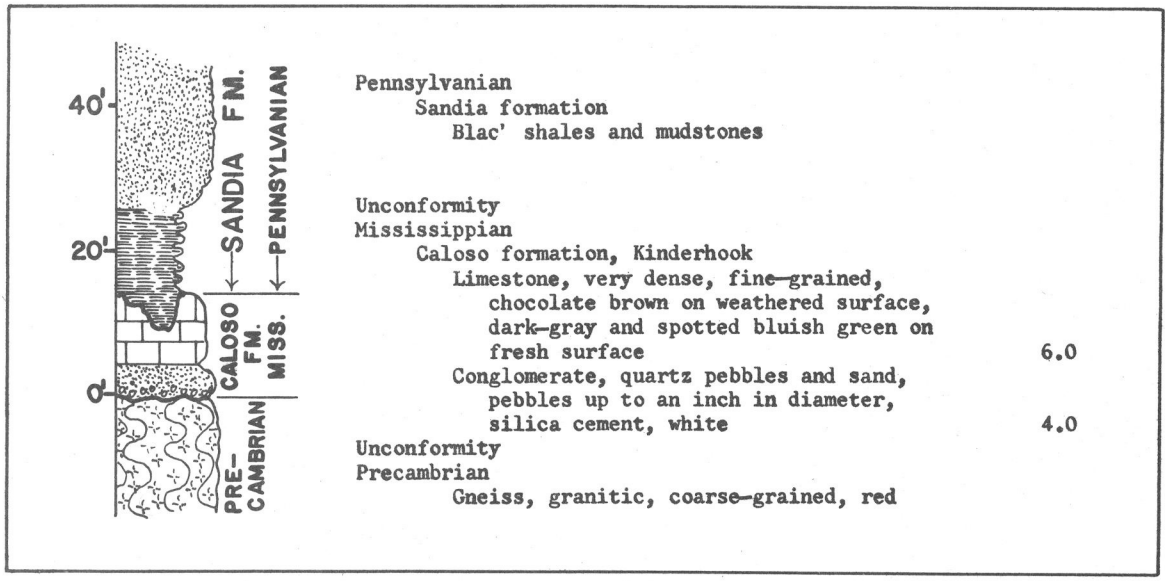
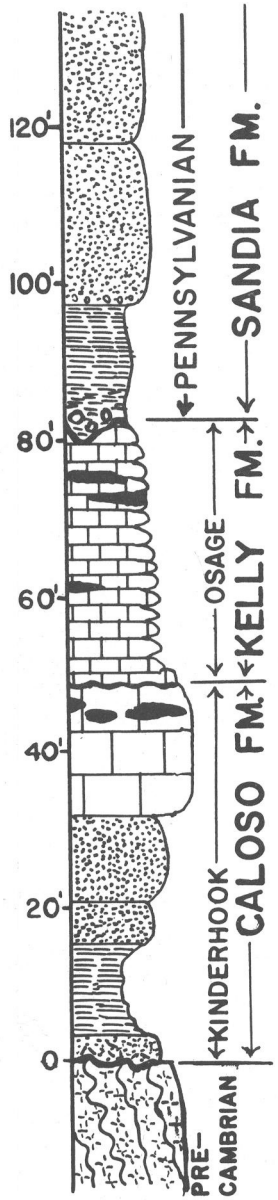


Figure 23. Navajo Gap section, Ladron Mts.



Pennsylvanian
Sandia formation
Shales and thin mudstones, dark gray to black

Unconformity

Mississippian
Kelly formation, Osage
Limestone, medium-to coarse-grained, in places crinoidal, slabby-bedded, zones of white-banded bedding chert, light-buff, very fossiliferous 33.0

Unconformity
Caloso formation, Kinderhook
Limestone, fine-grained, dense, brown on weathered surface, dark-gray on fresh, jet-black chert nodules, massive 17.0
Sandstone, quartz, fine-grained, calcite cement, iron stains, brown 11.0
Sandstone, quartz, fine-grained, iron stains, pink 5.0
Shale, light-gray, calcareous, weak to weathering 12.0
Sandstone, medium-to fine-grained, calcite cement, iron stains, considerable amounts of reworked Precambrian gneiss in the form of feldspar and chlorite 4.0
Unconformity

Precambrian
Gneiss, coarse-grained, orthoclase, hornblende stained with iron oxide

Figure 24. Rio Salado section, Ladron Mts.

PALEONTOLOGY AND CORRELATION OF THE MISSISSIPPIAN OF NORTHERN NEW MEXICO

Megascopic fossils are very rare in the Arroyo Penasco formation of central and northern New Mexico. The small fauna that has been collected occurs only in a zone 65 feet or higher above the Precambrian. Much of the fauna is new and undescribed. Only those species that are known in the literature are considered in this paper.

The most richly fossiliferous known outcrop of Mississippian rocks in northern New Mexico is in Penasco Canyon, Nacimiento Mountains, where the top 30 feet of chert and limestone has produced numerous Eumetria verneuiliana Hall, Eumetria vera Hall, Linoproductus ovatus Hall, and a distinctive Conularia sp.

South of Taos, near Ponce de Leon Springs, numerous Lithostrotion sp. of the whitneyi type and an undescribed Spirifer have been found. North of Tecolote Canyon in the Sangre de Cristo Mountains, Spirifer beckenridgensis ? Weller, as well as numerous Conularia, is present.

The megafauna is of definite post-Osage character. The meagerness and generally poor preservation make more precise dating hazardous. The microfauna is rich in comparison to the megafauna and consists of several species of Endothyra and Plectogyra.
A very distinctive and robust Endothyra, which averages 98 mm in width and 40 mm in axial length, is found in the upper half of the Arroyo Penasco formation in the Nacimiento and San Pedro Mountains. It is found throughout most of the Arroyo Penasco formation in the Sangre de Cristo Mountains. The lower 3-5 feet of the Arroyo Penasco formation in Lujan Canyon, Rincon Range, and Gallinas Canyon, of the Sangre de Cristo Mountains, contains numerous large Plectogyra. Elsewhere Plectogyra is much less common than Endothyra.

The Plectogyras and Endothyras from the Arroyo Penasco formation are similar to those found in the Meramec rocks of the Mississippi Valley (E. J. Zeller, personal communication, 1955). A number of slides were sent to Dr. M. L. Thompson, who commented upon the absence of any foraminifera which might suggest a Chesterian age.

The limestone portion of the Arroyo Penasco formation in the Sangre de Cristo Mountains is, therefore, Meramec. The Arroyo Penasco formation in the San Pedro, Nacimiento, and Sandia Mountains, which is 30-40 feet above the Precambrian and contains Plectogyra and Endoth ra, is unquestionably Meramec. The lower unfossiliferous strata could be classifiedreasonably as earlier Meramecian, although the possibility exists that these lower beds could be facies of either the Kinderhookian Leadville limestone or Caloso formation.

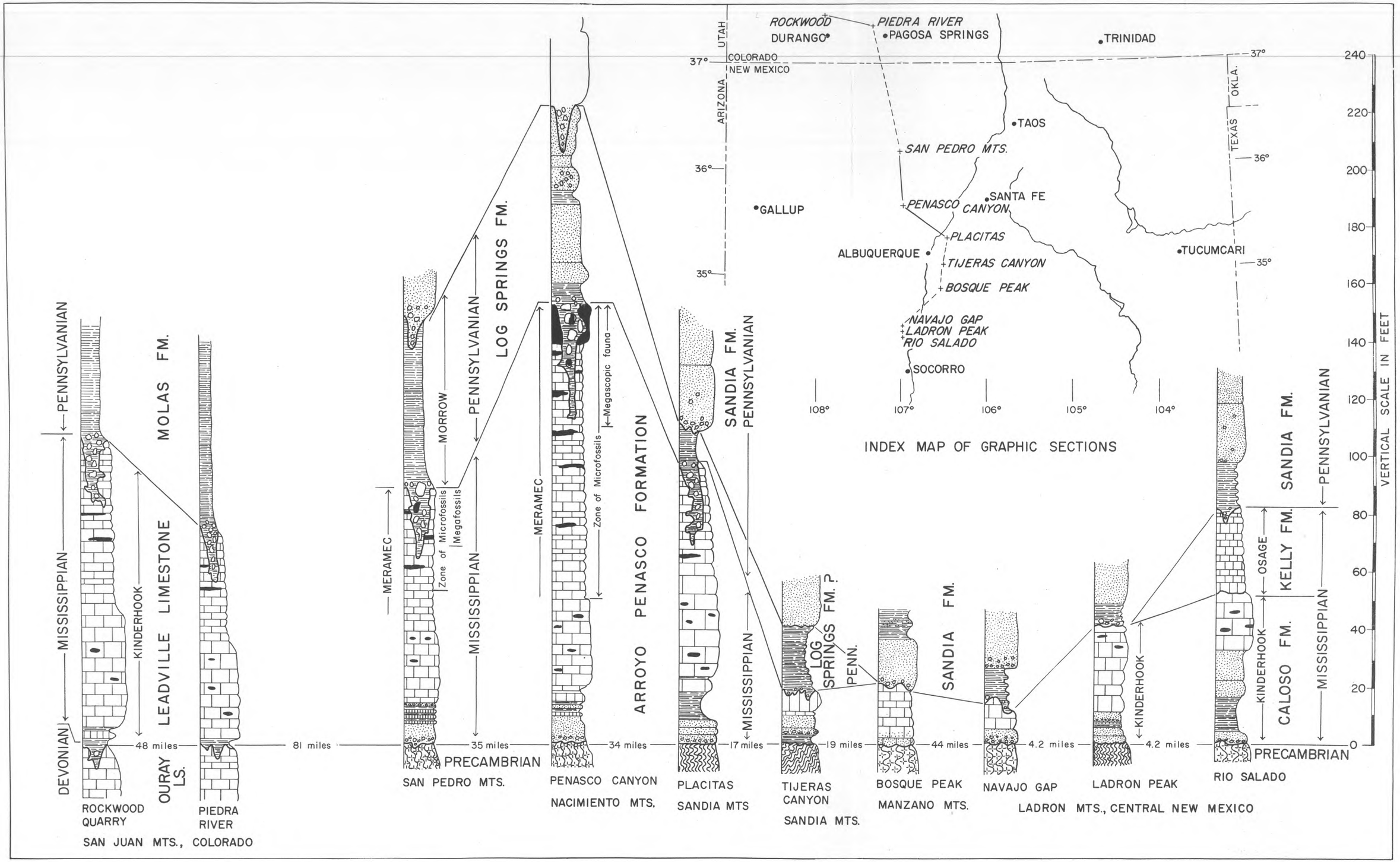


Figure 25. Mississippian rocks from the San Juan Mts., Colorado, to the Ladron Mts., New Mexico.

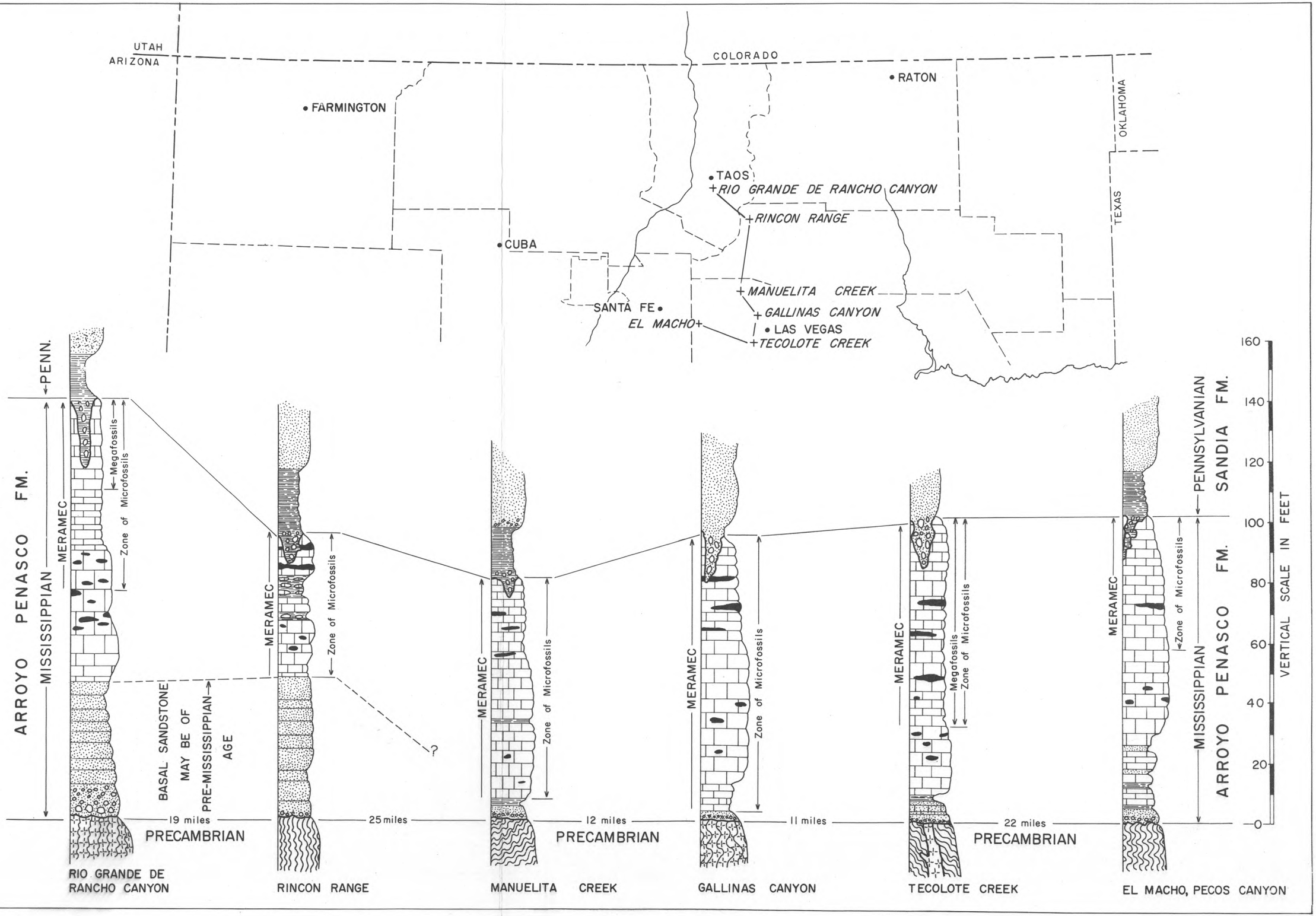


Figure 26. Mississippian rocks of the Sangre de Cristo Mts. from Taos to El Macho.

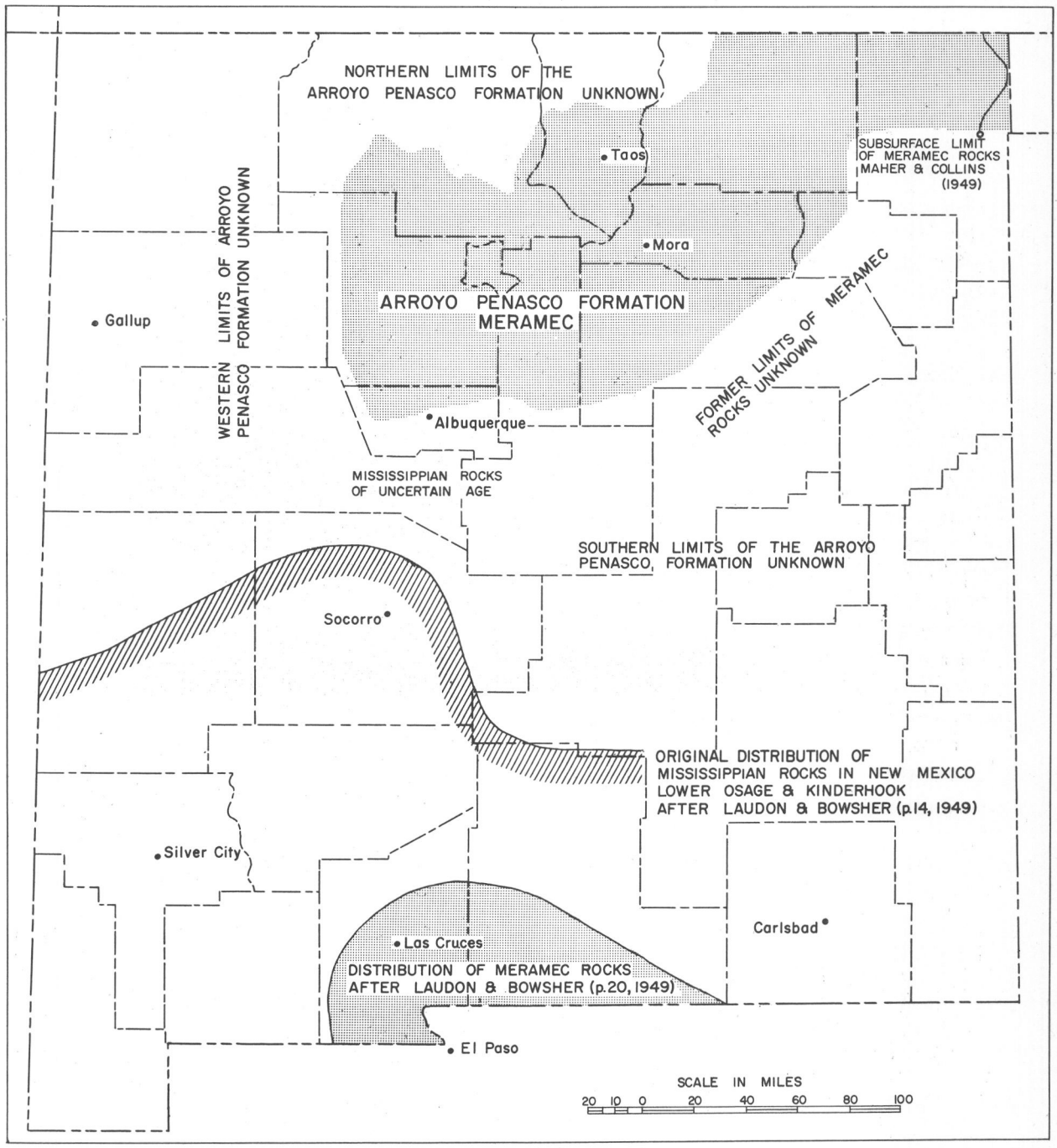


Figure 27. Preliminary Mississippian paleogeographic map of New Mexico.

GEOLOGIC HISTORY OF THE MISSISSIPPIAN AND MORROW PENNSYLVANIAN OF NORTHERN NEW MEXICO

This study indicates clearly a definite sequence of events of Mississippian and Morrow (Lowermost Pennsylvanian) times in central and northern New Mexico. Previous to Mississippian inundation, the Precambrian terrane was reduced to a peneplain with a few elongated, low quartz monadnocks. The regolith on the Precambrian terrane was removed by the transgressing Mississippian sea in most regions. Except for 0-50 feet of basal sandstone, which is particularly prominent in the northern Sangre de Cristo Mountains, the Mississippian Arroyo Penasco formation is almost completely free of clastic material, thus indicating no high areas of denudation or major crustal movements during sedimentation. The Mississippian sedimentation deposited a blanket of at least 150 feet of limestone over northern New Mexico. The seas then withdrew, exposing this veneer to erosion and groundwater activity, which produced solution cavities and collapse breccia. Large zones of limestone have been recrystallized.

In the northwestern section of the State, Morrow (earliest Pennsylvanian) deposition began at scattered localities, so that clastic sediments were distributed on a deeply weathered, uneven surface. These are the intensely red, ferruginous shale and sandstones of the Log Springs formation. The Log Springs sedimentation was halted by strong, orogenic movements and subsequent erosion, followed in the Nacimiento and Jemez Mountains, and probably over a much wider area, by a Morrow (early Pennsylvanian) marine invasion. This sedimentation was halted by folding and faulting. Elevation resulted in the erosion of all Mississippian sediments in northern New Mexico, except those protected in synclines and downfaulted blocks.

REFERENCES

Cross, W., Howe, E., Irving, J. D., and Emmons, W. H. (1905) Needle Mountains, Colorado, U. S. Geol. Survey Geol. Atlas, n 131.

Girty, G. H. (1903) Carboniferous formations and faunas of Colorado, U. S. Geol. Survey Prof Paper 16, pp 1-546.

Henbest, L. G. (1946) (abs) Stratigraphy of the Pennsylvanian in the west half of Colorado and in adjacent parts of New Mexico and Utah, Am. Assoc. Petrol. Geol. Bull., v 30, n 5, p 750-751, May 1946.

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

Kelley, V. C., and Silver, C. (1952) Geology of the Caballo Mountains, Univ. of N. Mex. Pub. in Geol. 4.

Laudon, L. R., and Bowsher, A. L. (1949) Mississippian formations of southwestern New Mexico, Geol. Soc. America Bull., v 60, pp 1-87.

Maher, J. C., and Collins, J. B. (1949) Pre-Pennsylvanian geology of southwestern Kansas, southeastern Colorado and the Oklahoma Panhandle, U. S. Geol. Survey Oil and Gas Inv. Prelim.Map 101.

Moore, R. C., et al. (1944) Correlation of Pennsylvanian formations of North America, Geol. Soc. America Bull., v 55, pp 657-706.

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

Northrop, S. A., and Wood, G. H. Jr. (1945) (abs) Large schizophoria in basal Pennsylvanian of New Mexico, Geol. Soc. America Bull., v 56, p 1185.

Ransome, F. L. (1904) The Geology and ore deposits of the Bisbee quadrangle, Arizona, U. S. Geol. Survey Prof. Paper 21.

Read, C. B., Wilpolt, R. H., Andrews, D. A., Summerson, C. H., and Wood, G. H. Jr. (1944) Geologic map and stratigraphic sections of Permian and Pennsylvanian rocks of parts of San Miguel, Santa Fe, Sandoval, Bernalillo, Torrance and Valencia Counties, north-central New Mexico, U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 21.

Read, C. B., Wood, G. H., Wanek, A. A., and Mackee, P. V. (1949) Stratigraphy and geologic structure in the Piedra River Caflyon, Archuleta County, Colorado, U. S. Geol. Survey Oil and Gas Inv. Map 96.

Thompson, M. L. (1942) Pennsylvanian system in New Mexico, New Mexico School of Mines, State Bur. Mines and Mineral Res. Bull. 17, 92 pp.

Thompson, M. L. (1948) Protozoa; studies of American fusulinids, Univ. Kansas Paleont. Contr. n 4, art 1,•184 pp.

Weller, S. (1914) The Mississippian 8rachiopoda of the Mississippi Valley basin, Illinois Geol. Survey, Mon. I.