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Pennsylvanian System in New Mexico

by
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THE STATE BUREAU OF MINES AND MINERAL RESOURCES

The New Mexico State Bureau of Mines and Mineral Resources, designated as "a department of the New Mexico School of Mines and under the direction of its Board of Regents," was established by the New Mexico Legislature of 1927. Its chief functions are to compile and distribute information regarding mineral industries in the State, through field studies and collections, laboratory and library research, and the publication of the results of such investigations. A full list of the publications of the New Mexico Bureau of Mines is given on the last pages of this Bulletin, following the index.

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Pennsylvanian System in New Mexico

By

M. L. THOMPSON

INTRODUCTION AND ACKNOWLEDGMENTS

Plans are outlined in this preliminary report for the stratigraphic classification of the Pennsylvanian system in New Mexico, with special emphasis on the classification of the Pennsylvanian rocks of the central portion of the State. Most former students of the Pennsylvanian in New Mexico have not considered these sedimentary rocks divisible into small stratigraphic units, and the entire system has been referred usually to one or two thick formations. Detailed lithologic and paleontologic studies, especially of the fusulinid faunas, indicate that the Pennsylvanian of New Mexico can be subdivided into smaller recognizable stratigraphic units. It is the purpose of this report to set up a basis for a detailed classification of the Pennsylvanian of New Mexico.

Data on which this study is based have been accumulated since the fall of 1939. Field studies have been made over most areas in which Pennsylvanian rocks occur at the surface in New Mexico, except in the extreme southwestern part of the State. Also, detailed studies have been made of Pennsylvanian rocks and fusulinid faunas in east central Arizona and extreme western Texas for comparison with the New Mexico section. Up to the present time, detailed descriptions and studies of faunal collections have been prepared of more than fifty stratigraphic sections in New Mexico, many of which include the entire Pennsylvanian system; the locations of some of these are shown on the accompanying outline map (Pl. 1). General collections and generalized descriptions of more than one hundred additional stratigraphic sections of the Pennsylvanian from various parts of New Mexico have also been used in this study. However, only a few of these stratigraphic sections will be referred to specifically in this preliminary report.

The Pennsylvanian rocks of New Mexico contain paleontologic zones and lithologic units which are recognizable over large portions of central New Mexico from the Nacimiento Mountains, southward to the Hueco and Franklin mountains of Texas (Fig. 1). In fact, thin lithologic units, bounded by definite and continuous paleontological zones, are recognizable over areas of thousands of square miles in the central portion of the State. Pennsylvanian rocks of many other regions in North America are of major importance as petroleum and natural gas reservoirs. The possible similar importance of the thick system of rocks of this age so widespread in New Mexico should not be

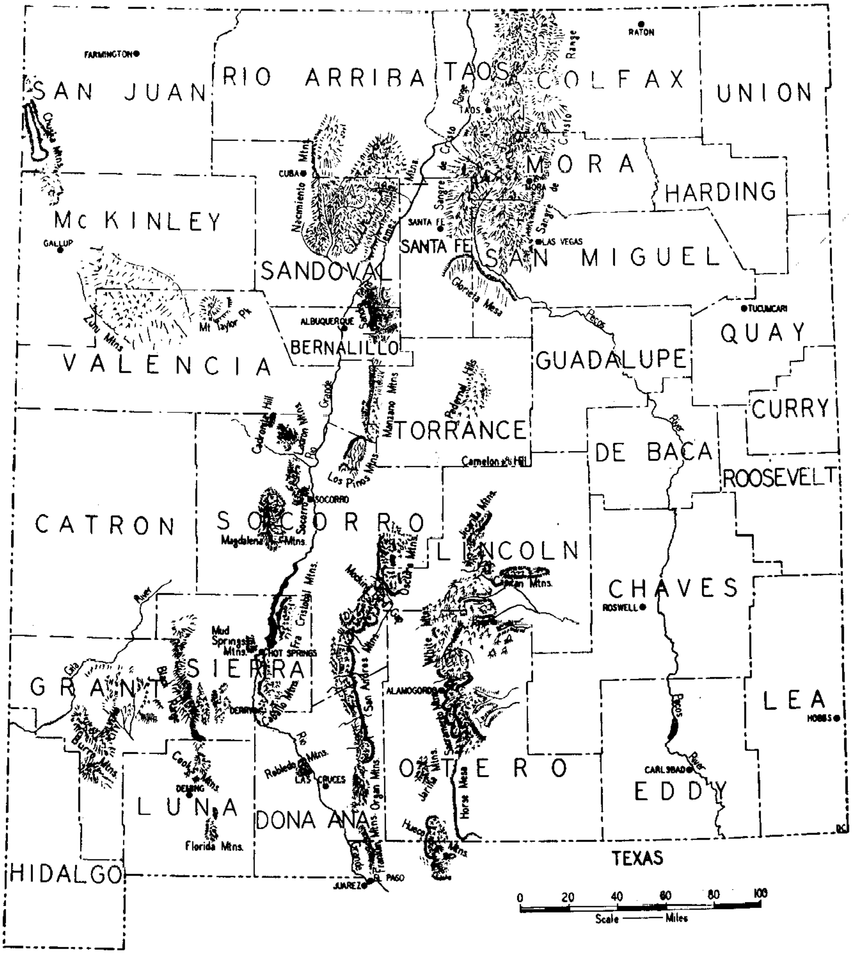
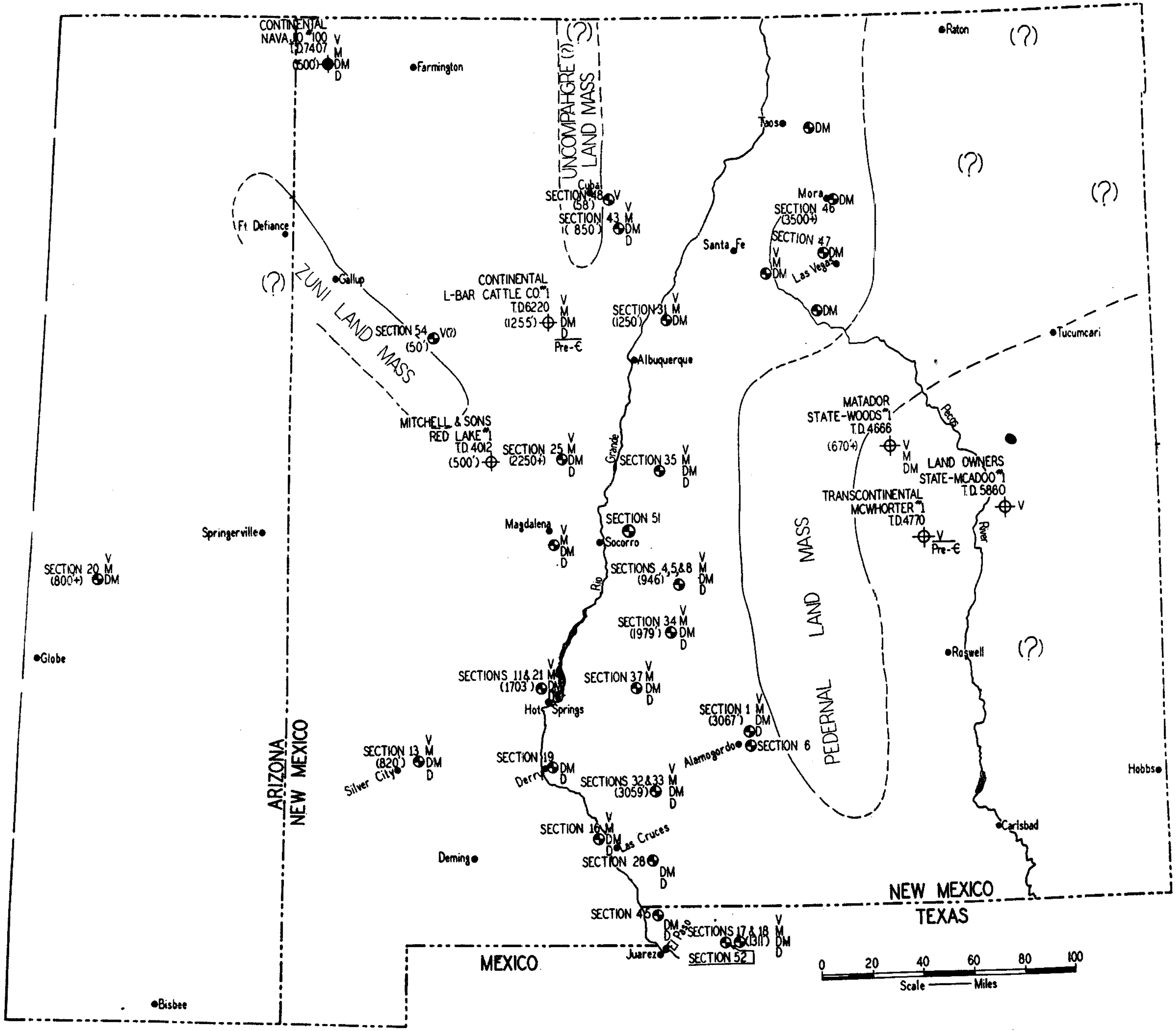


FIGURE 1.-Outline map of New Mexico

overlooked. Furthermore, the recent discovery of petroleum and gas in basal Pennsylvanian rocks in the Rattlesnake field, San Juan County, New Mexico, adds obvious importance from a purely commercial point of view to the Pennsylvanian strata of the western and central portion of the State.

In recent years numerous geologists, more especially the geologists of oil companies, have made inquiries in regard to available published information about the Pennsylvanian sediments of New Mexico. A large general report on the detailed stratigraphy and fusulinid faunas of the Pennsylvanian of New Mexico is now in the process of completion. However, it is considered advisable to present at this time a preliminary classified



MAP OF NEW MEXICO AND IMMEDIATELY SURROUNDING AREAS

Showing the locations of some of the principal stratigraphic sections and Pennsylvanian land masses mentioned in text. (Numbers in parentheses indicate thickness of Pennsylvanian measured; section and number indicate Bureau field sections, and letters to right of section indicate D = Derry series, DM = Des Moines series, M = Missouri series, and V = Virgil series.)

tion and general discussion of the Pennsylvanian rocks of New Mexico in order that this general information may be avail-able immediately to those who are especially interested in the basic geology of this region. More nearly complete supporting data for the conclusions reached in this report, a more detailed classification of the rock units, and descriptions of the contained fusulinid faunas will be included in the larger report.

I wish to take this opportunity to express my sincere appreciation to the many who have made contributions to this study. Field conferences have been held with many people, among whom I would like to mention especially E. N. Kjellesvig-Waering, R. E. King, R. C. Spivey, and John Emery Adams. J. W. Skinner and R. E. King have contributed subsurface information on eastern New Mexico and A. E. Brainard has contributed subsurface information and well samples on the San Juan Basin country of northwestern New Mexico. Laboratory conferences with E. N. Kjellesvig-Waering to discuss the numerous problems of the New Mexico Pennsylvanian fusulinids have been especially helpful. Field assistants have included James B. McKay, Douglas E. Jones, and G. J. Eggink. Douglas E. Jones has also worked for two years as technical assistant in helping to prepare the numerous collections of fusulinids. I especially would like to express my sincere appreciation to C. E. Needham, former President of the New Mexico School of Mines, who has given freely of his extensive information in regard to the Pennsylvanian of New Mexico, and who has, furthermore, been on numerous field conferences during the preparation of this study. Sincere thanks are also due Sterling B. Talmage for his many constructive criticisms of the manuscript.

GENERAL CONSIDERATIONS

GEOGRAPHIC DISTRIBUTION

SURFACE EXPOSURES

Pennsylvanian rocks are exposed widely in New Mexico from the Hueco and Franklin mountains and the Silver City area on the south, to the Zuni, Nacimiento, and Sangre de Cristo mountains on the north and northeast. However, the larger and more important exposures of Pennsylvanian rocks occur on the up-tilted and eroded fault-blocks which form the prominent mountain ranges east and west of the Rio Grande Valley. In fact, excellent exposures of the entire thickness of the Pennsylvanian system are to be found in almost every mountain range of central New Mexico. Pennsylvanian rocks also outcrop in some of the mountains of extreme southwestern New Mexico, but they have not been studied for inclusion in this report.

SUBSURFACE OCCURRENCE

No rocks of Pennsylvanian age are known at the surface in the eastern one-third or in the northern portion of the western one-fourth of New Mexico. However, Pennsylvanian sediments have been definitely identified in a number of deep wells in some parts of these areas. Rocks of Pennsylvanian age have been re-corded also from a number of wells in the northeastern portion of the State, but these occurrences of Pennsylvanian need verification.

Several deep wells have been drilled in the Rattlesnake field of San Juan County, northwestern New Mexico, in which oil and gas were obtained from the lower portion of the Pennsylvanian section. Fusulinids I have studied from some of these wells demonstrate the presence of about 1,500 feet of rocks of Virgil, Missouri, Des Moines, and Derry ages. Winchester (1933, p. 93)1 reports Pennsylvanian rocks in a well drilled on French Mesa anticline in Rio Arriba County, north of the Pennsylvanian out-crops in the Nacimiento Mountains. Darton (1928, p. 132) records 500 feet of Pennsylvanian on the Red Lake anticline in the extreme northwest corner of Socorro County. Samples I have examined from Continental Oil Company's No. 1 L-Bar Cattle Company well drilled about four miles east of Marquez show the presence of slightly more than 1,450 feet of Pennsylvanian rocks lying on pre-Cambrian schists (Pl. 1). The Pennsylvanian in this well includes rocks of Virgil, Missouri, Des Moines, and Derry ages.

Darton (1928, pp. 307, 308) reports questionably Pennsylvanian rocks in a well drilled in extreme north central Union County, in the northeast corner of New Mexico, and (p. 312)

[1]References in parentheses are to bibliography at end of text.

also in a deep well drilled southeast of Tucumcari in Quay County. These occurrences need verification.

Winchester (1933, pp. 116, 117, 121) seriously questioned the correctness of some of the records of the many wells in northeastern New Mexico which have been reported as ending in granite without encountering any Pennsylvanian. Winchester was of the opinion that much of the so-called granite was in reality "granite wash," perhaps of Abo age, and that Pennsylvanian sediments may underlie much of the area of northeastern New Mexico which is not generally believed to contain Pennsylvanian rocks. It should be pointed out, however, that no evidence to support this premise has been brought to light by drilling since Winchester's report.

Winchester (p. 142) records probable Pennsylvanian rocks near the bottom of The Texas Company's No. 1 Wilson well on the Dunken dome in southwestern Chaves County. I cannot find evidence to prove the presence of Pennsylvanian in this well.

Hills (1942, p. 223) reported Pennsylvanian *Triticites* in Navajo's McAdoo No. 1 (Land Owner's No. 1 State McAdoo), and King later (1942, p. 676) reported upper Pennsylvanian fusulinids from the same well. These reports are, so far as I know, among the few unquestionable published records of Pennsylvanian fossils from the subsurface in the eastern one-third of New Mexico. Fusulinids studied by J. W. Skinner,[2] by E. N. Kjellesvig-Waering[3] and by myself from several wells in Guadalupe and De Baca counties, demonstrate the presence of Virgil immediately over pre-Cambrian (see Pl. 1).

PALEOGEOGRAPHY

Although Pennsylvanian rocks are widespread in New Mexico, several areas have been recognized which obviously were land areas throughout Pennsylvanian time. These ancient land areas trend northward and generally are referred to as "Ancestral Rocky Mountains." Although large areas of land were present in these ancient positive belts throughout Pennsylvanian time, evidence shows clearly that land was much more extensive during early Pennsylvanian time than near the close of the period. These land areas were partly covered by progressive overlap of Pennsylvanian strata before the end of the period. They were completely covered shortly after the beginning of the Permian period. The time of the original formation of these positive areas is not known. However, it seems obvious that at least one important uplift took place after the Mississippian period; essentially pure Mississippian limestones occur in areas closely adjacent to obviously high Pennsylvanian mountains, and no lithologic changes are evident in these limestones as the Pennsyl-

[2] J. W. Skinner, personal communication.
[3] E. N. Kjellesvig-Waering, personal communication.

vanian land areas are approached. Since no older Paleozoic rocks are definitely known below the Permian on most of these old land masses, it seems possible that they may have existed as positive areas throughout much of early Paleozoic time.

PEDERNAL LAND MASS

Red shales and sandstones, variegated shales, and limestones of Permian age (Abo and Yeso formations) rest directly on igneous and metamorphic rocks of pre-Cambrian age in an area extending from the eastern side of the Sacramento Mountains, Otero County, apparently continuously to northern Torrance County. This condition exists possibly continuously through eastern Mora County into southern Colorado near or just west of the longitude of Raton, Colfax County. Much evidence points to the conclusion that these pre-Cambrian masses are the remnants of mountains that existed along this area all during Pennsylvanian time and into Permian time. These pre-Cambrian rocks probably represent the buried remnants of a large land area of the Ancestral Rocky Mountains, which may have extended al-most unbroken from Colorado down across central New Mexico and almost to the south border of the State. This land mass, and north-south barrier to the Pennsylvanian seas, will be referred to in this report as the Pedernal Land Mass (Pl. 1), named for the Pedernal Hills in Torrance County. Just how far east or north-east in New Mexico from Pedernal Mountain this Pennsylvanian land extended continuously is not definitely known, for our sub-surface information in northeastern New Mexico is meager.

Inliers of metamorphic rocks have been observed beneath variegated shales and limestones of middle or upper Yeso age in the area northeast of the Sacramento Mountains on the eastern side of the Mescalero Indian Reservation near Tps. 12 and 13 S., R. 15 E., Otero County. Similar conditions have been reported just west of the Capitan Mountains, Lincoln County. The well drilled at Picacho (Darton, 1928, p. 231) , about 18 miles north-east of the pre-Cambrian exposures on the Mescalero Reservation, apparently encountered pre-Cambrian granite near the base of the Yeso formation and at a depth of about 1,670 feet. This well is thought to be located near the eastern edge of Pedernal Land Mass.

Further evidence that a high land mass existed just to the east of the western side of the Sacramento Mountains is found in the nature of the Pennsylvanian sediments of that region. Very coarse conglomerates with cobbles of reworked quartzite and other reworked metamorphic rocks are present in that area. Furthermore, northeastward from the Sacramento Mountains area the Pennsylvanian section becomes thicker, more highly clastic, and more nearly of deltaic character. This thickening and increase in clastic content is especially pronounced in the north end of the mountains and northward toward Tularosa.

border. These Pennsylvanian rocks include arkoses, arkosic conglomerates and sandstones, and black shales. Thick Pennsylvanian clastics are especially well exposed in Mora Canyon; around Tres Ritos and the mountains east of Rio Pueblo ; Taos Canyon; and to the east and northeast of Taos. The sources of these thick clastics must have been nearby, and the land mass from which they came is thought to have been to the east ; it seems to have been the northward continuation of the Pennsylvanian land mass around the Cherryvale dome east of Mora and Las Vegas. Al-though no area has been seen in this general region in which the eastern edge of the Pennsylvanian has been exposed, it seems probable that the Pennsylvanian ended against the land mass by progressive overlap. However, along the Pecos River Valley in western San Miguel County, evidence is found indicating that the Pennsylvanian Missouri and Virgil seas were gradually restricted westward and southwestward off the old land mass.

Hills (1941), Skinner,[5] and King[6] report Pennsylvanian Virgil sediments from. deep wells in the region of eastern Guadalupe, De Baca, and southern Quay counties. Samples that were examined September, 1942, of the lower portion of Matador Oil Company's No. 1 Woods-State well[7] (see Pl. 1), De Baca County, show the presence of at least 670 feet of Pennsylvanian rocks of Missouri and Des Moines age. Three hundred and fifty feet of samples, which were missing above the top of this section, probably include the Virgil reported by Skinner. We do not have sub-surface data from deep wells in the distance of about 30 miles between the north end of the known area of the Pedernal Land Mass and the south end of the Pennsylvanian land area of north-east New Mexico. However, it seems very unlikely that the Pennsylvanian Virgil seas crossed this narrow area and joined with the Virgil seas that were present in central New Mexico west of the Pedernal Land Mass. The information now available indicates that the Pedernal Land Mass probably was connected with the Pennsylvanian land areas at Esterito and Cherryvale domes so as to form a continuous land barrier all during Pennsylvanian time. It also seems probable that land areas during Pennsylvanian time were very extensive in northeastern New Mexico.

ZUNI LAND MASS

Red sands and shales, generally identified as Permian Abo formation, occur on the southwestern and western sides of the Zuni Mountains directly in contact with pre-Cambrian rocks, and this same general condition exists for at least 14 miles from the northwest to the southeast portions of the Zuni uplift. On the east and northeast sides of the Zuni Mountains, thin lime-stones which are probably of Pennsylvanian Virgil age rest on

[5].J. W. Skinner, personal communication.
[6] R. E. King, personal communication.
[7] Published by permission of South Basin Oil Company.

thin arkosic sandstones and conglomerates, which in turn rest on pre-Cambrian rocks (Section 54, Pl. 1). Just how close to the pre-Cambrian outcrops the Pennsylvanian may extend in other parts of the Zuni Mountains is not known. No other rocks are known at the surface in the general region of the Zuni Mountains which seem to be of possible Pennsylvanian age. No de-tailed records of deep wells drilled near the Zuni uplift are avail-able. Several wells 40 to 50 miles out from the Zuni Mountains give some information. A well drilled on the Red Lake anti-cline, about 35 miles southeast of the edge of the pre-Cambrian outcrop in the Zuni Mountains, is reported (Darton, 1928, p. 132) to have encountered only about 500 feet of Pennsylvanian rocks above the pre-Cambrian. The portion of the Pennsylvanian en-countered in this well was not reported. More than 2,000 feet of Pennsylvanian rocks, composed largely of marine limestone with subordinate marine shales and sandstones, have been measured on Cadronito Hill northeast of Ladron Peak, about 50 miles southeast of the Zuni uplift. Continental's L-Bar Cattle Company No. 1 well recently drilled four miles east of Marquez and 40 miles east of the southeast end of the Zuni Mountains encountered about 1,450 feet of Pennsylvanian Virgil, Missouri, Des Moines, and Derry rocks that overlie pre-Cambrian schists (see Pl. 1).

Field studies in the region of the Zuni Mountains indicate that the Permian sediments overlie the pre-Cambrian in this area by progressive overlap and it seems probable that the Pennsylvanian overlaps against the pre-Cambrian in the same manner.

An old land mass has long been recognized in the region around Ft. Defiance, Arizona. This old land mass has lower Permian overlapping against the pre-Cambrian and its general geographic alignment in Arizona indicates that it was probably connected structurally with the Pennsylvanian land mass in the Zuni uplift area, only a short distance to the southeast in New Mexico. This old land mass, which extended probably continuously from the Zuni Mountains to Ft. Defiance, is here designated as the Zuni Land Mass (Pl. 1).

UNCOMPAHGRE (?) LAND MASS

Pennsylvanian rocks are exposed widely in the Nacimiento uplift of Sandoval and Rio Arriba Counties of north central New Mexico. In the southern portion of the uplift at the Soda Dam on the Jemez River near Jemez Springs (Section 51, Pl. 1), the Pennsylvanian is more than 800 feet thick. All series of the system found in other parts of New Mexico are present at this locality. In the area east of Cuba, Rio Arriba County, on the north-west corner of the Nacimiento uplift, the Abo formation rests directly on pre-Cambrian rocks. Only a few miles southeast of Cuba (Section 49, Pl. 1), however, thin limestones and clastics of upper Pennsylvanian Virgil age occur between the Abo and the pre-

Cambrian. Studies of faunas collected from the top of the Pennsylvanian section at numerous localities from the southeast to the northwest sides of the Nacimiento uplift show clearly that the top of the Pennsylvanian throughout this area is of about the same age and is referable to the Virgil series. It therefore seems obvious that the Pennsylvanian is in contact with the pre-Cambrian in this region by progressive overlap. In contrast with my observations and studies in this region, Renick (1931, pp. 13-17) expressed the opinion that the Pennsylvanian is absent beneath the Permian Abo on the west and northwest sides of the uplift due to post-Pennsylvanian uplift and erosion of the Pennsylvanian prior to the deposition of the Abo. If this interpretation were correct, the upper portion of the Pennsylvanian in areas where the section is thick should be considerably higher stratigraphically than in areas where the Pennsylvanian section is very thin.

The results of these studies show clearly that the eastern edge of a Pennsylvanian land mass was located just east of Cuba on the northwest edge of the present Nacimiento uplift and that this land mass was not worn down or submerged and buried until after the beginning of Permian time. It is possible that this Pennsylvanian land area may be the southern end of the Uncompahgre Land Mass, extending southward from southern Colorado (Pl. 1).

The geographic relationship between the Pennsylvanian land areas in the Nacimiento region and the Zuni Land Mass is not known, for our subsurface data between these two areas are meager. However, it seems probable that seas extended across the area between the present Zuni and Nacimiento Mountains and connected the Pennsylvanian seas of the Rio Grande Valley area with the Pennsylvanian seas of the San Juan Basin. The thick Pennsylvanian section present in the deep well drilled in extreme northeast Valencia County (Pl. 1) strongly supports this interpretation.

LATE OR POST-PENNSYLVANIAN LAND AREAS

In the Florida Mountains of southwestern New Mexico, at least near Gym Peak, Gym limestone of Permian age rests on Ordovician Montoya limestone. Darton (1928, p. 329) reports Gym limestone resting on Mississippian Lake Valley limestone in Cooks Range to the north of the Florida Mountains. The absence of Pennsylvanian limestone apparently is not due to the presence of a Pennsylvanian land mass but is due to post-Pennsylvanian disturbances and subsequent pre-Permian or early Permian removal of the Pennsylvanian by erosion. These post-Pennsylvanian disturbances around the Florida Mountains were probably of the same age as the post-Pennsylvanian disturbances in the south end of the Hueco Mountains and the Diablo Mountains of extreme western Texas, discussed by King and King (1929,

p. 913). The direction of the structural trends of the disturbances in New Mexico is thought to have been southeasterly.

LITHOLOGY

The Pennsylvanian of most areas in central and southern New Mexico is composed largely of marine limestones and calcareous shales, with only small amounts of sandstones and red beds. This condition is true especially in the Rio Grande Valley south of the Jemez Mountains and Albuquerque. Sections typical of this region were measured at the north end of the Oscura Mountains in eastern Socorro County (Section 8, P1. 1) and in the Mud Springs Mountains of Sierra County (Section 11, Pl. 1).

The samples I have examined from deep wells drilled in the Rattlesnake field of San Juan County and in extreme northeast Valencia County suggest that the Pennsylvanian of the San Juan Basin and of the area to the southeast also is composed largely of marine limestones and shales.

In a large basin-like area throughout the San Andres Mountains and at the south end of the Tularosa Basin east of El Paso the Pennsylvanian Virgil rocks are composed of very thick black silts and shales, dark silty limestones, sandstones, and some wide-spread beds of gypsum. The faunas indicate that many of these clastics are of brackish water to deltaic origin.

In north central New Mexico over the general area of the Sangre de Cristo Range north of the Pecos River, the Pennsylvanian rocks are largely of clastic origin. They are composed of shales, arkosic sandstones, and conglomerates, with a subordinate amount of silty and argillaceous to essentially pure limestone.

THICKNESS

The total thickness of the Pennsylvanian system in New Mexico varies markedly, as is shown by the figures on the accompanying map (P1. 1). Work in connection with this study indicates that time units of the Pennsylvanian section are generally thinner in areas where the rocks are predominantly pure limestone than in areas where the rocks are predominantly elastics. The Pennsylvanian in the north end of the Oscura Mountains contains practically all portions of the system known in other parts of New Mexico, but the entire section is only about 950 feet thick. In this area the Pennsylvanian is composed largely of limestones and highly calcareous shales. However, thin red shale and arkosic sandstone beds are scattered throughout, and the upper 113 feet of the system is largely red shale. On Little Burro Mountain in Mocking Bird Gap (Section 34, Pl. 1), only about 18 miles to the south of the northern end of the Oscura Mountains, the total Pennsylvanian section is about 2,000 feet thick. The only portion of the Pennsylvanian known from the Mocking Bird Gap that is not found in the northern portion of the Oscura Mountains is about 200 feet of limestone of uppermost Virgil age. The Mocking Bird Gap section contains numerous beds of sandstone throughout which total over 500 feet in thickness.

The thickest Pennsylvanian sections that I have measured in central and southern New Mexico are found in the north end of the Sacramento Mountains (Sections 1 & 7, Pl. 1) and in the south end of the San Andres Mountains (Section 32, Pl. 1). In the north end of the Sacramento Mountains, at least 3,065 feet is definitely assigned to the Pennsylvanian. The lower 2,000 feet of this section is predominantly clastic, of sandstone, fine conglomerates, siltstones, shales, and highly silty to argillaceous dark limestones. The upper 1,000 feet is predominantly bluish gray limestones, with interbedded sandstones and conglomerates, and a subordinate amount of gray to red shales. In the extreme south end of the Sacramento Mountains the lower portion of the Pennsylvanian is almost entirely limestone. Northwest to Alamogordo this portion of the section changes to almost entirely deltaic to clastic marine sediments, as mentioned above. Northeastward from Alamogordo toward the Pedernal Land Mass the Pennsylvanian section is still thicker and more highly clastic.

The Pennsylvanian in the south end of the San Andres Mountains is about 3,067 feet thick (Section 32, Pl. 1). The lower 400 feet is massive limestone of upper Derry, Des Moines, and Missouri ages. The upper 2,600 feet is largely Virgil in age and is composed almost entirely of clastic sandstones to conglomeritic sandstones, dark gray siltstones, dark gray shales, and highly argillaceous and silty dark gray limestone. Two thick beds of gypsum also occur at 250 and 500 feet, respectively, below the top of this clastic portion of the section. A well drilled northeast of Newman in the south end of the Tularosa Basin encountered a similar section, including gypsum beds.

One of the thinnest sections of the Pennsylvanian that I have measured in which all series are present is in the Santa Rita area. The section in that area is only 820 feet thick. However, the upper part of the Virgil is missing (Section 13, Pl. 1). Measurements in the Nacimiento Mountains show thicknesses ranging from zero to 850 feet, but in this area the Derry, Des Moines, and Missouri series are present only in the southeastern portion of the mountains where the maximum thickness of 850 feet has been measured.

The total thickness of the Pennsylvanian section in the Sangre de Cristo Mountains exceeds 3,500 feet and, so far as I have observed, only the Des Moines series is present.

Deep wells drilled in De Baca and Guadalupe Counties of eastern New Mexico penetrated thin Pennsylvanian sections.

PRE-PENNSYLVANIAN-PENNSYLVANIAN CONTACT

The base of the Pennsylvanian in New Mexico is everywhere unconformable on older rocks. Stratigraphically the youngest rocks found beneath the Pennsylvanian occur in southern New

Mexico and they are Mississippian Chester in age. Northward in the San Andres Mountains to Mocking Bird Gap, the basal Pennsylvanian bevels rocks ranging in age from Mississippian Chester through Cambrian (?) Bliss sandstone and into the pre-Cambrian. However, all of the lowermost Pennsylvanian rocks in this area are referable to the Derry series. In some of these regions, considerable post-Mississippian pre-Pennsylvanian deformation and erosion occurred.

North and northeast of a line joining Mocking Bird Gap and Cadronito Hill, the Pennsylvanian rests on pre-Cambrian rocks, except in a few places where older limestones and elastics of undetermined age lie unconformably beneath the Pennsylvanian.

Sixteen feet of coarse conglomerate and coarse sandstones, overlain by 90 feet of massive limestone, overlie pre-Cambrian schists on the northwest side of the Sandia Mountains (Section 31, Pl. 1). My field notes on the upper 38 feet of this limestone read, "Limestone; light gray; finely crystalline; massive; resembles marble; upper surface contains cracks and solution holes that are filled with the overlying Pennsylvanian sandstone." The overlying beds referred to are coarse sandstones and fine conglomerates of the Sandia formation. It is obvious the basal Pennsylvanian sandstone rests unconformably on the limestone. No fossils have been found in this limestone and its age is unknown. However, it occurs in only a few places in the Sandia Mountains and its composition indicates it was not deposited only locally but was partially removed by erosion before the Pennsylvanian was laid down. This lower limestone series in the, Sandia Mountains is unnamed and it probably is of lower Paleozoic age.

In Gallinas Canyon northwest of Las Vegas on the east side of the Sangre de Cristo Range a thin sparsely fossiliferous lime-stone of unknown age occurs beneath definite Pennsylvanian. This limestone may be of middle or lower Paleozoic age. The Continental Oil Company's No. 100 Navajo well in the Rattlesnake field of the San Juan Basin of northwestern New Mexico encountered several hundred feet of middle and lower Paleozoic rocks beneath the base of the Pennsylvanian.

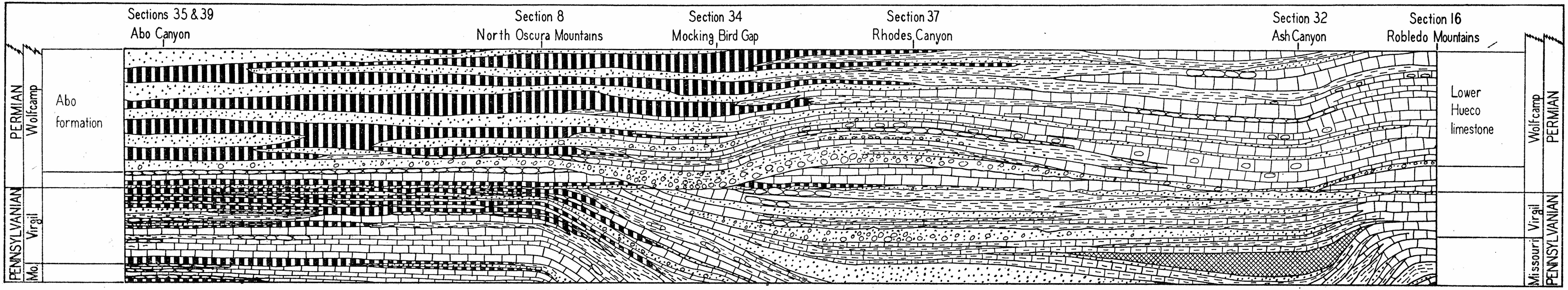
In general, the pre-Pennsylvanian surface in New Mexico was essentially flat. However, numerous low elevations have been recognized in some areas beneath the base of the Pennsylvanian. Also, shallow depressions are known beneath the Pennsylvanian, some of which may have been portions of pre-Pennsylvanian or early Pennsylvanian erosional channels. Such irregularities are more common on the flanks of the Pennsylvanian land masses. A few such irregularities are well exposed in portions of the Sacramento Mountains, the northern portion of the San Andres Mountains, and the Nacimiento and Jemez Mountains. In many areas, the depressions in the pre-Pennsylvanian rocks are filled with very coarse conglomerates but coarse conglomerates are not confined to the depressions nor do all low portions of the pre-Pennsylvanian surface contain conglomerates.

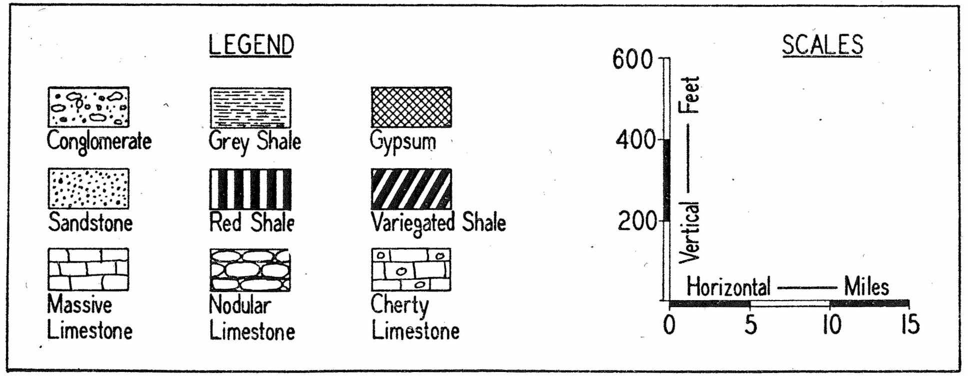
PENNSYLVANIAN-PERMIAN CONTACT

The Pennsylvanian-Permian contact in New Mexico every-where is unconformable, but in most local areas the Pennsylvanian and Permian strata are essentially parallel. However, when considered from a regional point of view, considerable structural discordance exists between the upper strata of the Pennsylvanian and the lower strata of the overlying Permian. The general condition along the Pennsylvanian-Permian contact in south central New Mexico is illustrated diagramatically in the accompanying sketch (P1. 2).

In south central New Mexico, Pennsylvanian rocks of upper Virgil age unconformably underlie fusulinid-bearing Permian marine sediments of lower Wolfcamp age. This same general condition exists almost continuously in central New Mexico at least as far north as the latitude of the Manzano Mountains south of Albuquerque, except that to the north the uppermost Pennsylvanian beds are slightly older. In the area from Albuquerque northwest to the Nacimiento uplift and northeast to Pecos, non-marine red beds of the Permian Abo formation rest unconformably on Pennsylvanian strata of middle Virgil age. Therefore, the unconformity between the Pennsylvanian and the Permian in central New Mexico is of greater magnitude than it is in the south central portion of the State. In the north central part of New Mexico the stratigraphic break is still greater; where a con-tact has been observed north of the Pecos River in the Sangre de Cristo Mountains, non-marine red beds which apparently are Permian Abo in age rest on upper Des Moines sediments.

My field studies indicate that only a small amount of the Pennsylvanian was removed by erosion in central New Mexico prior to the deposition of the overlying Permian. However, in an area from Cooks Range on the north to the Florida Mountains on the south and apparently extending southeastward, consider-able post-Pennsylvanian deformation and subsequent pre-Permian erosion took place. Along this area the Pennsylvanian-Permian contact bevels the entire Pennsylvanian system and cuts down through a large portion of the lower Paleozoic section.





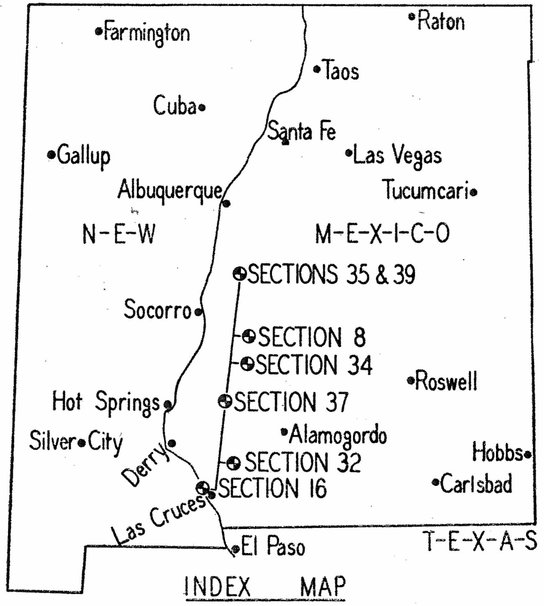


DIAGRAM OF THE PENNSYLVANIAN-PERMIAN CONTACT
Along the general trend of the Rio Grande Valley of central New Mexico

PREVIOUS CLASSIFICATIONS

By far the most important single contribution to our general knowledge of the Pennsylvanian rocks in New Mexico was presented by Darton (1928) in his well-known *"Red Beds" and associated formations in New Mexico.* Although Darton recognized several formations in the Pennsylvanian of New Mexico, he did not apply any formal formational names to them and referred the entire Pennsylvanian system to the "Magdalena group".

With the exception of the studies by Darton, few regional studies have been published of the Pennsylvanian of New Mexico. Brief studies of the Pennsylvanian have been made in some of the mining districts and mountain ranges of New Mexico, but these have been local and have contributed but little to our knowledge of the broad picture of the Pennsylvanian as exposed in the mountains of the Southwest. One of the earliest attempts to classify the Pennsylvanian of New Mexico was made by Herrick (1900). Herrick proposed to divide the "Coal Measures" (Pennsylvanian) of the Sandia Mountains into a lower "series" of sandstone, shales and black limestones which he called Sandia, and an upper series of massive limestones for which he did not propose a name. Herrick gave the name Coyote to one of the interbedded sandstones of these upper limestones. The name Coyote came from Coyote Canyon, south of the Sandia Mountains, where this sandstone was said to be well exposed. Herrick and Johnson (1900) graphically illustrated the Coyote sandstone, and indicated its position to be about 375 feet above the top of the Sandia formation. However, since Herrick did not clearly define the upper limits of the Sandia formation (or series), it is not possible to determine the exact position of the Coyote sandstone; furthermore, since there are several sands in Coyote Canyon, any of which may fit Herrick's definition, the name Coyote sandstone will not be further used in this report.

Keyes (1903) proposed the name Madera for the upper limestones of the Pennsylvanian ("Upper Carboniferous") in the region of the Sandia Mountains, probably either for the "Madera area" of that region or for the little village of La Madera. Keyes proposed the term Placitos (origin unknown) for the "lower black limestone" which he indicated included much of the Pennsylvanian limestone on the Sandia Mountains. At the same time, Keyes re-defined Herrick's Sandia formation as the Sandia quartzite, to include only the basal sandstones and quartzites of the Pennsylvanian in the Sandia Mountains. Two years later, Keyes (1905) referred to the basal clastics of the Pennsylvanian as the Sandia quartzites, the overlying dark limestones were not named and the upper blue to gray limestones were referred to as the Madera limestone. The following year Keyes (1906) used the term Madera (Maderan) with reference to Permian limestones. Later workers have applied the term Madera to different portions of the massive limestones of the Pennsylvanian of central New Mexico, ranging in age from lower Des Moines series to upper Virgil series. Since the term Madera was so poorly defined originally by Keyes, and apparently has been used in so many different senses by Keyes and others, I propose that the term Madera be dropped from the Pennsylvanian nomenclature of New Mexico. The term Sandia of Herrick has had a somewhat similar history. However, I propose the name Sandia be retained for the lower 127 feet of coarse-grained sandstone, conglomerates and variegated shales at the base of the Pennsylvanian in the Sandia Mountains. This formation will be discussed under the Des Moines series.

Keyes proposed in 1906 to divide the Pennsylvanian into two (or possibly three) series which he called Ladronesian below and Manzanan above. He listed the term Alamito shale under the Ladronesian and four names under the Manzanan; in ascending order, Sandia shale, Montosa limestone, Coyote sandstone, and Mosca limestone. Keyes did not give the source or definition of any of these terms. Much later, Keyes (1909 and 1915) published some of the terms originally used in 1906, mainly in entirely different senses, and introduced several other terms, but he did not define any of them. These terms proposed by Keyes are not considered established and will not be discussed further.

Gordon (1907) proposed the term Magdalena group for all sedimentary rocks present in the Magdalena Mountains and other areas of central New Mexico between the Kelly limestone (Mississippian) below and the Abo formation (Permian) above. Gordon recognized two formations in the Magdalena group, the Sandia formation below and the Madera limestone above. He gave a total thickness of 1,150 feet for the Magdalena group in the Magdalena Mountains and stated that in that area the Sandia formation is 500 to 700 feet thick. Almost all Pennsylvanian rocks recognized in other areas of America have correlatives in the Pennsylvanian rocks of the Magdalena Mountains. The term Magdalena, therefore, seems to be essentially synonymous with the systemic term Pennsylvanian. Since 1907 Gordon's proposal has been generally accepted, and all rocks of Pennsylvanian age in New Mexico have been referred to as the Magdalena group, the Magdalena limestone, or the Magdalena formation (Needham, 1937, 1940), and it seems inadvisable to attempt to preserve this well established term by merely restricting the name in any sense to a small portion of the Pennsylvanian of New Mexico. I am not using the term Magdalena in the stratigraphic nomenclature of the Pennsylvanian rocks of New Mexico.

Paige (1916) proposed the term Fierro limestone to include all rocks of Mississippian and Pennsylvanian age in the Silver City area of southwestern New Mexico. However, Spencer and

Paige (1935) later proposed to drop the term Fierro limestone in favor of the Lake Valley limestone for the Mississippian sediments and Magdalena group for the Pennsylvanian rocks in the Santa Rita and Silver City region. At this same time, Spencer and Paige proposed two formations as divisions of the Magdalena group: Oswaldo formation for the lower 400 feet and the Syrena formation for the upper 400 feet. Studies which I have made in the Silver City-Santa Rita area show that each of these "formations" includes large portions of at least two series of the Pennsylvanian and are not useful as regional stratigraphic units. There fore, the terms Oswaldo formation and Syrena formation will not be considered further.

Schmitt (1933) proposed to divide the Pennsylvanian of the Central Mineral Area near Santa Rita into the "Lower Magdalena limestone" and the "Upper Magdalena formation," The "Upper Magdalena formation" was subdivided by Schmitt into the Humboldt formation above for the upper 261 feet and the Mountain Home shale below for the lower 130 feet, but he did not define either formation. Since the term Humboldt was used at least three times to apply to stratigraphic units in the United States previous to Schmitt's report, and not in the same stratigraphic sense as used by Schmitt, the term Humboldt will not be considered further in this report as a stratigraphic name for Pennsylvanian rocks in New Mexico. The term Mountain Home shale was "provisionally assigned" by Schmitt "for convenience in mapping" and was listed in his succession of rocks in the area but was not discussed further. My information indicates that the Mountain Home shale of Schmitt includes most of the Missouri series. The term Mountain Home will not be used further in this report.

Nelson, 1940, proposed to subdivide the lower portion of the "Magdalena formation" into three members; from the base upward, La Tuna member, Berino ember, and Bishops Cap member. However, as stated by Nelson, these members were established for this part of the section mainly for convenience of reference, and they do not necessarily represent definite stratigraphic or lithologic units. They indicate obvious differences in topographic expression on the slopes of the ranklin Mountains that weather somewhat differently. I have made collections of fusulinids from throughout all three members at Nelson's type section, and find that one of these members includes portions of two series. It therefore seems advisable not to attempt to apply these member terms to the Pennsylvanian rocks of central New Mexico. However, they will undoubtedly prove to be very useful for the purpose of mapping in the Franklin Mountains of Texas. The above references include most of the names that previously have been proposed for the classification of the Pennsylvanian sedimentary rocks of New Mexico, but unfortunately only one seems to be of specific use for a more detailed classification.

Most of the stratigraphic divisions proposed by earlier workers for the Pennsylvanian of New Mexico are shown in the accompanying chart (Table I). As is indicated on this chart, it is not possible to determine in most cases the stratigraphic boundaries of these units. Furthermore, the positions which I have indicated for several of these units may not be very close to the stratigraphic levels that the authors of the terms had in mind.

TABLE 1.

TERMINOLOGY USED BY SEVERAL AUTHORS FOR CLASSIFICATION OF PENNSYLVANIAN ROCKS IN NEW MEXICO

HERRICK, 1900 SANDIA MTS.	KEYES, 1903 SANDIA MTS.	KEYES, 1905 SANDIA MTS.	KEYES, 1906 CENTRAL NEW MEXICO		GORDON, 1907 RIO GRANDE VALLEY		KEYES, 1915 NEW MEXICO		PAIGE, 1916 SILVER CITY QUADRANGLE	SCHMITT, 1933 CENTRAL MINING AREA		SPENCER AND PAIGE, 1935 SANTA RITA AREA		NELSON, 1940 FRANKLIN MTS.	
370 feet (?) Unnamed limestones, shales and sandstones --- Coyote sandstone 40 ft (?) --- 425 feet (?) Unnamed limestones --- Sandia series 175 feet (?)	Madera limestone --- Placitos limestone --- Sandia quartzite	"Madera" limestone --- Unnamed (?) --- Sandia quartzite	Manzanan series --- Ladronesian ser.	Mosca limestone (Not defined) Coyote sandstone (Not discussed) Montosa limestone (Not defined) Sandia shales (Not discussed) --- Alamito shale (Not defined)	Magdalena group	Madera limestone --- Sandia formation, 500-700 feet	Maderan series --- Lunasan series --- Ladronesian ser.	Tellera limestone (Not defined) Gallegos sandstone (Not defined) Antonito limestone (Not defined) --- Mosca limestone (Not defined) Coyote sandstone (Not discussed) Montosa limestone (Not defined) Sandia shale (Not discussed) --- Alamito shale (Not defined)	Fierro limestone (Included all Mississippian and all Pennsylvanian sediments of the Silver City Area)	Upper Magdalena formation --- Lower Magdalena formation	Humbolt formation 261 feet --- Mountain Home shale 130 feet --- 457 feet	Magdalena group	Syrena formation 400 feet --- Oswaldo formation 400 feet	Magdalena formation	Bishops Cap member 619 feet --- Berino member 555 feet --- LaTuna member 361 feet

PRESENT CLASSIFICATION

GENERAL

Entirely different highly detailed stratigraphic nomenclature has been established for the classification of the Pennsylvanian system in several large areas in North America. Three of the better established classifications are in the upper Ohio River Valley and Pennsylvania region, the northern Mid-Continent region, and north central and central Texas. Even the larger of the subdivisions, the series, are not exact correlative time units between any two of these areas. Therefore, they cannot be considered synonymous with only a difference in terminology. How-ever, there has been a strong movement in recent years to re-define the limits of the series in some of these regions so that the series limits will correspond in geologic time.

Perhaps the most clearly defined of the classifications is that now in use in the northern Mid-Continent region, which includes four series, in ascending order, Morrow, Des Moines, Missouri, and Virgil. These terms, now in use in the Mid-Continent region, will not meet all needs in a classification of the Pennsylvanian system in New Mexico. A thick section of rocks occurs in New Mexico that is stratigraphically different from the Des Moines series, but which is younger stratigraphically than the type Morrow of Arkansas.

In the type region of the Pennsylvanian in the State of Pennsylvania, the system has been divided into four series, from oldest to youngest, Pottsville, Allegheny, Conemaugh, and Monongahela. These terms are all well established in the literature, but the stratigraphic units to which they are applied are com-posed largely of brackish-water to continental deposits at their type areas. It therefore is difficult to correlate these geologic units with any degree of assurance with the Pennsylvanian in other areas in which the system is composed largely of marine sediments, as is the case with the Pennsylvanian in New Mexico. Furthermore, most of these well established stratigraphic units, so far as I can tell, are not made up entirely of closely related rock units. There are also other objections to the adoption of this classification for the Pennsylvanian system in New Mexico.

The classification of the Pennsylvanian in northern and central Texas adopted by the Texas Bureau of Economic Geology (Sellards, 1937) was recently revised by Cheney (1940). Cheney raised the groups of the Texas Bureau to the rank of series and revised their limits to make the boundaries of the series corre-spond in geologic time with the boundaries of the series now in use in the northern Mid-Continent region. Cheney further-more proposed to recognize one additional series, the Lampasas, between the Morrow and the Des Moines of the Mid-Continent classification. Cheney recognized five series, in ascending order, Morrow, Lampasas, Strawn, Canyon, and Cisco. The upper portion of the Pennsylvanian is missing in north central Texas and therefore the top of the Cisco does not represent the top of the system in America.

Faunal collections and other information which I have concerning the Lampasas series indicate that it includes rocks which I would classify as of Des Moines age. Also, the definition of that series is largely dependent on subsurface rocks which are not available to most geologists for detailed study. Although the term Lampasas series probably can serve an excellent purpose in the subsurface classification of the Pennsylvanian rocks of central and north central Texas, the series is not considered sufficiently well defined and understood for long range usage in New Mexico and other areas of North America. I do not consider it advisable to apply the term Lampasas series to any rocks in New Mexico.

The stratigraphic term Bend group (see Wilmarth, 1938, pp. 158-161), or Bend or Bendian series or system, has been used in geologic literature for a long time to apply to a portion of the lower Pennsylvanian rocks exposed in central Texas. However, the term Bend, or Bendian, has been used in so many different senses and to apply to so many different ages of rocks, both Mississippian and Pennsylvanian, that it seems inadvisable to at-tempt to apply that term to a portion of the New Mexico Pennsylvanian section. However, the term Bend or Bendian apparently is very useful to designate a thick section of rocks around the Central Mineral Region of central Texas.

Of the twelve or thirteen proposed Pennsylvanian series terms discussed above, three of them, Des Moines, Missouri, and Virgil, are being used here for the Pennsylvanian of New Mexico. In addition, the term Derry series is here being proposed for all Pennsylvanian rocks in south central New Mexico which occur in surface exposures below the Des Moines series. Terms for numerous smaller units, such as groups and formations, are also here being proposed for the subdivision of these series. However, since the lithology of the Pennsylvanian of New Mexico varies so markedly geographically, especially in its lower and upper portions, not all lithologic units in New Mexico will be named in this preliminary report.

The accompanying chart (Table II) shows the subdivisions being used in this report for the stratigraphic classification of the Pennsylvanian system of central and southern New Mexico.

DERRY SERIES

The term Derry series is here being proposed for all rocks in the central to the extreme south central areas of New Mexico between the base of the Pennsylvanian system and the basal part

TABLE II
THE PENNSYLVANIAN SYSTEM IN CENTRAL AND SOUTHERN NEW MEXICO

Series	Group	Formations and Members
Virgil	Fresnal	Bruton formation
	Keller	Moya formation
		Del Cuerto formation
Missouri	Hansonburg	Story formation
		Burrego formation
	Veredas	Council Spring limestone
		Adobe formation
		Coane formation
Des Moines	Bolander	
	Armendaris	Garcia formation
		Whiskey Canyon limestone
		Elephant Butte formation — Warmington limestone member
Derry	Mud Springs	Cuchillo Negro formation
		Hot Springs formation
	Green Canyon	Apodaca formation
		Arrey formation

of the Pennsylvanian Des Moines series. The Derry series is named for the little village of Derry in Sierra County, located on U. S. Highway 85, on the flood plain of the Rio Grande near the north end of the Hatch Basin, and just north of the Dona Ana County line. The type locality is on the steep west slope of the hill about three-fourths mile east of the center of Derry, near the center of sec. 32, T. 17 S., R. 4 W.

At no place has the base of the Derry series been examined in New Mexico where it is conformable on older rocks. At the type locality, the Derry unconformably overlies the Devonian Percha shale. Where observations have been made elsewhere, the Derry unconformably overlies rocks of Mississippian Chester, Lake Valley or Kelly age, Devonian age, Cambrian (?) age, or pre-Cambrian age. At all exposures yet observed, the Derry series is overlain by Des Moines sediments, which are being referred below to the Armendaris group. Although the strata of the Derry are essentially parallel with the strata of the lower part of the Des Moines, the faunal break between these two series strongly suggests that they are unconformable. However, there obviously is no great stratigraphic break between the Derry and the Des Moines at any contacts that I have studied in New Mexico.

Pennsylvanian rocks were deposited very widely in North America during Derry time. Sediments of Derry age have been included in the Pottsville series of Pennsylvania and eastern Ohio, in the basal part of the Des Moines series of some areas in the Mid-Continent region; the basal part of the Hartville limestone of Wyoming; the basal part of the Oquirrh formation of the Wasatch Mountains of Utah; the Atoka formation of Oklahoma; most of the Lampasas series as defined by Cheney in Texas; and at least a large portion of the Bend group as now defined in Texas. Rocks of Derry age are widespread outside of North America and are known from many regions, including Japan, China, Mongolia, Russia, the Carnic Alps, Egypt, Spain (?), Spitzbergen (Svaldbard), and Peru (?).

The Derry series of New Mexico is composed largely of marine limestones, shales, conglomerates, and coarse sandstones. However, locally it contains, especially in its lower portion, dark shales, sandstones, and thin coal beds of continental origin. The entire series is slightly more than 130 feet thick at the type locality and is composed of marine limestones, with a few sandstones and shales. South of Powwow Canyon in the Hueco Mountains of Texas, the Derry is slightly over 600 feet thick and there it is composed almost entirely of marine limestones. At Cadronito Hill, northwest of Ladron Peak, the Derry series is about 600 feet thick and is composed largely of marine and non-marine clastics of shales, thin coals, and sandstones.

Rocks of Derry age have been found widespread in New Mexico and they are known to occur from the San Juan Basin of northwestern New Mexico to the Hueco and Franklin mountains of extreme western Texas (see Pl. 1). However, northward and northwestward from extreme southern New Mexico to the region south of Albuquerque, the Derry series overlaps on to pre-Pennsylvanian rocks. Therefore, the lowermost portion of the Derry exposed in New Mexico occurs in the Franklin Mountains at the south side of the State.

The faunas of the Derry are large and varied, and contain abundant brachiopods, corals, crinoids, gastropods, and foraminifera. Also, the dark shales, which occur locally near the base of the series, contain large numbers of plant fossils. Calcareous algae are extremely abundant in association with the marine fauna, and they seem to be highly varied.

Fusulinid foraminifera are extremely abundant in the Derry. Rocks of Derry age can be zoned and correlated very easily over much of New Mexico by the use of fusulinids. The following fusulinid genera have been identified in the Derry series at its type locality: *Millerella, Ozawainella* (?), *Eoschubertella, Profusulinella, Pseudostaffella,* and *Fusulinella.* Sediments here assigned to the Derry series sometimes are referred to as in the "Zone of *Fusulinella."* However, representatives of the genus *Fusulinella* occur only in the uppermost portion of the Derry series. I have before me three representatives of the genus *Fusulinella, as* that genus is now defined, from the uppermost portion of the Des Moines series and therefore the limits of the range of the genus *Fusulinella* alone do not correspond to either stratigraphic limit of the Derry series. However, one closely related group of species of the genus *Fusulinella,* perhaps a subgenus of *Fusulinella,* is confined to a small portion of the upper part of Derry series and constitutes very good index fossils for that part of the section. Certain groups of species of *Profusulinella* and species of *Eoschubertella*, and the associated forms of other genera, designate easily recognizable fusulinid faunal zones for other parts of the Derry series.

The most primitive fusulinids that I have studied from North America were obtained from the Brentwood member of the Bloyd shale of the Morrow group at Hale Mountain, Morrow, Arkansas. Although I have numerous collections that contain abundant fusulinids from Hale Mountain, the variety of forms present is very small, and all of them are biologically extremely primitive. From biological studies, it is suggested that all of the Morrow fusulinids are stratigraphically older than any forms from the Derry series of New Mexico. It seems probable from a study of these fusulinids, however, that the type Morrow is not greatly older stratigraphically than the base of the Derry series in extreme southern New Mexico.

The second most primitive group of fusulinids that I have studied from America is from about 150 feet below the top of the type section of the Marble Falls limestone at Marble Falls, Texas (Thompson, 1942). Some of the fusulinids from the Marble Falls limestone seem to be identical with fusulinids from the basal portion of the Derry series in the Hueco and Franklin Mountains. They suggest a close correlation between the upper portion of Marble Falls limestone and the basal portion of the Derry series. However, it should be pointed out that fusulinids closely similar to those found in the Marble Falls limestone and in the basal portion of the Derry series have stratigraphic ranges much higher. Well above the base of the Derry series these primitive types of fusulinids are associated with primitive forms of the genus *Profusulinella*, a genus more highly developed biologically than any fusulinids found in the type section of the Marble Falls limestone.

With the exception of the two occurrences listed above, and the report by Galloway and Harlton (1928, p. 350) of a fusulinid from the Wapanucka limestone of Oklahoma, no fusulinid is known from America which is as primitive stratigraphically as the fusulinids from the basal portion of the Derry series in southern New Mexico.

The Derry series is here being subdivided into two groups and four formations. Although many smaller lithologic units are recognizable in the Derry series over large areas in New Mexico, it is not considered advisable to subdivide the series into smaller stratigraphic units at this time. The groups and formations here established for subdivisions of the Derry are recognizable over wide areas in central New Mexico, but they vary considerably in thickness and lithology among some localities in this region. This lateral variation is shown clearly in the accompanying illustration (Fig. 2), which includes diagrammatic illustrations of the thickness and general lithology of the Derry series and its subdivisions as they are exposed at the type locality near Derry, on the flanks of Cuchillo Negro Peak in the south end of Mud Springs Mountains, and in Whiskey Canyon in the northern part of Mud Springs Mountains, The descriptions of individual units of the type section of the Derry series taken from field notes, are given below. For comparative purposes concerning the Derry series shown on the accompanying illustration, descriptions of the individual units as exposed on Cuchillo Negro Peak are also given below.

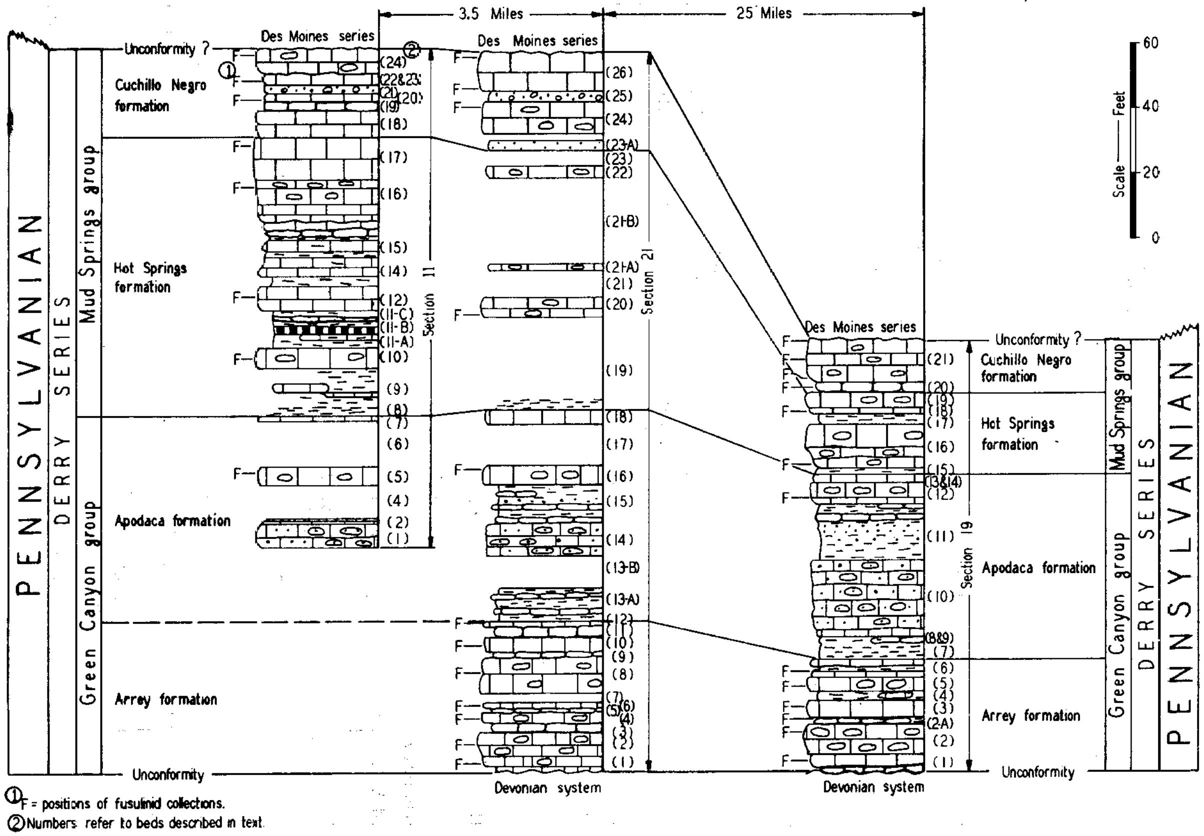


FIGURE 2.-Diagrams of sections of the Derry series.

SECTION 19

Type section of the Derry series, the Green Canyon group, and the two formations of the Green Canyon group; 0.8 mile east of Derry; Sierra County, New Mexico.

Top — Thickness Feet

DERRY SERIES

MUD SPRINGS GROUP

CUCHILLO NEGRO FORMATION ---------- 16.0

21 Limestone; gray to dark gray; fine-grained, dense and hard; fusulinids abundant, especially in lower 8.0 feet; highly cherty throughout; upper 5.0 feet highly algal, dark gray, massive, and contains scattered fusulinids; long fusulinids very abundant in lower 2.0 feet: *Fusulinella* ---------- 13.0

20 Limestone; highly nodular to irregularly bedded; poorly exposed and forms slope; medium gray to gray; contains fusulinids: *Fusulinella, Eoschubertella* ---------- 3.0

HOT SPRINGS FORMATION ---------- 24.0

19 Limestone; medium gray to gray; massively bedded; algal; contains discontinuous layers of gray to dark gray chert ---------- 4.5

18 Limestone; medium to light gray; dense and hard; scatter- ed algae; one bed: *Fusulinella, Pseudostaffella, Millerella* ---------- 2.0

17 Covered. Greenish gray shale shows on slope ---------- 3.0

16 Limestone; dark gray in upper 5.0 feet, lower 8.0 feet light gray; massively bedded in beds up to 1.5 feet; highly fossiliferous; breaks down easily to slope; fusulinids in lower 2.0 feet; thin beds of chert scattered throughout: *Fusulinella Millerella* ---------- 13.0

15 Shale; green to greenish yellow, fissile ---------- 1.5

GREEN CANYON GROUP

APODACA FORMATION ---------- 55.5

14 & 13 Limestone; greenish gray; highly siliceous, dense and hard, lower 1.0 nodular, breaks down into slope ---------- 2.5

12 Limestone; gray to medium gray; dense and hard, massively bedded; highly cherty; chert beds and irregular masses up to 1.0 foot thick; lower 2.0 feet weathers out in slabby beds: *Profusulinella, Millerella*-- 6.5

11 Upper part poorly exposed, limestone and shale showing in places. Middle 5.0 feet sandy shale and sandstone; sandstone yellow. Lower 6.0 feet shale; dark gray to carbonaceous, fissile, with abundant fossils in base ---------- 17.0

10 Limestone or siltstone; argillaceous and micaceous; upper 1.0 foot algal; next 2.0 feet hard and silty; lower 10.0 feet contains nodular lime with wavily bedded, argillaceous siltstone; entire exposure weathers with irregular, thin beds, orange to dark brown on faces of cliff, highly cherty ---------- 20.5

9 & 8 Limestone; argillaceous and silty, interbedded with shale; weathers yellowish ---------- 4.0

7 Shale; bluish gray; fissile, abundant limestone nodules ---------- 5.0

ARREY FORMATION ---------- 32.0

6 Limestone; crinoidal; in beds (irregular) up to 1.0 foot thick, interbedded with highly calcareous and fossiliferous shale;

	shale more common in upper portion: *Millerella, Profusulinella* -----------	5.0
5	Limestone; bluish gray to light gray, one massive bed; abundant concentric masses and irregular beds of chert up to 1.7 feet thick; weathered face of chert appears laminated: *Profusulinella, Millerella* --	3.5
4	Shale; highly calcareous, interbedded with argillaceous limestone; fossiliferous: *Millerella* --	2.5
3	Limestone; gray; fine-grained, dense and hard; massively bedded; upper 1.0 foot and lower 1.0 foot highly nodular; algal throughout: *Millerella, Profusulinella* --	4.5
2-A	Limestone and shale; limestone, irregularly bedded; shale calcareous ----	2.0
2	Limestone; bluish gray; fine-grained, dense and hard; extremely cherty; chert about 15 percent of entire bed; forms lower cliff on scarp; horn corals common: *Millerella* --	9.0
1	Limestone; gray; upper 1.0 foot highly nodular, middle 3.0 feet massively bedded, in beds 1.0 foot thick, lower 1.0 foot highly nodular; fossiliferous throughout: *Millerella, Ozawainella (?)* ----------------------	5.5
	(Note: Base of Bed 1 rests unconformably on Devonian shale.)	

SECTION 21

The Derry series as exposed on the southeast side of Cuchillo Negro Peak, south end of the Mud Springs Mountains; Sierra County, New Mexico.

Top		Thickness Feet
	DERRY SERIES	
	MUD SPRINGS GROUP	
CUCHILLO NEGRO FORMATION --30.0		
26	Limestone; lower 2.0 feet slabby to irregularly bedded; extremely abundant fusulinids in next 3.0 feet, with abundant chert; upper portion contains common fusulinids: *Fusulinella, Pseudostaffella, Eoschubertella, Millerella* ---	12.0
25	Granular conglomerate to coarse sandstone; cross-bedded; very hard; weathers pink to brown ---	3.0
24	Limestone; gray; massively bedded; has beds and biscuit-shaped nodules of chert in lower 4.0 feet; abundant algae in upper 6.0 feet; fusulinids common in upper 4.0 feet: *Fusulinella* ----------------------------	10.0
23-B	Covered --	2.0
23-A	Sandstone; medium to fine-grained; highly micaceous; light gray where freshly exposed, dark brown on weathered surface, red streaks along bedding planes; very highly crossbedded -------------------------------------	3.0
HOT SPRINGS FORMATION --80.0		
23	Covered; apparently shale in lower part --	5.0
22	Limestone; gray; in two massive beds, with 0.5 foot bed of nodular chert between; yellowish discoloration in wavy bands in both massive beds; fossiliferous --	3.5
21-B	Covered; in animal burrowings along slope, dark gray shale shows on surface; mainly limestone on north end of section -----------------------------	27.5

21-A	Limestone; crinoidal; dark gray; thin-bedded; red chert shows on upper surface; beds rather discontinuous, separated by nodular zones ----------	2.0
21	Covered --	8.0
20	Limestone; gray; massive; lower 3.0 feet light gray, with large masses of algae and abundant fusulinids; upper 3.5 feet separated from lower part by 0.1 foot shale, slightly darker than lower portion and highly fossiliferous; upper 1.5 feet of this lower zone slabby limestone, very fossiliferous: *Fusulinella, Profusulinella, Eoschubertella, Millerella* ---	6.5
19	Slope; dark gray shale showing in places, mottled gray and soapy shale in lower 2.0 feet --	27.5

GREEN CANYON GROUP

APODACA FORMATION -- 65.0

18	Limestone; extremely cherty; dense; surface of chert has wavy bands. Immediately overlain by 1.0 foot greenish gray argillaceous siltstone or shale; underlain by 1.0 foot greenish gray, hard shale ----------------------	4.0
17	Covered ---	13.0
16	Limestone; gray; large algal reefs; fusulinids abundant in upper 2.0 feet; cherty throughout; surface very rough: *Profusulinella, Millerella* --------	6.0
15	Shale, silty; alternating with gray limestone; upper portion darker gray and thin-bedded to fissile --	12.0
14	Limestone; medium to dark *gray;* laminated; silty and micaceous, cherty; fossiliferous; dark brown chert weathers out on surface ----------	10.0
13-B	Covered ---	10.0
13-A	Shale; dark gray; silty; alternating with gray nodular to platy limestone - (Note: To the west of the southwest projecting nose of Cuchillo Negro Peak, an igneous sill cuts out portions of Beds 13 and 14, inclusive. The maximum measured thickness of this igneous intrusion is 49.1 feet.)	10.0

ARREY FORMATION --- 47.0

12	Limestone; gray, yellowish on weathering; massive and dense, one single bed; algal; small amount of chert in upper part ----------------------	1.0
11	Limestone; argillaceous; nodular; poorly exposed -----------------------------	3.0
10	Limestone; lower 1.0 foot gray, massive, 10 to 15 percent algae; upper 0.3 foot chert; upper 3.5 feet highly cherty, weathering brown; irregular chert on surface: *Millerella,Ozawainella (?), Profusulinella* --------------	4.5
9	Limestone; nodular; poorly exposed ---	2.0
8	Limestone; gray; massively bedded, lower 5.0 feet dense; algal masses up to two inches in diameter; upper 0.5 foot extremely cherty, with chert in definite zones; upper part of cherty zone very irregular and rough where weathered. *Millerella* --	11.0
7	Covered --	3.0
6	Limestone; gray; massive; fossiliferous, algal ----------------------------------	1.5
5	Limestone; nodular: *Millerella* --	1.5
4	Limestone; gray; massive; approximately 50 percent algae; three prominent lenticular chert bands in lower part, with	

	nodular chert above; horn corals very common: *Millerella,Profusulinella* ---	3.5
3	Limestone; nodular --	3.5
2	Limestone; gray; massively bedded; abundant nodules of chert up to 1.0 foot thick; bedded chert in upper half; common algae in lower part of upper bedded chert zone; highly fossiliferous: *Millerella* ------------------	7.5
1	Limestone; gray; nodular in lower 1.0 foot, massive in next 2.0 feet, nodular in upper portions; top portion has numerous worm borings filled with different material; very fossiliferous; some chert in lower portion; algal: *Millerella* ---	5.0
	(Note: Base of Bed 1 rests unconformably on Devonian shale).	

GREEN CANYON GROUP

The term Green Canyon group is here proposed for the rocks of the two basal formations of the Derry series; in ascending order, Arrey formation and Apodaca formation (Fig. 2). The name is derived from Green Canyon about a half mile north of the village of Derry but the type locality of the group is on the west facing slope of the hill approximately three-fourths mile east of Derry and is the same as the type locality of the Derry series. The thickness, lithology, faunas, geographic distribution, and some other general features of the Green Canyon group will be discussed briefly below under its two formations. However, general descriptions of individual units of the entire group, taken from the type locality, are given above.

ARREY FORMATION

The term Arrey is derived from the small village of Arrey on the west side of the Rio Grande on Highway 85, about 4.5 miles northwest of Derry. However, the type locality of the Arrey formation is on the west-facing slope of the hill about three-fourths mile east of Derry, where the formation is typically ex-posed.

At the type locality, the Arrey formation is composed of dense massive limestones, highly nodular limestones with irregular interbedded highly calcareous shales, and very common irregular masses and lenses of chert. Northward from the type locality the formation is more highly clastic, but southward it is essentially pure limestone. The entire formation is highly fossiliferous, with an abundance of calcareous algae, horn corals, and brachio-pods. Fusulinid foraminifera are also very common in the Arrey formation, but they are all very small and are recognized most easily in thin sections of the limestone. The general lithology, thicknesses of individual beds, and the relationship of these beds from Mud Springs Mountains and from the type locality are shown graphically above (Fig. 2). Brief descriptions of each in-dividual bed of the Arrey formation, taken from field notes, were given on a previous page.

The Arrey formation is widespread in southern New Mexico. However, it is not known with certainty at the surface in the north central portion of the State. Some of the clastic sediments near the base of the Pennsylvanian at Cadronito Hill and other regions of central New Mexico may be equivalent in age to a portion of the Arrey formation at its type locality near Derry. At the type locality, the Arrey formation is 32 feet thick. In the Mud Springs Mountains the formation is about 50 feet thick. To the south of the type locality the formation increases in thickness. On the south side of Powwow Canyon in the Hueco Mountains of extreme western Texas the Arrey formation is more than 300 feet thick. In Powwow Canyon the Arrey is composed almost entirely of essentially pure limestone. However, it is probable that the lowermost part of the Arrey formation as here de-fined in Powwow Canyon is older stratigraphically than the base of the formation at Derry.

Fusulinids found in the Arrey formation include representatives of the following genera: *Millerella, Ozawainella (?), Eoschubertella,* and *Profusulinella.*

APODACA FORMATION

The Apodaca formation is named for Apodaca Creek, a west tributary of the Rio Grande, located about 2.75 miles north by west of Derry. However, the type locality is on the west slope of the hill about three-fourths mile east of Derry, where the formation is typically exposed. At the type locality the Apodaca formation is about 55 feet thick and it increases in thickness to about 65 feet in the Mud Springs Mountains. The formation consists of dense gray limestones with common masses and lenses of chert, nodular limestones, calcareous shales, black to dark gray calcareous siltstones, and greenish to bluish gray shales. In the southern part of the State, the Apodaca formation consists of essentially pure limestones and reaches a total thickness of over 150 feet. Northward from the region of Derry, the Apodaca formation becomes more highly clastic. In the region of the Ladron Mountains it is practically entirely clastic, of shales, highly argillaceous limestones, and sandstones.

The Apodaca formation is highly fossiliferous and contains abundant invertebrate fossils and calcareous algae. Fusulinid foraminifera are also extremely abundant in thin zones through-out the formation and representatives of the following genera have been recognized: *Millerella, Ozawainella (?), Eoschubertella, Pseudostaffella,* and *Profusulinella.*

MUD SPRINGS GROUP

The term Mud Springs group is here proposed for all strata between the top of the Green Canyon group below and the base of the Des Moines series above. The name comes from Mud Springs Mountains north by west of Hot Springs where the group is well exposed in numerous localities throughout the length of the mountains. The type locality is near the north end of the Mud Springs Mountains at the west end of Whiskey Canyon, just west of the westernmost box canyon, in the SW 1/4 sec. 1, T. 13 S., R. 5 W., Sierra County. The lithology and thickness of the Mud Springs group do not vary so markedly geographically as do the lithology and thickness of the underlying Green Canyon group. Also, this portion of the Derry series has been recognized over a much larger area in New Mexico than has the Green Canyon group. However, the maximum thickness of sediments so far measured in New Mexico that are definitely assignable to the Mud Springs group is considerably less than the maximum thickness so far measured for the Green Canyon group.

The general lithology of the Mud Springs group at its type locality and from nearby areas is shown graphically in the accompanying illustration (Fig. 2). The descriptions of individual units of this group at its type locality, taken from field notes, are as follows:

SECTION 11

Type section of the Mud Springs group and its two formations; Whiskey Canyon, northern Mud Springs Mountains; Sierra County, New Mexico.

Top		Thickness Feet
	DERRY SERIES	
	MUD SPRINGS GROUP	
	CUCHILLO NEGRO FORMATION---------- 28.0	
24	Limestone; medium to light gray; dense and hard; massively bedded, beds up to 3.0 feet thick; large nodules and irregular masses of chert common throughout; fusulinids abundant: *Fusulinella, Pseudostaffella, Eoschubertella, Millerella* ----------	8.0
23 & 22	Limestone; gray to medium gray; rather slabby bedded; fusulinids extremely abundant; lower 1.0 foot nodular: *Fusulinella, Pseudostaffella, Eoschubertella, Millerella*----------	3.0
21	Sandstone; coarse-grained to granular; greenish gray; mainly quartz; abundant small white pellets; locally, extremely hard, sub-quartzitic ----	3.5
20	Limestone; brownish gray; very highly algal; fusulinids rather abundant 1.0 foot from top; irregular masses light gray chert abundant in upper portion: *Fusulinella, Pseudostaffella, Eoschubertella, Millerella* --------	2.5
19	Covered; apparently all limestone ----------	3.0
18	Limestone; medium to light gray; dentritic and massive algae present; rather massively bedded; beds 1.0 foot to 1.5 feet thick ----------	8.0
	HOT SPRINGS FORMATION ---------- 85.5	
17	Limestone; gray to light gray; massively bedded to highly nodular, especially in middle portion; beds up to 1.0 foot thick; stained brown along bedding; bed near middle very highly crinoidal; fusulinids very abundant 2.0 feet from base; upper 6.0 feet massively bedded, beds up to 2.5 feet thick; extremely algal in upper 3.0 feet: *Fusulinella, Pseudostaffella, Eoschubertella, Millerella* ----------	13.0

16	Limestone; medium gray to dark gray; evenly bedded; brown to pinkish brown along bedding and in wavy bands in beds; middle 3.0 feet and upper bed highly crinoidal; in beds up to 2.0 feet thick; upper 6.0 feet extremely cherty; fusulinids abundant near top: *Fusulinella*	13.0
15	Limestone; slabby; argillaceous; interbedded with shale; brownish gray; weathers light gray	14.0
14	Limestone; gray to light gray; dense and hard; yellowish tinge; one massive bed	2.5
13	Shale; light gray; contains nodular lime	3.0
12	Limestone; fossiliferous extremely crinoidal; breaks down like sandstone; gray to light gray with brownish spots; fusulinids abundant throughout; massively and evenly bedded in beds up to 1.0 foot thick: *Fusulinella, Eoschubertella,Pseudostaffella, Millerella*	7.0
11-C	Shale, calcareous, interbedded with nodular highly fossiliferous limestone	5.0
11-B	Shale; red; fissile; soft	3.0
11-A	Shale; poorly exposed; interbedded with earthy and highly cherty limestone	5.0
10	Limestone; gray; hard; glistening; massive beds up to 1.6 feet thick; black masses hard chert common in upper portion; fusulinids scattered: *Fusulinella, Eoschubertella, Millerella*	6.0
9	Slope; shale, dark gray showing in places; mottled gray shale in lower part; with limestone poorly exposed	14.0

HOT SPRINGS FORMATION

The term Hot Springs is derived from the town of Hot Springs on the Rio Grande about 3 miles southeast of the south end of the Mud Springs Mountains, Sierra County. The type locality of the formation, however, is in the west end of Whiskey Canyon and just west of the westernmost box canyon, near the north end of Mud Springs Mountains.

At the type locality as here proposed, the Hot Springs formation is composed of dark gray to light gray massive to nodular highly cherty limestone and thick shale beds (see Fig. 2). At least six distinct limestone sequences have been recognized in the type section but faunal evidence indicates that adjacent lime-stone sequences were deposited without obvious interruption. The formation is about 85 feet thick at the type locality and it retains essentially the same thickness over a considerable area in central New Mexico. To the south in the region of Derry, the formation is only about 24 feet thick. However, at Derry the formation is composed almost entirely of limestone. In some areas farther north, the Hot Springs formation overlaps on to the pre-Cambrian and there it contains considerable coarse clastics in its lower portion.

The fauna of the Hot Springs formation is large and varied. Calcareous algae are extremely abundant in some strata of the formation. One of the most abundant elements of the fauna of the formation is the fusulinid foraminifera. Although the fusulinids of the Hot Springs formation have short vertical ranges, they are very widespread geographically and have been observed at various localities over an area from Silver City on the south-west, Cadronito Hill on the west, the Hueco Mountains on the south, Oscura Mountains on the east, and questionably from the Jemez Mountains on the north. The following fusulinid genera have been observed in the Hot Springs formation in the Mud Springs Mountains : *Millerella, Ozawainella (?), Eoschubertella, Pseudostaffella,* and *Fusulinella.*

CUCHILLO NEGRO FORMATION

The name Cuchillo Negro formation is here being proposed for all strata between the top of the Mud Springs formation below and the base of the Des Moines series above. The name was derived from Cuchillo Negro Peak where the formation is well exposed in the south end of the Mud Springs Mountains. How-ever, the type locality of the formation is near the west end of Whiskey Canyon in the north part of Mud Springs Mountains and just west of the westernmost box canyon, in the southwest part of sec. 1, T. 13 S., R. 5 W. At the type locality the formation is about 28 feet thick and it is composed almost entirely of medium to light gray, massive to nodular, cherty limestone. Calcareous algae are extremely abundant in some portions of the formation and make up more than 50 percent of some strata. Two thin beds of greenish to brownish coarse-grained sandstones to granule conglomerates occur in the lower portion of the formation in some areas of the Mud Springs Mountains. One of these sand-stones occurs at the base and the other occurs about 15 feet above the base of the formation.

The fauna of the Cuchillo Negro formation at its type locality is typical for the formation over much of central New Mexico. The mega-fauna is closely similar to that in the underlying Mud Springs formation and is composed of a large variety of fossils including many brachiopods, corals, bryozoans, crinoids, and gastropods. Fusulinid foraminifera are very abundant in almost all portions of the formation and the species occur wide-spread in New Mexico. Fusulinid species that have been found to be good index fossils for different parts of the Cuchillo Negro formation have been recognized from surface outcrops as far north in New Mexico as the Jemez Mountains. The following fusulinid genera have been identified from the type locality of the formation: *Millerella, Eoschubertella, Pseudostaffella,* and *Fusulinella.*

DES MOINES SERIES

The stratigraphic term Des Moines was originally proposed by Keyes (1893, p. 85) for a formation to include all Pennsylvanian ("Upper Carboniforous") rocks that outcrop for "more than 200 miles" along the Des Moines River Valley of central Iowa, and which occur stratigraphically between the top of the

Mississippian system and the base of the Missouri series of the Pennsylvanian. The Des Moines was later raised to the rank of a series (see Moore, 1936, p. 51) to include essentially the same portion of the stratigraphic section for which it was originally proposed by Keyes. However, the stratigraphic interpretation of the basal portion of the Missouri, and therefore the upper portion of the Des Moines, has been revised in the Mid-Continent area several times since Keyes' report, to conform to later and more nearly complete stratigraphic information. As the Des Moines series is now defined in the Des Moines River Valley, it includes all rocks in that area between the base of the Pennsylvanian and the base of the Missouri series. Stratigraphically, the oldest fusulinid known from the Des Moines series along the Des Moines River Valley is *Fusulinella iowensis* Thompson from an unnamed limestone only about 20 feet above the base of the Pennsylvanian in Jefferson County, Iowa (see Thompson, 1934, p. 297) . This is a highly developed form of the genus *Fusulinella,* and it is associated with a very primitive form of the genus *Fusulina.* Both of these forms are very closely similar to forms found in New Mexico in the basal part of the sediments here referred to the Des Moines series. It therefore seems to me that the base of the Des Moines as here defined in New Mexico is of essentially the same age as the base of the type Des Moines series in the Des Moines River Valley of Jefferson County, Iowa.

All Pennsylvanian sediments in New Mexico between the top of the Cuchillo Negro formation of the Derry series and the base of the Coane formation of the Missouri series are here being referred to the Des Moines series. Rocks of Des Moines age are the most widespread geographically of any of the Pennsylvanian of the State. Des Moines sediments are known from the surface at numerous localities from north central New Mexico to the Hueco Mountains of western Texas, and as far southwest as the area of Silver City. Rocks of this age are also known from the subsurface as far northwest as the San Juan Basin in the north-west corner of New Mexico. The Des Moines as here defined may well be referred to as the "Zone of *Fusulina,"* for the oldest known representatives of the fusulinid genus *Fusulina* occurs in the basal part of the Des Moines series and forms of this genus are last known from the uppermost part of the series.

The strata at the base of the Des Moines series are essentially parallel to the strata at the top of the underlying Derry series. However, faunal evidence indicates that the two series are separated by an unconformity of small magnitude. Also, the strata of the upper part of the Des Moines series are essentially parallel with the lower strata of the overlying Missouri series. The faunal evidence shows clearly that these two series are separated by an unconformity of considerable magnitude. Physical evidence also supports the faunal evidence of this latter stratigraphic break, for reworked Des Moines fusulinids are found in the basal clastic beds of the overlying Missouri sediments. However, paleontological data, especially of the fusulinids, show clearly that the strata immediately above and below the Des Moines-Missouri contact in New Mexico are of essentially the same stratigraphic age as the strata immediately above and below this contact in Iowa, Kansas, Oklahoma, and many other areas of North America.

Des Moines rocks of central and southern New Mexico are largely of marine origin. They are composed of highly cherty limestone, with a subordinate amount of highly nodular and argillaceous limestone, a few thin shales, and arkosic sandstones. How-ever, in north central New Mexico the Des Moines rocks are composed almost entirely of clastics of arkosic sandstones and conglomerates, dark shales, and highly argillaceous limestones. In the region of the Sacramento Mountains near the Pedernal Land Mass the Des Moines contains considerable clastics, apparently of deltaic to non-marine origins. The thickness of the series varies markedly among some localities. In the north end of the Oscura Mountains, the total thickness of the series is only 320 feet. In the south end of the Oscura Mountains near Mocking Bird Gap, the series is slightly more than 550 feet thick. In the Mud Springs Mountains and on Cadronito Hill the series is slightly more than 800 feet thick. The total thickness of the Des Moines series exceeds 3,500 feet in the Sangre de Cristo Range of north central New Mexico.

The Des Moines of central and southern New Mexico is here being divided into the Armendaris group below and the Bolander group above. The Armendaris group is being subdivided into three widespread and easily recognizable formations, in ascending order, Elephant Butte formation, Whiskey Canyon limestone, and Garcia formation. One limestone member has been recognized in the Elephant Butte formation. The Sandia formation of the area near Albuquerque is also referable to the Armendaris group.

Although several widespread lithologic units have been observed that are easily recognizable in the Bolander group, I am not subdividing the group into smaller stratigraphic units at this time.

ARMENDARIS GROUP

The term Armendaris group is here being proposed for all rocks between the top of the Derry series below and the base of the Bolander group above. The name is derived from the large Armendaris Grant to the east and northeast of Hot Springs. However, the type locality is in the north end of the Mud Springs Mountains in the west end of Whiskey Canyon, in and on either side of the westernmost box canyon in the southwest part of sec. 1, T. 13 S., R. 5 W.

At the type locality the group is about 457 feet thick. It is entirely of marine origin and is composed very largely of gray to light gray cherty limestone, with a few thin shale and sand-stone beds scattered throughout. This group is very widespread geographically in New Mexico and is known from all large areas of outcrop of Pennsylvanian sediments in the State. The group is also known from deep wells drilled in the extreme northwest corner of New Mexico. The general lithology of the Armendaris group at the type locality is shown graphically in the accompanying illustrations (Figs. 3 and 4). The general descriptions of the individual units of the group at the type locality, taken from field notes, is as follows :

SECTION 11

Type section of the Armendaris group and its three formations; Whiskey Canyon, Northern Mud Springs Mountains; Sierra County, New Mexico.

Top		Thickness Feet
	DES MOINES SERIES	
	ARMENDARIS GROUP	
GARCIA FORMATION	-- 212.7	
90	Limestone; light gray, brown to lavender where freshly exposed; prominent nodules of chert --	2.0
89	Limestone; light gray, lavender to brown along joints and fractures; dense and hard; contains abundance of horn corals in lower 3.0 feet and upper 2.0 feet; fusulinids --------------------------------	8.0
88	Limestone; light gray, brownish mottling; poorly exposed; fusulinids common in upper part: *Fusulina, Millerella, Eoschubertella, Pseudostaffella* --	2.0
87	Limestone; argillaceous; fine-grained; light gray to lavender; brittle; breaks down to slope; nodular with shale interbedded ----------------------	12.0
86	Limestone; coarse-grained and crinoidal; weathers speckled brown, light gray to gray; fusulinids present; in two main beds with thin nodular beds between --	3.0
85	Limestone; irregularly bedded to nodular; poorly exposed -------------------	2.0
84	Limestone; medium to light gray; fine-grained, dense and hard; lower 6.0 feet one massive bed; fossiliferous; next 3.0 feet irregularly bedded; next 8.0 feet one massive bed; upper 6.0 feet appears sandy where weathered; fusulinids in uppermost part: *Eoschubertella, Wedekindellina, Fusulina* --	23.0
83	Limestone; medium to light gray; nodular to irregularly bedded; fossiliferous; upper portion shaly ---	6.0
82	Shale; light yellowish gray in lower 2.0 feet, reddish brown in next 3.0 feet; weathered; uppermost part is light brown --------------------------------	8.0
81	Limestone; light yellowish gray to lavender; appears argillaceous; nodular; weathers to rounded, spalled surfaces; upper part interbedded with light yellowish hard shale ---	29.0
80	Limestone; highly nodular; argillaceous; interbedded with gray calcareous shale; all extremely fossiliferous --------------------------------	22.0
79	Limestone; light gray, purplish mottling; upper 2.0 feet highly crinoidal; thin zones dark gray chert near base; algae abundant in upper 2.0 feet --	5.0

78	Shale; light greenish gray, purplish brown mottling along joints; thin zones of chert	2.0
77	Limestone; light gray, with purplish red mottling; dense and hard, fine-grained; upper part weathers reddish brown	2.0
76	Limestone; highly nodular, interbedded with calcareous shale; poorly exposed	6.0
75	Limestone; light gray, purplish tinge; nodular to nodular beds in lower 11.0 feet; cherty and algal in upper part; lower nodular part brittle and interbedded with hard light gray shale; chert in upper 4.0 feet, in irregular masses up to 0.5 foot in diameter	15.0
74	Limestone; medium to dark gray; fossiliferous; fine-grained, dense and hard; lower 5.0 feet has lenticular beds up to 2.0 feet thick; upper part one massive bed; fusulinids rare; prominent zone chert 1.5 feet from top: *Fusulina, Wedekindellina*	16.0
73	Limestone; highly algal; extremely and loosely nodular, interspersed light greenish gray highly calcareous shale; nodules up to 0.1 foot in diameter	2.5
72	Limestone; fine-grained, dense and hard; light gray, with slight purplish tinge; two massive beds; chert abundant in upper part; highly algal	4.5
71	Shale; gray, weathers light gray; thin-bedded to fissile	5.0
70	Shale; medium to dark gray; thin-bedded and fissile, blocky in fresh exposures; contains alternating zones of finely crystalline, dense and hard limestone nodules; reddish to purple along vertical joints	17.0
69	Limestone; medium gray; dense and hard; crystalline; highly crinoidal; beds up to 2.0 feet thick; nodules and thin beds of porous chert weather out on surface	6.0
68	Limestone; medium gray; fine-grained, dense and hard; highly nodular; beds up to 0.8 foot thick, alternating with 1.0 foot beds of shale, light gray to greenish yellow, containing small nodules of limestone	4.0
67	Shale; silty and micaceous; light greenish gray, purplish stains along joints	1.0
66	Limestone; medium gray; coarse-grained; fossiliferous; one solid bed	0.7
65	Shale; greenish gray to yellow; poorly exposed	4.0
64	Conglomerate; coarse sand to granules; dense and hard; largely quartz and small limestone granules up to 0.1 foot in diameter, with white inclusions suggestive of weathered feldspar crystals; grayish brown where fresh, dark brown where weathered	5.0
WHISKEY CANYON LIMESTONE		162.8
63	Limestone; fine-grained, dense and hard in upper part; light gray; lower 2.0 feet largely crinoid stems and thin-bedded; upper surface finely cherty and red from adhering patches of sand; algae	8.0
62	Limestone; approximately 75 percent algae; lower 2.0 feet nodular; easily broken down; irregular chert abundant among algal masses	10.0
61	Limestone; medium to light gray, purple on fresh surfaces; highly fossiliferous; slabby beds; chert in irregular beds throughout; limestone beds up to 2.0 feet thick; weathered	

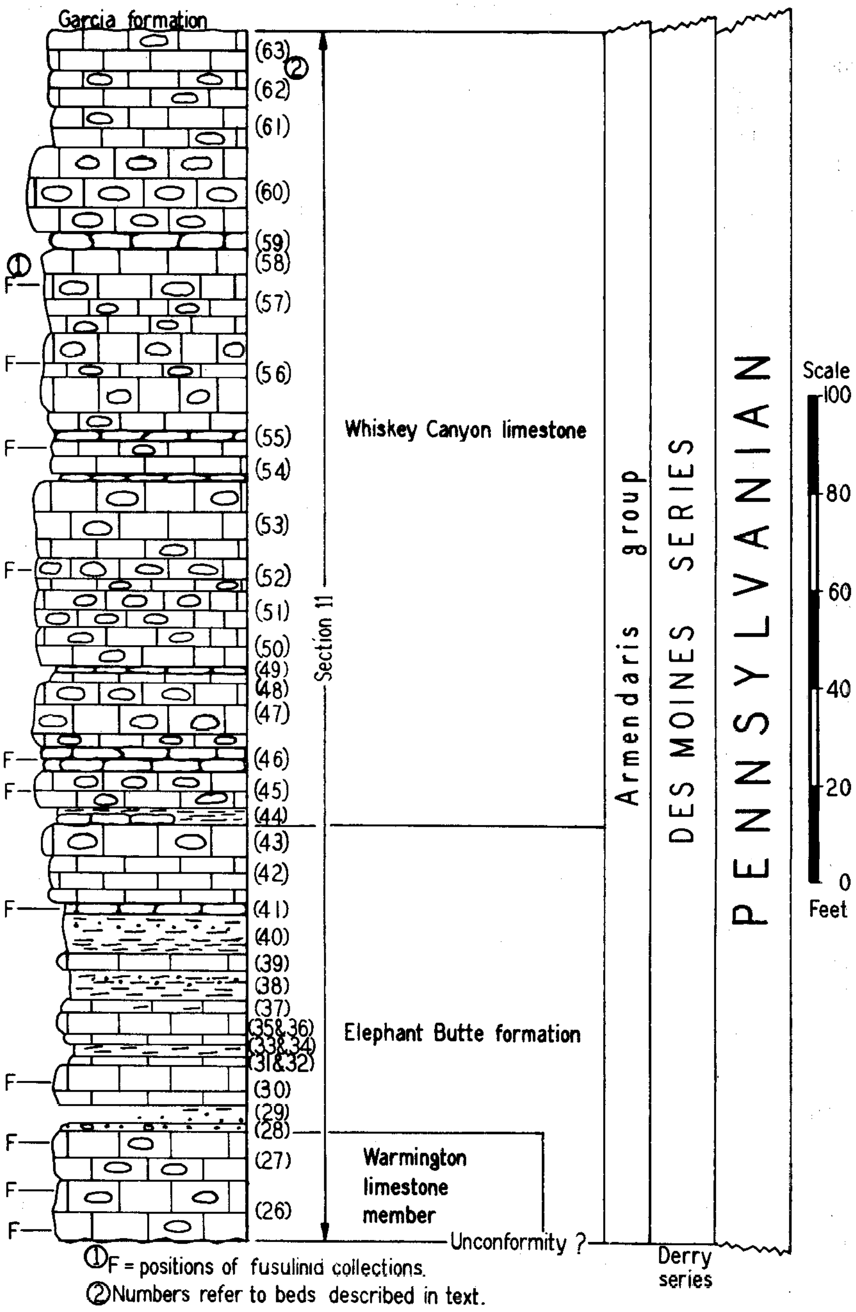


FIGURE 3.-Diagram of the lower two formations of the Armendaris group.

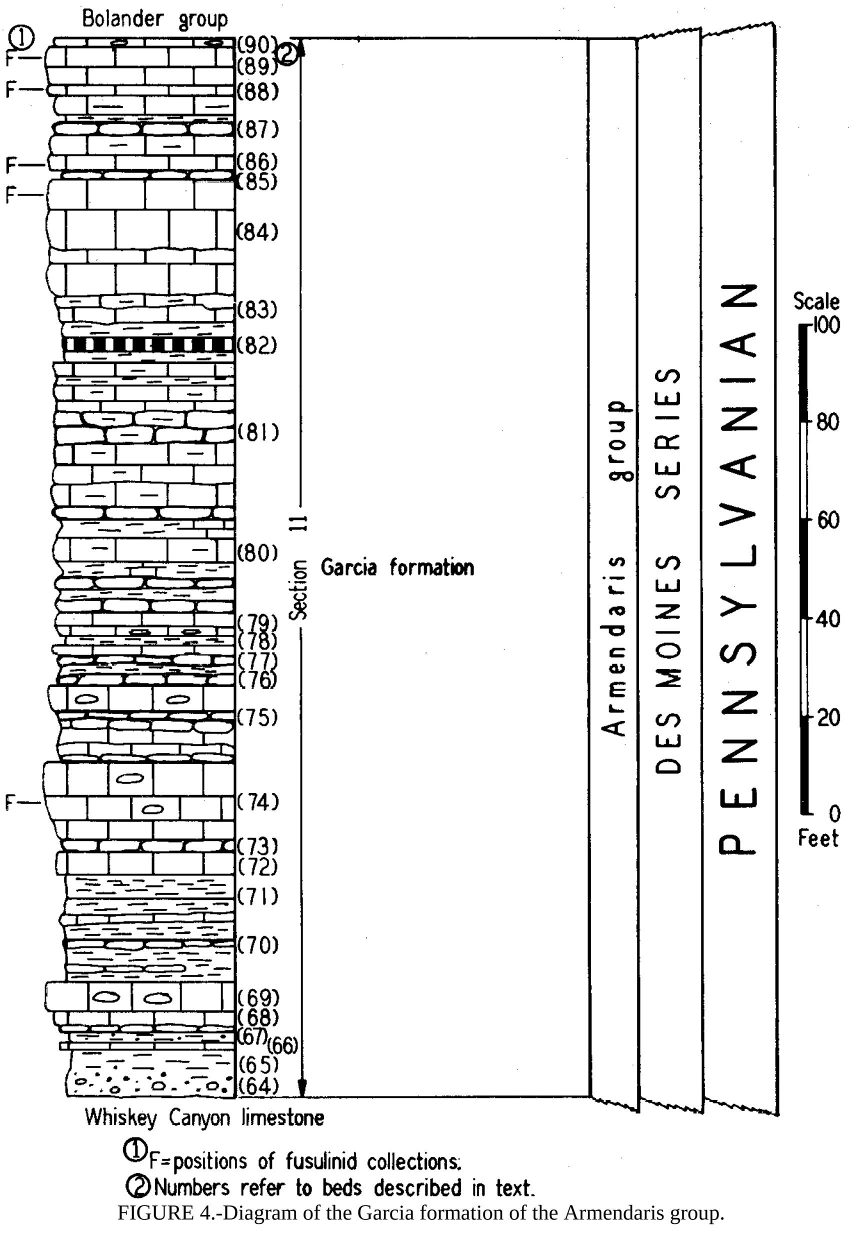


FIGURE 4.-Diagram of the Garcia formation of the Armendaris group.

	surfaces appear sandy; largely crinoidal near middle part; brachiopods and bryozoans abundant throughout	8.0
60	Limestone; extremely cherty, chert beds and nodular masses up to 2.0 feet thick; cliff faces largely covered by chert; cliff-forming; upper 12.0 feet highly algal	17.0
59	Limestone; nodular to bedded; alternates with thin layers of hard shale	3.0
58	Limestone; medium gray; weathers with a sandy appearing surface; common chert, which is sandy in appearance and weathers out with lenticular and banded surface; crossbedded (elastic?)	4.5
57	Limestone; algal; light gray; coarse to fine-grained; nodular to massive; highly cherty, chert in discontinuous bands; highly crinoidal near middle part; fusulinids extremely abundant 2.0 feet from top; upper 3.0 feet slabby and hard: *Millerella, Eoschubertella, Fusulina, Wedekindellina, Pseudostaffella*	12.0
56	Limestone; medium gray; coarse-grained; lower 7.0 feet one massive bed, followed in order by beds of 1.0 foot, 2.0 feet, and 6.0 feet; upper portion of each bed is algal; lower bed contains two prominent zones of lenticular chert; prominent bands of discontinuous and nodular chert in upper 9.0 feet, becoming more abundant in upper 3.0 feet: *Fusulina, Wedekindellina, Eoschubertella, Pseudostaffella, Millerella*	16.0
55	Limestone; medium to light gray; evenly and massively bedded; alternates with shaly and nodular limestone up to 0.2 foot thick; limestone beds up to 5.0 feet thick; fusulinids common in lower portion; chert present in several discontinuous nodular beds; algae rather common: *Fusulina,Wedekindellina*	9.0
54	Limestone; medium gray; massively bedded; highly algal; nodular beds chert up to 1.0 foot thick throughout; lower 1.0 foot nodular and easily weathered; upper 4.0 feet one massive bed	5.0
53	Limestone; light *gray;* hard; purplish to brownish on fresh surfaces, weathers to light purple along bedding planes; algae abundant in upper 10.0 feet; biscuit-shaped and irregular masses of chert common throughout but abundant in middle 5.0 feet; abundant bryozoans in lower 6.0 feet	16.0
52	Limestone; medium gray; appears lenticular on weathered edges; bands of dark brown chert 0.3 foot thick common in upper 3.0 feet; fusulinids abundant in upper 3.0 feet; *Wedekindellina, Eoschubertella, Millerella, Fusulina*	6.6
51	Limestone; highly algal; light gray, brownish to purplish on fresh surfaces; algal masses as large as four inches in diameter; common dark brown chert weathers out on surface; chert in irregular dendritic to porous masses; algae approximately 50 percent of rock	7.0
50	Limestone; medium to light gray, purplish to brownish on fresh surfaces; algal masses abundant in upper 5.0 feet; dense and hard; thin wavy beds of chert in lower 3.0 feet with nodules and beds of chert in upper part	8.0
49	Limestone; finely nodular; reentrant under cliff	1.4
48	Limestone; gray, mottled; fossiliferous; weathers with finely sandy appearing surface; one massive bed; bryozoans and brachiopods abundant; irregular and dendritic chert common on surface	2.8

47	Limestone; medium-grained; highly algal; highly cherty, chert in large nodules and irregular beds up to 1.0 foot thick, chert extremely abundant in upper 3.0 or 4.0 feet	13.0
46	Limestone; medium to light gray; dendritic algae common; nodular-bedded but forms cliff; scattered large fusulinids; large reefs *Chaetetes: Fusulina, Wedekindellina*	5.0
45	Limestone; brown to purplish, weathers brown; fusulinids rather common 3.0 feet from base; beds up to 2.0 feet thick; extremely hard, apparently silicified; nodular beds of chert up to 0.5 foot thick near top: *Fusulina, Pseudostaffella, Millerella*	7.5
44	Limestone; brownish to purplish gray; highly nodular, interbedded shale; forms reentrant under cliff	3.0
ELEPHANT BUTTE FORMATION		81.5
43	Limestone; light gray; massively bedded, in beds up to 4.0 feet thick; cherty, chert weathers on surface as dendritic to wavy beds; surface dark brown; highly algal throughout	6.0
42	Limestone; light gray to brownish, prominent red and yellow mottling; brittle; appears finely sandy	7.0
41	Limestone; basal 1.0 foot nodular, upper part massively bedded; algal and cherty in upper 3.5 feet; fusulinids abundant in lower nodular fades: *Fusulina*	4.5
40	Shale; light gray; thin-bedded; badly weathered; micaceous	8.0
39	Limestone; thin-bedded, nodular in middle part; highly algal in upper portion	3.0
38	Shale; light gray; silty; badly weathered; laminated	6.0
37	Limestone; gray; argillaceous; weathers yellowish	2.0
36	Limestone; medium to light gray; fossiliferous; massively bedded; weathers yellow to purplish brown; productids common	2.0
35	Limestone; gray; fossiliferous; dense and hard	2.0
34	Limestone; weathers light gray, yellowish and brownish on fresh surfaces	2.0
33	Shale; light gray; poorly exposed	2.0
32 & 31	Limestone; slabby; highly fossiliferous	2.0
30	Limestone; light gray with a slight purplish tinge; fine-grained, dense and hard; massively bedded, in beds up to 2.0 feet thick; algae common; fusulinids rather scattered; middle 3.0 feet highly crinoidal: *Millerella, Fusulina*	8.0
29	Mainly covered; shale and sandstone on slope	4.0
28	Conglomerate; pebbles to large granules; dark reddish; sub-quartzitic	1.0
Warmington limestone member		22.0
27	Limestone; light gray; highly fossiliferous and algal; small masses of chert scattered throughout; beds up to 2.0 feet thick; *Chaetetes* abundant in upper part; upper surface red-dish brown; sand grains sticking on upper surface: *Fusulina, Fusulinella*	10.0
26 & 25	Limestone; medium to light gray; massive to nodular; highly cherty; chert in wavy beds; lower 1.0 foot purplish on fresh exposures and breaks down into slope; crinoid stems abundant in upper 2.0 feet: *Fusulina, Fusulinella*	12.0

ELEPHANT BUTTE FORMATION

The term Elephant Butte formation is here proposed for all rocks between the top of the Derry series and the base of the heavy Des Moines limestone, named the Whiskey Canyon lime-stone below. The name is derived from Elephant Butte, in the Rio Grande Valley at Elephant Butte Dam, almost exactly seven miles due east of the south end of the Mud Springs Mountains. The type locality, however, is in the west end of Whiskey Can-yon, in the north portion of the Mud Springs Mountains, just west of the westernmost box canyon, in the southwest part of sec. 1, T. 13 S., R. 5 W.

The stratigraphic position, subdivisions, general lithology, and thickness of the Elephant Butte formation are shown graphically in the accompanying illustration (Fig. 3), and the general descriptions of individual units at the type locality are given above. The Elephant Butte formation is composed largely of limestone, with one thin bed of conglomeratic sandstone about 22 feet above the base, and several beds of calcareous gray silty and micaceous shale near the middle. At the type locality the formation is about 82 feet thick.

The middle and upper parts of the Elephant Butte formation break down easily into slope. The overlying Whiskey Can-yon limestone is highly resistant and therefore the Elephant Butte occurs as covered slope below cliffs of Whiskey Canyon limestone on most mountain slopes. However, the lower part of the Elephant Butte formation is dense gray limestone. This formation is easily recognizable lithologically and contains a characteristic fusulinid fauna. This lower limestone unit is here named the Warmington limestone member of the Elephant Butte formation.

The Elephant Butte formation occurs widespread in New Mexico. It has been recognized from north of the Sandia Mountains to the Franklin Mountains in the southern part of the State.

The fauna of the Elephant Butte formation is large and varied. Calcareous algae are also abundant in all of the larger limestone sequences in the formation. Abundant free mega-fossils occur in many of the slabby and argillaceous limestones and nodular shales. Fusulinid foraminifera are extremely abundant in many of the limestones and calcareous shales throughout the formation, and the following genera have been identified: *Millerella*, *Eoschubertella*, *Fusulinella*, *Fusulina*, and *Wedekindellina*. The species of *Fusulina* found in this formation biologically are among the most primitive representatives of that genus known from North America. These species occur widespread geographically in New Mexico but they all have short vertical ranges. Although a very primitive species referable to the genus *Wedekindellina* has been observed in the Elephant Butte formation at Derry, no species of *Wedekindellina* has been observed in the type section.

Warmington limestone member.—The name Warmington limestone member is here being proposed for the basal 22 feet of the Elephant Butte formation. This member is composed of medium gray to light gray dense and cherty limestone. It has been traced over much of central New Mexico. This lithologic unit contains a distinctive fusulinid fauna, which has been recognized over large areas of New Mexico.

The term Warmington is derived from the little village of Warmington in the Rio Grande Valley south of Caballo Dam. However, the type locality of the member is the same as the type locality of the Elephant Butte formation and is located in the western end of Whiskey Canyon in the northern portion of the Mud Springs Mountains.

The general lithology, thickness, and position of the Warmington limestone member are shown graphically in the accompanying illustration (Fig. 3) and descriptions of its individual units are given on preceding pages.

The fusulinid fauna of the Warmington limestone contains the oldest definite representative of the genus *Fusulina known* from the Pennsylvanian in New Mexico. In addition to *Fusulina,* the faunas of the Warmington member contain representatives of the fusulinid genera *Pseudostaffella, Eoschubertella, Millerella,* and *Fusulinella.* However, the Warmington species of *Fusulinella* are among the most highly developed forms of that genus known from New Mexico.

SANDIA FORMATION

The term Sandia was originally proposed by Herrick (1900) for the lower part of the Pennsylvanian rocks in the Sandia Mountains. However, Herrick did not clearly define the limits of the formation at that time. Keyes later (1903, 1905) re-defined the Sandia to include only the lower sandstones and conglomerates of the Pennsylvanian in the Sandia Mountains. Some geologists (Gordon, 1907) have placed in the Sandia formation the lower 500 to 700 feet of Pennsylvanian in the Rio Grande Valley; here, however, the lower 500 to 700 feet of Pennsylvanian rocks include all rocks of Derry age and a part of the rocks of Des Moines age.

In the Sandia Mountains, the Sandia formation as here interpreted corresponds in age to the lower part of type section of the Armendaris group. The fauna in the uppermost arenaceous beds of the Sandia corresponds in age almost exactly with the fauna in the lower part of the type section of the Elephant Butte formation. The Sandia is about 127 feet thick in the north end of the Sandia Mountains and is composed largely of cross-bedded sandstone and arenaceous to highly calcareous shales and highly argillaceous and arenaceous dark gray to black limestone.

The Sandia formation is confined to the general region of the Sandia Mountains. South of the Sandia Mountains, the Sandia sandstones and arenaceous beds change laterally into the lower limestones of the Elephant Butte formation. Northward from the Sandia Mountains, the Sandia formation overlaps against the pre-Cambrian.

WHISKEY CANYON LIMESTONE

The term Whiskey Canyon limestone is here proposed for the massive bluish gray to gray cherty limestones of the lower part of the Des Moines series, between the top of the Elephant Butte formation below and the base of the Garcia formation above. This limestone is the most prominent of the lithologic units near the base of the Pennsylvanian system in central New Mexico. It forms many of the prominent limestone cliffs of the mountain ranges of this region. The limestone is massive and resistant practically throughout, and contains several thick zones of light gray chert near its base, and scattered masses and lenses of chert in its lower and upper portions. The type section of the limestone is about 163 feet thick.

The name is derived from Whiskey Canyon in the north end of the Mud Springs Mountains where the formation is typically exposed. The type locality is in the westernmost box canyon of Whiskey Canyon, in the southwest part of sec. 1, T. 13 S., R. 5 W. The stratigraphic position, general lithology and thickness of the Whiskey Canyon limestone are shown graphically in the accompanying illustration (Fig. 3), and a general description of the individual units of the limestone, taken from field notes is given above.

The Whiskey Canyon limestone is widespread in central and southern New Mexico and it is well developed from the Nacimiento Mountains on the north to the Franklin Mountains on the south. The fauna of the Whiskey Canyon limestone is large and varied. However, due largely to the resistant nature of the formation, few mega-fossils have so far been collected and studied from the type locality.

Fusulinid foraminifera are extremely abundant in many zones throughout the Whiskey Canyon limestone and some of the species have been recognized over large areas in New Mexico. The following fusulinid genera have been recognized from the type section: *Millerella, Eoschubertella, Pseudostaffella, Wedekindellina,* and *Fusulina.*

GARCIA FORMATION

The name Garcia formation is here introduced for all sediments between the top of the Whiskey Canyon limestone below and the base of the Bolander group above. The term Garcia is derived from the Garcia Road, four to five miles west of the Mud Springs Mountains. However, the type locality of the formation is just to the east of the westernmost box canyon of Whiskey Canyon in the northern part of the Mud Springs Mountains. At the type locality the formation is exceedingly well exposed. The type section is composed of about 213 feet of rocks, including essentially pure highly fossiliferous limestone, argillaceous to slightly arenaceous and cherty limestones, several thin gray to red shales, and a 50 foot bed of highly conglomeratic sandstone at its base. The formation is widespread in New Mexico. How-ever, it varies considerably lithologically among some localities. The Garcia formation has been recognized in many of the mountain ranges of central New Mexico.

The general lithology and the thickness of the Garcia formation are shown graphically in the accompanying illustration (Fig. 4) and the lithology and thickness of the individual units, taken from field notes, are given on preceding pages.

The fauna of the Garcia is large and varied and it is very typical of the fauna of the middle part of the Des Moines series in North America. This is especially true of the fusulinid fauna. The formation contains biologically highly developed representatives of the genus *Wedekindellina* and biologically intermediate forms of the genus *Fusulina.* Forms closely similar, and probably closely related in age to the fusulinid species of the type section of the Garcia formation are in our collections from the Des Moines series of Arizona, Utah, Colorado, Wyoming, Iowa, Kansas, Oklahoma, and Texas. Therefore, rocks corresponding in age to the Garcia formation are apparently widespread in North America. The following genera of fusulinids have been identified from the Garcia formation: *Wedekindellina* and *Fusulina.*

BOLANDER GROUP

The name Bolander is here proposed for the group of rocks of the upper portion of the Des Moines series between the top of the Armendaris group below and the base of the Missouri series above. Although many widespread individual lithologic units, as well as faunal units, have been recognized in the Bolander group in New Mexico, it does not seem advisable to subdivide the group into smaller stratigraphic units at this time. The name Bolander is derived from the small deserted village of Bolander, about 8 miles northeast of the Mud Springs Mountains. However, the type locality of the group is just west of the large box canyon in the central part of Whiskey Canyon in the north portion of the Mud Springs Mountains, in the south central part of sec. 1, T. 13 S., R. 5 W.

At the type locality, the group is about 233 feet thick. The type section is composed largely of gray to light gray fossiliferous limestone, several beds of fossiliferous gray shale, and one well developed bed of conglomerate to highly conglomeratic sandstone about 70 feet below the top of the group. The general lithology and thickness of the Bolander group are shown diagrammatically in the accompanying illustration (Fig. 5) and the general lithology and thicknesses of the individual units of the group, as exposed at the type locality in Whiskey Canyon, are as follows:

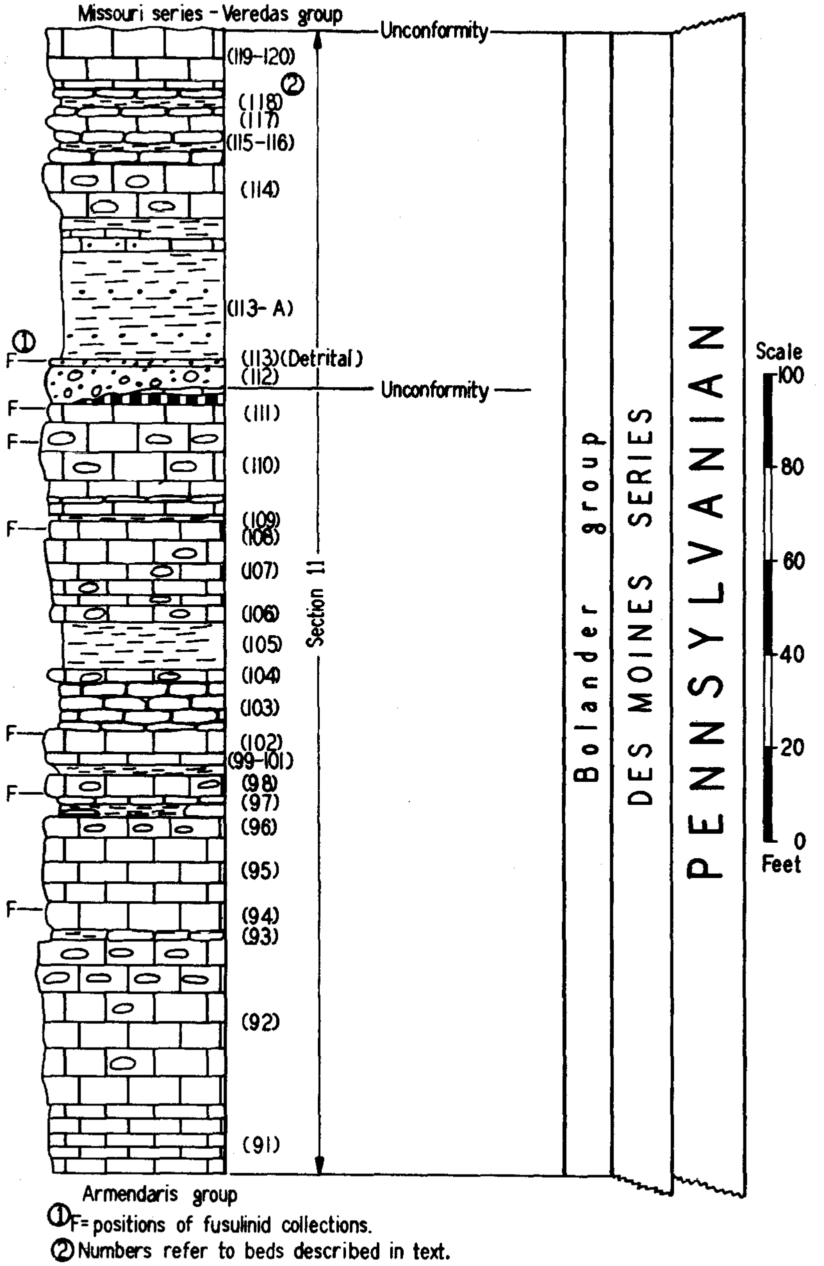


FIGURE 5.-Diagram of the Bolander group.

SECTION 11

Type section of the Bolander group; Whiskey Canyon, northern Mud Springs Mountains; Sierra County, New Mexico.

Top		Thickness Feet
	DES MOINES SERIES	
	BOLANDER GROUP	
120 & 119	Limestone; medium to light gray; alternating gray and light gray ledges; massive beds up to 1.5 feet thick; weathers light yellowish gray ---------	13.0
118	Limestone; bluish gray; nodular; interbedded with light gray shale -------	6.0
117	Limestone; bluish gray; medium-grained, dense and hard; one massive bed --	2.5
116 & 115	Limestone; highly nodular, interbedded with light gray poorly exposed shale --	7.0
114	Limestone; gray, slight brownish tinge; irregular beds up to 1.0 foot thick; algal toward top; nodules and irregular masses chert throughout; abundant porous chert masses on upper surface ----------------------------	11.0
113-A	Shale; slightly silty; contains thin irregular beds of argillaceous limestone in upper part; shale alternating greenish yellow to purplish on weathered faces; original color unknown ------------------------------------	30.0
113	Limestone or conglomerate; very sandy; with coarse quartz sand and small chert pebbles scattered throughout; abundant detrital fusulinids: *Fusulina* (detrital) ---	1.0
112	Conglomerate; pebbles to coarse sand; pebbles up to 1.5 inches in diameter, composed of chert and limestone; chert pebbles well rounded; limestone sub-rounded; grades upward into coarse-grained sandstone; contains detrital fusulinids; thin beds scattered throughout which are limestone conglomerate that appears to be of an edgewise type, with pebbles 6 to 8 inches in width --	8.0
	(Note: Four feet of red shale and an overlying 1.0 foot bed of limestone occur locally between Bed 111 and Bed 112, strongly indicating a physical unconformity at this position.)	
111	Limestone; colored line Bed 110: *Fusulina* ----------------------------------	4.0
110	Limestone; light gray; fine-grained and hard; brownish to purplish on fresh surfaces; alternating irregular beds approximately 1.0 foot thick with 0.1 foot zones nodular lime-stone interbedded in lavender colored shale; lower ledge has abundant bryozoans; dark brown chert covers faces of cliff where exposed and weathered; upper 12.0 feet more massively bedded; fusulinids scattered in upper portion: *Fusulina,Eoschubertella, Millerella* --	20.0
109	Shale; light bluish gray to greenish gray; thin-bedded and soft; purple stains on bedding planes --	1.0
108	Limestone; light gray; granular; highly fossiliferous; weathers like sand; discoidal and fusiform fusulinids scattered: *Fusulina, Ozawainella (?)* ---	4.0
107	Limestone; light gray; fine-grained, dense, glistening; slight purplish tinge on fresh surfaces; cherty, chert weathering out on surface as thin irregular masses; thinly	

	and evenly bedded except for upper 2.0 feet, which form one bed; upper bed fossiliferous, bryozoans, etc.	14.0
106	Limestone; light gray; coarse-grained; highly crinoidal; fossiliferous; nodular chert scattered throughout	3.5
105	Shale; thin-bedded to fissile; light yellowish to greenish gray, badly weathered; purplish in places	10.0
104	Limestone; gray to light gray; dense, hard; highly algal; upper 0.5 foot weathers somewhat nodular; irregular masses of chert show on upper surface	2.5
103	Limestone; nodular; light gray, brownish tinge on fresh surfaces; weathers out as large spheroidal masses	10.0
102	Limestone; like Bed 100; evenly bedded; beds up to 1.0 foot thick; upper layer weathers light yellowish gray; lower layers gray; fusulinids abundant in upper portion: *Fusulina, Millerella*	4.5
101-99	Limestone; brownish gray, weathers bluish gray; irregularly bedded; lower 1.0 foot mainly shale	4.5
98	Limestone; light gray; dense and hard; dendritic and nodular algae common in lower 1.0 foot; highly cherty; upper 2.5 feet one massive bed; fusulinids abundant 1.5 feet from base: *Fusulina, Millerella*	4.0
97	Limestone; shaly; light gray; interbedded with light gray shale	5.0
96	Limestone; light gray; granular in appearance; prominent zone of dark brown porous chert 1.0 foot from base and in upper portion	4.5
95	Limestone; medium to light gray; evenly bedded; algal	14.0
94	Limestone; medium to light gray; massively bedded; weathers with mottled dark and light gray surface; fossiliferous; fossils showing only in cross sections on surface; fusulinids abundant on upper surface: *Fusulina*	5.5
93	Limestone; gray; glistening; dense and hard; shale in lower 1.0 foot	2.5
92	Limestone; medium to light gray; fine-grained, dense and hard; massive beds up to 1.5 feet thick; abundant thin beds and nodules of chert; on north side of canyon, upper 10.0 feet form one solid chert bed	35.0
91	Limestone; light gray; thinly and evenly bedded in 0.1 foot beds; brown to purple zones along bedding; breaks down easily into slope; weathers bluish gray	15.0

As is shown on the accompanying illustration (Fig. 5), and as indicated in the above description of the type section of the Bolander group, a physical unconformity separates the upper 70 feet from the lower portion of the group. Although this unconformity is evident from field studies, faunal evidence does not indicate the magnitude of this stratigraphic break. However, it is of interest to note that detrital specimens of the same fusulinid species *(Fusulina)* are found in the clastic conglomerate immediately over this unconformity as are found as detrital inclusions in the conglomerate at the base of the overlying Missouri series.

The fauna of the Bolander group is very large, and seems to be typical of the faunas of the upper part of the Des Moines series found in other regions of North America. The late Des

Moines age of the Bolander group is clearly demonstrated by the fusulinid foraminifera. From a biological point of view, the fusulinids of the Bolander group are among the most highly developed Des Moines forms known from North America. They are very closely similar to fusulinids found in the uppermost portion of the Des Moines series in the Mid-Continent region. The following genera of fusulinids have been identified from the type section of the Bolander group: *Fusulina*, *Eoschubertella*, *Ozawainella (?)* , and *Millerella.*

MISSOURI SERIES

The stratigraphic term Missouri was originally proposed by Keyes (1893, pp. 85, 114) for the "Upper Coal Measures" of northwest Missouri and Iowa. Keyes designated this unit as the "Missouri terrane" and "Missouri formation." Apparently the term was intended to apply to all upper Pennsylvanian rocks above the Des Moines series in northwestern Missouri. However, the upper limit of the "formation" was not defined or even indicated. This unit has since been referred to as a series, group, formation, or other stratigraphic division. Moore (1936, p. 68) and Wilmarth (1938, pp. 1388, 1389) have given extensive summaries of the usage of the term Missouri for the Pennsylvanian of the northern Mid-Continent region. Wheeler (1896) and Prosser (1897) considered the Missouri of series rank and placed its upper limits in the Mid-Continent area well above the base of a portion of the stratigraphic section that is now considered Permian Wolfcamp. That is, these workers placed the top of the Missouri series near the middle portion of the Permian Council Grove group in the Mid-Continent area. The upper limit of the series was placed near this point in the Council Grove group by most workers until 1932 when Moore (1932) proposed the term Virgil series for the upper portion of the Pennsylvanian. The lower limit of the Virgil series, and therefore the upper limit of the Missouri series, was placed by Moore at the contact between the Pedee group of the Missouri series below and the Douglas group of the Virgil series above. The upper limit of the Missouri series is generally considered at this horizon in the Mid-Continent area and is so interpreted in this report.

The lower limit of the Missouri series also has been re-defined several times since Keyes' report in 1893. The changes in interpretation have not been as large, however, as the changes in the interpretation of the upper limit of the series. Most earlier workers considered the base of the Missouri in the Mid-Continent area at the base of the Hertha limestone and at the top of the Pleasanton shale. However, Moore (1940, p. 46) and others now place the base of the Missouri series in Kansas, Iowa, and Missouri at the base of the Bourbon formation (= Pleasanton shale of Iowa) and at the top of the Marmaton group of the Des Moines series.

In New Mexico the base of the Missouri series is placed at the base of the Veredas group and at the top of the underlying Bolander group. The upper units of the Bolander group contain faunas very closely similar to the faunas of the upper portion of the Marmaton group of the Mid-Continent area. These stratigraphic units of the Bolander group beyond a reasonable doubt are closely related in age to the upper part of the Marmaton. Also, the lower portion of the Veredas group contains faunas almost identical with the faunas of the lower portion of the Missouri Bronson group, which immediately overlies the Bourbon formation in Iowa, Missouri, and Kansas. It seems obvious that the lower part of the Veredas group of New Mexico is equivalent in age to a part of the lower portion of the Bronson group of Kansas. The basal 12 feet of limestone of the Veredas group has not yielded a diagnostic fauna. This lower 12 feet of the Veredas is so very closely similar, however, lithologically and structurally to the immediately overlying beds that it seems obvious they are closely related in age. It should be pointed out, however, that there is considerable question as to the relationship between the basal formation of the Veredas group and the overlying Adobe formation.

Although strata of the Missouri series are essentially parallel with strata of the underlying Des Moines series, faunal evidence and lithologic evidence indicate that the Missouri series is separated from the Des Moines series by an unconformity.

The upper limit of the Missouri series in New Mexico is placed at the top of the Hansonburg group defined below. The strata of the upper portion of the Missouri series are essentially parallel with the lower strata of the overlying Virgil series in all areas where studied in central New Mexico. A faunal change has been recognized between these series in all areas of New Mexico and may indicate an unconformity of small magnitude. The lithologic change between these two series also suggests an unconformity. At almost all points where studied, the basal Virgil sediments are elastics of red shales and arkosic sandstones and they immediately overlie Missouri limestones. However, if an unconformity exists at this point, it is not thought to have been of long duration.

In New Mexico the lower formation of the Missouri series is marked by the first stratigraphic occurrence of questionable representatives of the fusulinid genus *Triticites.* This lower fusulinid fauna is followed shortly in New Mexico by a fauna almost identical with the Swope limestone fusulinid fauna in the Mid-Continent region, which is characterized by *Waeringella (?) ultimata* (Newell and Keroher) [= *Wedekindellina ultimata* Newell and Keroher]. Possibly unconformably above this fusulinid zone in New Mexico are numerous limestones and shales which carry suites of fusulinids very closely similar to those found in the Missouri series of the Mid-continent region. Also, fusulinids occur in the Bolander group of the Des Moines series of New Mexico, immediately beneath the base of the Veredas group, that are almost identical biologically with *Fusulina eximia* Thompson. These New Mexico fusulinids are underlain by lime-stones which carry a form very closely similar to *Fusulina megista* Thompson. Both of these fusulinid species were de-scribed (Thompson, 1934) from the upper portion of the Des Moines series of Iowa.[7]

The Missouri series in New Mexico is composed largely of limestones. Numerous thin arkosic sandstones and sandy red shales are scattered throughout the series but they make up only a small percentage of the entire section. The middle and upper parts of the Missouri are composed largely of light gray massive to massively bedded limestones, many of which are traceable over large areas in central New Mexico. However, one wide-spread and thick zone of red shales, highly arkosic sandstone, and gray shales occurs only a short distance beneath the top of the series.

The Missouri is very widespread geographically in New Mexico and has been recognized at the surface in many places from the Nacimiento Mountains on the north to the Hueco Mountains on the south. In Mocking Bird Gap south of the Oscura Mountains, the series is more than 500 feet thick. At the north end of the Oscura Mountains, the total thickness of the series is only about 240 feet. On Cadronito Hill northwest of the Ladron Mountains, the Missouri is more than 600 feet thick.

The Missouri is divided below into two groups and sub-divided into five formations. Although many lithologic members of these formations have been traced over wide areas, it is not considered advisable to propose further stratigraphic subdivisions at this time. The general lithology, thicknesses and sub-divisions of the Missouri series in central New Mexico are shown graphically in the accompanying illustration (Fig. 6).

VEREDAS GROUP

The term Veredas is here being proposed for the group of rocks which includes three formations that are named below in ascending order, Coane formation, Adobe formation, and Council Spring limestone. The stratigraphic limits of the group at the type locality are the top of the Bolander group of the Des Moines series below and the base of the Hansonburg group of the upper part of the Missouri series above. The general lithology, thick-

[7] *Fusulina eximia.* stratigraphically is among the highest fusulinids so far described from the Des Moines series of the Mid-Continent region. That form occurs in Iowa in the limestone named Cooper Creek by Cline (1941) and the types were obtained from the type locality of the Cooper Creek limestone. Cline indicates that this limestone is only 44 feet below the top of the Des Moines series in southern Iowa. Fusulina *megista* was originally obtained from a limestone assigned to the Worland limestone by Cline, about 20 feet below the Cooper Creek limestone.

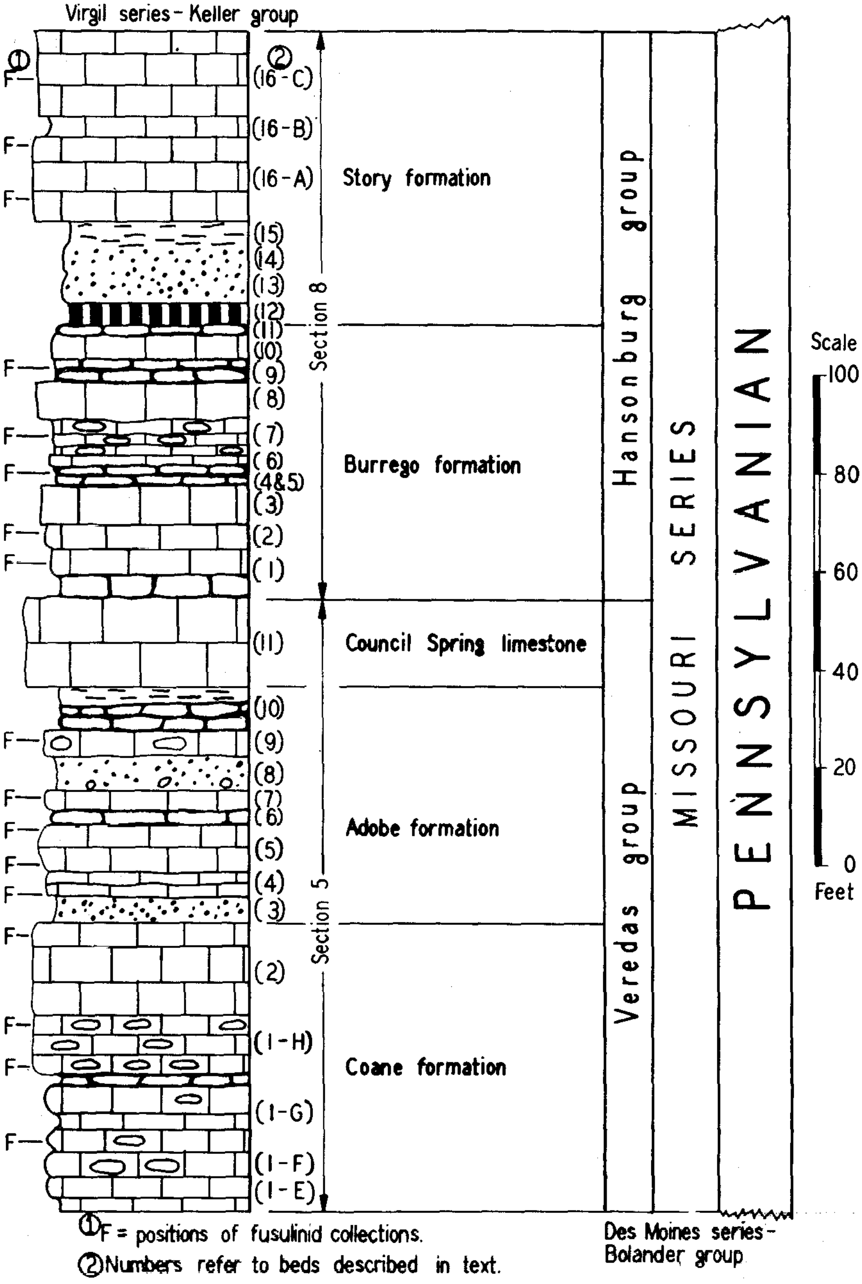


FIGURE 6.-Diagram of the Veredas and Hansonburg groups.

ness and subdivisions of the Veredas group at its type locality are shown graphically in the accompanying illustration (Fig. 6) . The descriptions and thicknesses of the individual units of the group, taken from its type locality, are as follows:

SECTION 5

Type section of the Veredas group and of its three formations; north Oscura Mountains; Socorro County, New Mexico.

Top		Thickness Feet
	MISSOURI SERIES VEREDAS GROUP	
COUNCIL SPRING LIMESTONE	---------- 18.0	
11	Limestone; second cliff from bottom of mountain slope; light gray to white; coarsely crystalline; tends to break into beds in lower three or four feet exposed; no bedding in upper part; many vertical joints --------	18.0
ADOBE FORMATION	---------- 47.3	
10	Upper 4.0 feet highly calcareous shale with few thin beds of irregular limestone; lower 5.0 feet highly algal limestone, nodular in lower 2.0 feet ----------	9.0
9	Limestone; light gray, massively and irregularly bedded; beds 0.4 to 1.0 foot thick; chert rather common on weathered surfaces; fusulinids abundant: *Triticites* ----------	5.0
8	Sandstone; green, weathers brown; very highly arkosic and micaceous; medium-grained in upper portion, granular conglomerate in lower 1.0 foot ----------	7.0
7	Limestone; medium gray; massively bedded; beds 0.2 to 0.8 foot thick; fusulinids rather common; algae very abundant; upper 1.0 foot composed almost entirely of crinoid stems: *Triticites* ----------	4.0
6	Irregular nodular lime and calcareous shale; poorly exposed ----------	3.0
5	Limestone; bluish gray; dense; hard; lower 1.5 feet one massive bed; next 3.5 feet massively bedded and teeming with fusulinids; upper 2.0 to 3.0 feet highly algal; weathers to a rough, pitted surface: *Triticites* ---	10.0
4	Limestone; gray to light gray; irregularly bedded, beds up to 0.6 foot thick; interbedded with calcareous shale and nodular lime; several limestone beds almost entirely brachiopods; fusulinids abundant: *Triticites* ----------	5.0
3	Sandstone; green; medium to fine-grained; cross-bedded in lower part; fossiliferous in upper 2.0 feet, with many crinoid stems; weathers brown ----------	4.3
COANE FORMATION	---------- 59.0	
2	Limestone; bluish gray; dense; massive; scattered masses of chert; weathers to pitted, granular surface; upper 10.0 feet very highly algal; upper 8.0 feet weathers into beds up to 1.5 feet thick; fusulinids scattered in upper part: *Waeringella (?)* ----------	19.0
1-H	Limestone; medium gray; very dense and hard; irregular thin beds, up to 0.1 foot thick; interbedded with irregular lenses and masses of chert which weather brown; fusulinids common: *Waeringella (?)* ----------	12.0

1-G	Limestone; bluish gray; massively bedded; abundant irregular masses of chert; in two sequences, with algae abundant in upper portion of each: *Triticites (?)* --	16.0
1-F	Limestone; bluish gray; fine-grained, dense; massively bedded; irregular masses of chert abundant, highly cherty in lower 2.0 feet -----	5.0
1-E	Limestone; light to tannish gray; fine-grained; hard; in massive beds up to 2.0 feet thick; upper 1.0 foot highly crinoidal; lower 2.0 feet poorly exposed ---	7.0

The geographic term Veredas is derived from Canyon de las Veredas, located in the central part of the Oscura Mountains. However, the type locality of the Veredas group is on the northwest side of the Oscura Mountains on the west slope of the range, in the eastern part of the SE¼ sec. 36, T. 5 S., R. 5 E., Socorro County. The base of the type section of the group is about 150 feet above the base of the mountain slope and the top of the type section is at the top of the second prominent limestone cliff above the base of the slope. At the type locality the Veredas is composed of gray to light gray limestones, thin calcareous shales, and two thin beds of arkosic sandstones. However, in Mocking Bird Gap, about 18 miles south of the type locality, approximately 30 percent of the Veredas group is sandstone. To the north and northwest of the type locality, in the region of the Ladron Mountains and in the south end of the Manzano Mountains, the group contains a large percentage of gray shale and a subordinate amount of sandstone.

The Veredas group has been recognized over a wide area in New Mexico. It is easily identified by its fusulinid faunas and distinctive lithology. Very thin lithologic units of the group have been traced over areas of hundreds of square miles in central New Mexico.

The faunas of the Veredas group are very large and varied. Calcareous algae are also abundant throughout this part of the Pennsylvanian section of central New Mexico. The fusulinids are highly varied and they constitute one of the most distinctive elements of the faunas of the group. Although the fusulinids in the Veredas group are exceedingly abundant in numerous strata throughout the group, many of the species have short vertical ranges. The only fusulinid genera which have been identified from the type locality are *Triticites* and *Waeringella (?).*

At the type locality the Veredas group is about 125 feet thick. This is one of the thinnest sections of the group so far measured in New Mexico. However, in almost all other areas, the group contains considerably more elastics than at the type locality.

COANE FORMATION

The formation here named Coane is very distinctive litho-logically and faunally. The base of the formation at the type locality is placed at the top of the Bolander group of the Des

Moines series. The top of the formation is placed at the base of the widespread arkosic sandstone at the base of the overlying Adobe formation. An unconformity may separate the Coane and Adobe formations. At the type locality, the Coane formation is composed of light bluish gray to gray cherty limestone. However, in other areas of central New Mexico the lower part of the formation contains clastic beds of gray shales and sandstones.

The general lithology and thickness of individual units of the Coane formation are shown graphically in the accompanying illustration (Fig. 6). Descriptions of individual units of the formation, taken from field notes at the type locality, are given above.

The term Coane is derived from the old station of Coane on the east side of the Oscura Mountains. However, the type locality of the formation is the same as the type locality of the Veredas group and is on the west steep face of the northwest side of the Oscura Mountains. The type section of the Coane is about 58 feet thick. In the Ladron Mountains of northern Socorro County, the Coane formation is more than 100 feet thick. In the Robledo Mountains of Doña Ana County, the formation is less than 50 feet thick.

The lowest stratigraphic occurrence of fusulinids in the Coane formation is about 12 feet above the base of the type section. The fusulinids found at this horizon are questionably primitive forms of the genus *Triticites.* Fusulinids are extremely abundant from about 28 feet above the base to the top of the formation at its type locality. However, specimens of only one species have been found among the numerous thin sections pre-pared of collections from that part of the section. This form is referred with question to the genus *Waeringella* Thompson. This species is very closely similar to *Waeringella (?) ultimata* (Newell and Keroher), described from the Swope limestone of the lower part of the Missouri series of Kansas and Missouri.

ADOBE FORMATION

The term Adobe formation is here introduced for all rocks in the northern part of the Oscura Mountains between the top of the Coane formation below and the base of the limestone above which is here being named the Council Spring limestone. At the type locality the formation is composed of non-cherty to highly cherty gray limestones, gray shales, and arkosic sandstones. The general lithology and thicknesses of the formation are shown graphically in the accompanying illustration (Fig. 6), The individual units of the formation have been described on previous pages from the type locality.

The geographic term Adobe is derived from the little village by that name, located about three miles northeast of the north end of the Oscura Mountains. However, the type locality is on the northeast slope of the Oscura Mountains, and is the same as the type locality of the Veredas group, given above.

In most areas of central New Mexico the basal part of the Adobe formation is a fossiliferous highly arkosic sandstone to granule conglomerate. In many regions the top of the formation immediately beneath the Council Spring limestone is shaly limestone to highly calcareous shale. However, the finer details of lithology and thickness vary considerably among some localities.

Although the Adobe formation contains several resistant cherty limestone beds, the interbedded sands and shales easily weather into slope. The entire formation is largely slope in many areas with thin projecting limestone beds.

At the type locality, the Adobe formation is about 47 feet thick. In the area of Ladron Mountains and Cadronito Hill, the formation is more than 200 feet thick. However, in the latter locality the Adobe formation contains thick strata of gray shales.

The fauna of the Adobe formation is very large and is highly varied. At the type locality, some of the limestones are composed largely of brachiopod shells. Other of the limestone beds are highly crinoidal. The tests of fusulinid foraminifera make up a large percentage of some beds of limestone and shale throughout the type section of the formation. The Adobe fusulinids are highly varied but all forms so far studied are referable to the genus *Triticites.*

COUNCIL SPRING LIMESTONE

The term Council Spring limestone is here proposed for the massive limestone that occurs between the top of the Adobe formation below and the base of the Burrego formation of the Hansonburg group above. The limestone is light gray to white, coarsely crystalline to fine-grained and massive to massively bedded. Generally, the weathered faces of cliffs show a tendency to break into vertical columns, but the formation breaks into thick massive beds on weathered cliffs in a few localities.

The name Council Spring is derived from Council Spring near the top of the Oscura Mountains, about five miles south of the north end of the mountains. The type locality of the Council Spring limestone is on the northwest steep face of the mountain and is the same as the type locality of the Veredas group, given above.

The Council Spring limestone is one of the most distinctive lithologic units of the Veredas group and it forms prominent cliffs on many of the mountain slopes of the central part of the State. At the type locality the limestone is 18 feet thick. About two miles south of the type locality the entire limestone is exposed and its thickness measures slightly more than 18 feet.

Numerous cross sections of fossils have been observed on the faces of exposures of the limestone, but the massive nature of the rock makes the collecting of fossils unusually difficult. Near the type locality, representatives of the genus *Triticites* were collected from immediately above the Council Spring in the base of the Burrego formation and from the Adobe formation immediately beneath the Council Spring limestone. The only locality from which collections of fusulinids have been obtained from the Council Spring limestone is Cadronito Hill. The form in the Council Spring on Cadronito Hill is referable to the genus *Triticites.*

The general stratigraphic position of the Council Spring limestone is shown graphically in the accompanying illustration (Fig. 6), and a general description of the formation at its type locality has been given on a previous page.

HANSONBURG GROUP

The name Hansonburg is here proposed for the group of rocks in the upper portion of the Missouri series between the top of the Veredas group below and the base of the Keller group of the Virgil series above. The type locality of the group is on the northeast side of the Oscura Mountains, on the north bluff of the large arroyo or canyon that drains northwest past Julian Tank. The base of the type section begins at the top of the Council Spring limestone, which forms the bottom limestone cliff on the north side of the arroyo. The section extends eastward up the northeast slope of the canyon to the top of the middle limestone cliffs. The type locality of the group is in and near the east portion of the SE$^1/_4$ sec. 31, T. 5 S., R. 6 E., Socorro County. However, the name was derived from Hansonburg, the head-quarters of the Bursum Ranch, about five miles east of the north end of the Oscura Mountains.

The general lithology, subdivisions, and thickness of the individual units of the Hansonburg group are shown graphically in the accompanying illustration (Fig. 6). The descriptions of individual units of the group at its type locality and the type locality of its two formations are as follows:

SECTION 8

Type section of the Hansonburg group and its three formations; north Oscura Mountains; Socorro County, New Mexico.

Top		Thickness Feet
	MISSOURI SERIES	
	HANSONBURG GROUP	
STORY FORMATION	--	57.5
16-C	Limestone; light gray; coarse-grained; massively bedded; weathers to a rough, pitted surface; fusulinids abundant near middle portion: *Triticites* ---	17.0
16-B	Limestone; light gray; granular; evenly bedded ----------------------------	4.0
16-A	Limestone; light gray; dense and hard; massively bedded, in beds up to 5.0 feet thick; fusulinids abundant 4.0 feet from base; algae common in upper 7.0 feet: *Triticites, Dunbarinella (?), Pseudostaffella (?)* ------	17.0

15	Clay; light gray to white, blue and yellow spots; soft; greenish gray in lower 1.0 foot ----------	4.0
14	Sandstone; medium to fine-grained; highly micaceous; alternating indurated and soft layers about 0.5 foot thick; greenish, mottled; dark brown in upper 2.0 feet; locally, layers of soft red sand near top ----------	4.5
13	Sandstone; medium-grained; highly cross-bedded; lenticular; dense and hard on fresh exposures ----------	6.0
12	Shale; reddish brown, mottled with light gray; interbedded in upper part with medium-grained, purplish, highly micaceous sandstone ----------	5.0
BURREGO FORMATION ---------- 52.0		
11	Limestone; as in Bed 10; nodular; algal; two irregular beds ----------	2.0
10	Limestone; nodular in lower 1.0 foot; massively bedded in middle part; gray; highly algal in upper part ----------	5.0
9	Limestone; nodular; bluish gray; fusulinids abundant: *Triticites* ----------	5.0
8	Limestone; algal, up to 50 percent in upper part; gray; massively bedded; fusulinids throughout; ledge forming: *Triticites* ----------	8.0
7	Limestone; nodular to irregular beds; gray; highly algal; massively bedded; abundant fusulinids locally; highly cherty; contains abundance of brachiopods throughout: *Triticites* ----------	7.5
6	Limestone; purple; highly crinoidal; breaks down like sand; distinctive in appearance ----------	2.5
5 & 4	Limestone; highly nodular; algal; gray; dense and hard; fusulinids extremely abundant locally: *Triticites* ----------	4.0
3	Limestone; gray; highly algal; massively bedded; weathers medium gray ----------	8.0
2	Limestone; crinoidal; weathers like sand; fusulinids abundant: *Triticites*	5.0
1	Limestone; light gray; fine-grained and dense; glistening; nodular in lower 5.0 feet; fusulinids abundant; irregularly bedded, beds up to 1.0 foot thick in upper part; lower 5.0 to 6.0 feet weather yellow brown: *Triticites* ----------	5.0
	(Note: Bottom of section described above ends near the bottom of canyon or arroyo cutting across north end of Oscura Mountains, near east part of sec. 31. Bottom of Bed 1 is on north side of arroyo and immediately above prominent cliff of Council Spring limestone.)	

The fusulinid faunas of the Hansonburg group correspond closely with the fusulinid faunas of the upper portion of the Missouri series of the Mid-Continent area. The faunas of the two formations proposed below as divisions of the Hansonburg, Burrego formation below and Story formation above, are highly varied and distinctive. The mega-fauna of the group is also large but it has not been studied in detail. The following genera of fusulinids have been identified from the type section of the Hansonburg: *Triticites, Dunbarinella (?),* and *Pseudostaffella(?).*

At the type locality the Hansonburg group is about 115 feet thick. In Mocking Bird Gap it is more than 200 feet thick. With the exception of an interval of red shale, sandstone, and gray shale from 38 to 57.5 feet below the top, the type section of the group consists entirely of light gray to purple, massive to nodular, limestones. However, in Mocking Bird Gap and most other areas of central New Mexico the group contains interbedded sandstones and gray shales.

BURREGO FORMATION

The term Burrego formation is here proposed for the massive to massively bedded and nodular limestones that overlie the Council Spring limestone of the Veredas group and underlie the red shales and highly arkosic red sandstones at the base of the Story formation. Although the Burrego formation is almost entirely limestone at the type locality, in the area of Mocking Bird Gap it contains numerous thick sandstones and on Cadronito Hill the formation contains several thick shale strata. Most of the limestones of the type section of the Burrego are gray to light gray in color. However, some of the thin limestone beds are brilliantly colored from purple to orange and are traceable over wide areas.

In the northern part of the Oscura Mountains the Burrego formation is 52 feet thick. The formation is considerably thicker in the region of Mocking Bird Gap to the south of the type locality and in the region of the Ladron Mountains and Cadronito Hill northwest of the type locality.

The term Burrego is derived from Burrego Spring on the northeast side of the Oscura Mountains, near where the formation is well exposed. The type locality of the Burrego formation is north of Burrego Spring on the northeast side of the Oscura Mountains just above the limestone cliff of Council Spring lime-stone on the north side of the canyon. This is the same as the type locality of the Hansonburg group, the details of which are given above. The general lithology of the Burrego is shown graphically in the accompanying illustration (Fig. 6), and descriptions of the individual units of the formation have been given above.

The fauna of the Burrego formation is very large and varied. However, the mega-fauna has not been studied in detail. Highly varied fusulinid faunas are abundant in numerous strata through-out the formation. Many of the fusulinid species of the Burrego have been recognized over large areas in New Mexico and most of them are apparently confined to the Burrego formation. All fusulinids so far identified from the Burrego formation are referable to the genus *Triticites.*

STORY FORMATION

The term Story formation is proposed for the upper 58.5 feet of the type section of the Hansonburg group. The type section of the formation includes at its base 19.5 feet of reddish brown shale, arkosic and micaceous sandstone, and gray shale. Its upper 38.0 feet is composed of light gray, massive to massively bedded and highly fossiliferous limestone. The geographic term is de-rived from Story Tank, about three miles west of the central west front of the Oscura Mountains. However, the type locality of the formation is on the northeast side of the Oscura Mountains, and is the same as the type locality of the Hansonburg group, described above.

The general lithology and thickness of the type section of the Story formation are shown graphically in the accompanying diagram (Fig. 6) and the description of individual units is given above. As is shown by this diagram and the above description, the Story formation has two distinct lithologic units. The lower of these two units is composed entirely of elastics of red shale, arkosic sandstone, and gray shales. This unit has been recognized over much of central New Mexico including the area throughout the length of the Oscura Mountains, on Little Burro Mountain in Mocking Bird Gap, in the Los Pinos Mountains, near the Coyote Hills, and on Cadronito Hill.

The upper unit of the Story is composed of two massive thick beds of light gray limestone, separated by a thin bed of nodular to irregular limestone. This unit also has been recognized over a large area in central New Mexico. The thinnest section so far measured of the Story is at its type locality, where the formation is only 58.5 feet thick.

The upper portion of the Story formation is highly fossiliferous. Mega-fossils are numerous at the type locality and in many other localities, but they have not been studied in detail. The upper 38 feet of massive limestones contain abundant fusulinids. Although these fusulinids are considerably more highly developed biologically than the fusulinids of the underlying Burrego formation, they apparently are not among the most highly developed of the Missouri fusulinids known from North America. The forms which occur slightly more than 30 feet below the top of the formation resemble closely the forms from the upper part of the Kansas City group of the Missouri series of Kansas. Only one collection of fusulinids has been obtained from the uppermost two to three feet of the formation but they are too highly silicified to determine their affinities with certainty. The fusulinids so far identified from the Story formation are referable to the genera *Triticites, Dunbarinella (?),* and *Pseudostaffella (?).*

VIRGIL SERIES

The term Virgil series was proposed by Moore in 1932 for the Pennsylvanian rocks of Kansas above the top of the Pedee group of the restricted Missouri series and below the base of the Permian, as the Permian was defined at that time. The base of the series is still considered at essentially the same stratigraphic position by most workers. General ideas concerning the basal limits of the Permian in the Mid-Continent area have changed considerably since 1932. However, the base of the Permian Wolf-camp series in the Mid-Continent area is now placed by most students immediately above the top of the Brownville limestone of the Wabaunsee group of the Virgil series and at the base of the Council Grove group.

The lithology of the Virgil series in New Mexico varies more markedly geographically than the lithology of any of the other Pennsylvanian series. This lithologic variation is especially marked in the upper portion of the series. In some areas of New Mexico the entire Virgil is marine limestone. In other localities the series is composed almost entirely of deltaic to brackish-water silts and silty limestones to sandstones. In still other localities, the series consists largely of red beds of shale, sandstones and conglomerates. All gradations of these lithologic types are found among these widely separated localities. It is, therefore, impossible to set up a detailed classification from any one locality that will accommodate all lithologic variations of the Virgil series in all areas of New Mexico.

All rocks in New Mexico between the top of the Story formation of the Hansonburg group below and the base of the Permian Wolfcamp above are here being referred to the Virgil series. The Virgil is widespread in New Mexico and has been recognized at the surface as far northeast as the Pecos River, as far northwest as the Nacimiento Mountains, as far southwest as Silver City, and to near the south border of the State in the Hueco Mountains. Virgil rocks have also been encountered in deep wells drilled in the San Juan Basin area of northwest New Mexico and in the east central part of the State (see Pl. 1). However, the Virgil is very thin in the wells drilled in east central New Mexico, and only the lower portion of the series has been recognized from wells drilled in the San Juan Basin area.

In the Sangre de Cristo Range of northern New Mexico, thick sections of questionably Pennsylvanian rocks of reddish highly arkosic conglomerates and sandstones occur above the Des Moines Pennsylvanian. The age of these coarse elastics is unknown, but parts of them may be referable to the Virgil series.

The formations that are being named below for the stratigraphic classification of the Virgil series in New Mexico are lithologic units recognizable over large areas in the central part of the State. However, names are not being proposed at this time for all such widespread lithologic units of the Virgil. The Virgil is here divided into two groups, the Keller group below and Fresnal group above. The Keller group has been recognized in all areas where Virgil rocks are known in New Mexico. The Fresnal group, however, is much more restricted geographically. Rocks definitely recognized as of Fresnal age have not been observed in much of the northern outcrop area of the Virgil in New Mexico.

The base of the Virgil in New Mexico corresponds approximately with a sharp increase in the content of red beds of shale and sandstone, thick arkosic coarse-grained sandstones to conglomerates, and gray shale to siltstone beds. This increase in the clastic content of the Virgil has been noted in all areas except in the Robledo Mountains of south central New Mexico. In the Robledo Mountains the Virgil is almost entirely limestone.

The faunas of the Virgil series in New Mexico are closely similar to the faunas of the Virgil series in the northern Mid-Continent area. This is especially true of the fusulinid faunas. The most common elements of the fusulinid faunas of the Virgil are referable to the genus *Triticites.* Representatives of the genus *Dunbarinella* are also very widespread in the Keller group of the lower Virgil.

The strata of the lower part of the Virgil are essentially parallel with the strata in the upper portion of the Missouri series. However, faunal evidence indicates that an unconformity separates the Missouri and Virgil in New Mexico but the stratigraphic break at this point is not thought to have been of long duration. No evidence has been found in any area of New Mexico to indicate a physical angular unconformity between the Missouri and Virgil.

The strata in the upper part of the Virgil are essentially parallel to strata in the basal part of the overlying Permian. However, faunal evidence clearly demonstrates an unconformity of considerable magnitude between the Virgil and lower Permian in almost all areas of central and southern New Mexico. In Fresnal Canyon, where the basal strata of probably Permian rocks are barren of diagnostic fossils, a physical unconformity is obvious at the top of the Fresnal group of the Virgil.

At many points in southern New Mexico, including and south of Mocking Bird Gap, the uppermost beds of the Virgil carry a fusulinid fauna almost identical with the fusulinid fauna in and just below the Brownsville limestone at the top of the Virgil series in Kansas. Permian limestones occur immediately above these Pennsylvanian beds in central and southern New Mexico, which carry a fusulinid fauna that is obviously slightly younger stratigraphically than the basal Permian Wolfcamp fusulinid faunas of Kansas and of northern Texas. The fusulinid fauna from the uppermost portion of the Virgil section in central New Mexico, north of Mocking Bird Gap and to the latitude of Albuquerque, is considerably more primitive than the fusulinid fauna at the top of the Virgil section in and south of Mocking Bird Gap. These middle Virgil fusulinid-bearing strata of central New Mexico are immediately overlain by Permian limestones that carry a fusulinid fauna identical with the Permian fusulinid faunas of the basal Permian limestone of the southern part of the State. Also, in the northern and central portions of the Hueco Mountains, strata that contain a primitive Virgil fusulinid fauna are truncated by strata that contain a lower Permian Wolfcamp fusulinid fauna closely similar to the basal Permian fusulinid fauna of central New Mexico. These facts demonstrate still further the existence of a widespread unconformity in New Mexico between the top of the Virgil and the base of the Permian.

KELLER GROUP

The term Keller is here proposed for the group of rocks between the top of the Hansonburg group of the Missouri series below and the base of the Fresnal group above. At the type locality, the Keller group is composed largely of limestone. However, several thick beds of arkosic sandstone, conglomerate, and shale occur in the lower two-thirds of the group. The Keller group is widespread in New Mexico and rocks equivalent in age to the type section of the Keller have been found over most of the central and southern parts of the State. Rocks of Keller age have been identified from deep wells in the San Juan Basin area and from deep wells in the east central part of New Mexico. The lithology of the group varies markedly among some localities.

The geographic term Keller is derived from Keller Spring, on the east slope of the Oscura Mountains about 2 miles east of South Oscura Peak. The type locality of the group is at the north end of the Oscura Mountains on the northeast bluff of the canyon that cuts across the northern part of the mountains. The base of the type section begins at the top of the second limestone cliff above the arroyo bed and the top of the section is at the top of the fourth main limestone cliff that underlies the main cuesta or rock terrace projecting southwestward from the northeast side of the canyon. The section is located mainly in the NE¼ sec. 31, T. 5 S., R. 6 E., but it extends a short distance into the west central part of sec. 32. The upper formation of the Keller group forms the dip-slope on most of the top and east slopes of the Oscura Mountains. Numerous springs originate on this dip-slope, including Keller Spring, Moya Spring, and Del Cuerta Spring.

The general lithology of the type section of the Keller group and of the two formations here referred to the group is shown graphically in the accompanying diagram (Fig. 7). As is shown by this diagram, the group contains at its type locality two distinct lithologic units. The lower unit is about 81 feet thick and it is composed of numerous nodular to irregularly bedded lime-stones, interbedded with calcareous shales, arkosic sandstones,

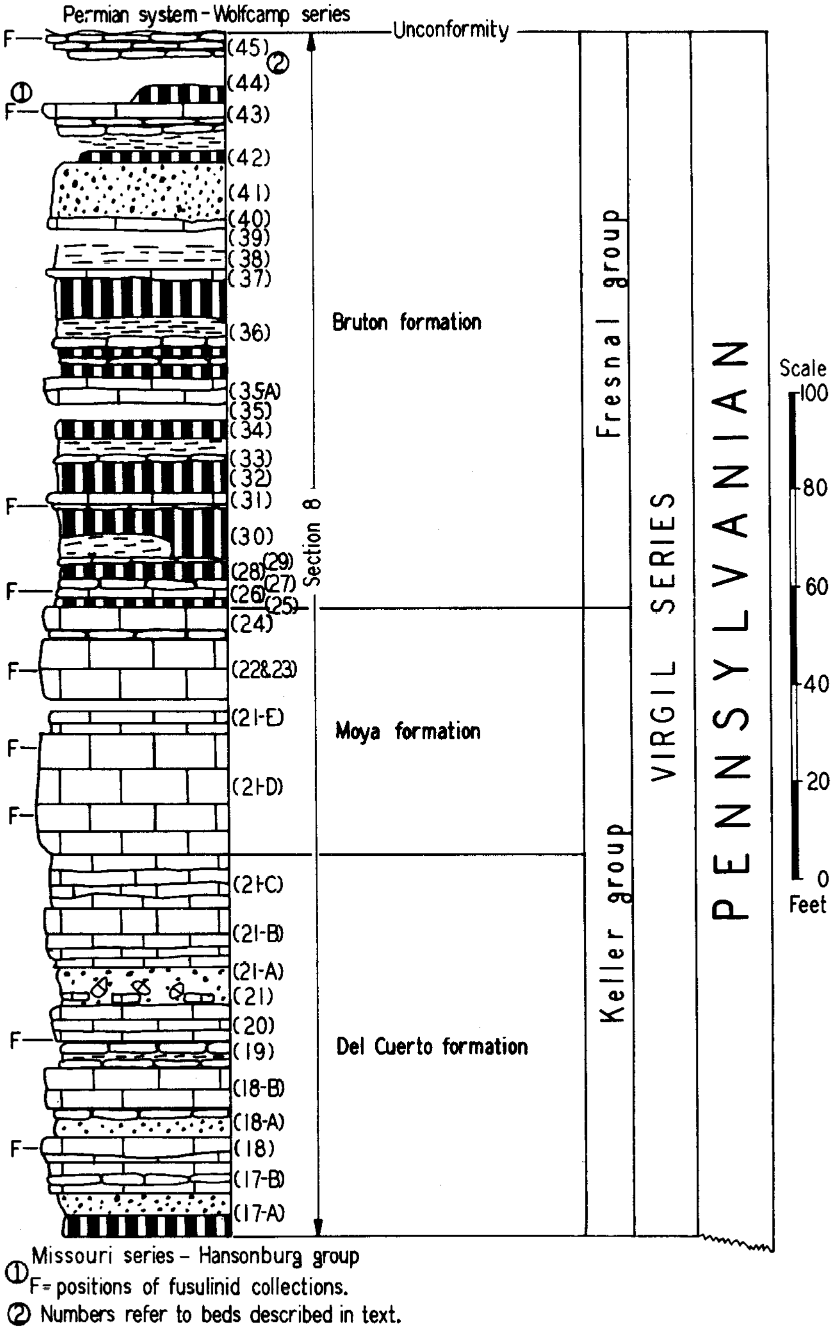


FIGURE 7.-Diagram of the Keller group and of the Bruton formation of the Fresnal group.

and conglomerates. This lower unit is here named the Del Cuerto formation. The upper unit is composed almost entirely of massive to irregularly bedded light gray limestone, and is here named the Moya formation.

The fusulinids of the Keller group are typical of the lower Virgil series over much of central New Mexico. Representatives of the genus *Triticites* make up by far the larger part of the fusulinid faunas but representatives of the genus *Dunbarinella* are also abundant in some areas, especially in the north area of the Sacramento Mountains.

The descriptions of the individual units of the type section of the Keller group and of the two formations here referred to the group are as follows:

SECTION 8

Type section of the Keller group and its two formations; north Oscura Mountains; Socorro County, New Mexico.

Top		Thickness Feet
	VIRGIL SERIES	
	KELLER GROUP	
MOYA FORMATION	-- 51.0	
24	Limestone; light gray; dense; massive; sections of fossils common; bellerophon gastropods abundant ---	7.0
23 & 22	Limestone; light gray; dense; massive; fusulinids: *Triticites*----------------	12.0
21-E	Limestone; light gray; algal; evenly bedded; poorly exposed in upper portion --	7.0
21-D	Limestone; fine-grained, dense and hard; fossiliferous; forms one massive cliff: *Triticites* ---	25.0
DEL CUERTO FORMATION	-- 81.0	
21-C	Limestone; argillaceous; thin irregular beds; weathers light yellowish red to orange; fossiliferous ---	13.0
21-B	Limestone; light gray; one massive bed in upper 5.0 feet, more thinly bedded below ---	12.0
21-A	Slope; 3.0 to 4.0 feet reddish brown, highly arkosic sandstone scattered on slope --	5.0
21	Slope: limestone conglomerate in upper 3.0 to 4.0 feet, highly arkosic, with calcareous cement; lower part contains 4.0 to 5.0 feet of nodular to irregularly bedded limestones ---	9.0
20	Limestone; gray, slightly purplish tinge; irregular masses: *Triticites*-----	2.0
19	Slope; nodular to slabby limestone poorly exposed ------------------------	6.0
18-B	Limestone; massively bedded; extremely fossiliferous; bluish gray; contains abundance of horn corals in lower portion ------------------------	8.0
18-A	Slope; coarse reddish brown arkosic sandstone poorly exposed in several places in area, with nodular limestone in upper portion ------------- 6.0 nodular limestone in upper portion -- 6.0	
18	Limestone; nodular to irregularly bedded; light gray; dense and hard; poorly exposed: *Triticites* --	5.0

17-B	Limestone; slabby to irregular nodular beds; gray to medium gray--	6.0
17-A	Slope; shows red shale in lower 4.0 to 5.0 feet; green to brown arkosic sandstone in upper 4.0 to 5.0 feet -------------------------------	9.0

DEL CUERTO FORMATION

The term Del Cuerto formation is here proposed for the rocks of the lower part of the Keller group between the top of the Story formation of the Hansonburg group below and the base of the Moya formation above. The geographic name is derived from Del Cuerto Spring on the east slope of the Oscura Mountains, about three miles east of South Oscura Peak. However, the type locality of the formation is on the northeast side of the Oscura Mountains and is the same as the type locality of the Keller group, given above.

At the type locality, the Del Cuerto formation is composed of irregularly bedded to nodular limestone, highly arkosic sand-stone, limestone conglomerate, and gray and red shale. In other areas of central New Mexico the formation generally is more highly clastic and thicker than at the type section. The type section is about 81 feet thick.

The Del Cuerto outcrops are covered on most mountain slopes in central New Mexico. This covered condition is due largely to the non-resistant nature of its rocks, and due partly to the large overhanging limestone cliffs of the Moya formation. In spite of this covered condition in many localities, the Del Cuerto formation has been recognized over a large area in central New Mexico. The fauna of the Del Cuerto is large, and includes a large variety of brachiopods, gastropods, corals, and fusulinid foraminifera. Some limestone beds are composed largely of corals. Still other beds are composed almost entirely of the shells of brachiopods. The shells of fusulinids make up large parts of some limestone strata.

The fusulinids of the Del Cuerto are all primitive Virgil types. However, the lowest fauna found at the type locality of the formation contains species that appear to be more advanced biologically than the fusulinids from the basal part of the Virgil series in the Hueco Mountains. The only fusulinids found in the type section of the Del Cuerto are referable to the genus *Triticites.*

The general lithology and thicknesses of individual units of the type section of the Del Cuerto are shown in the accompanying illustration (Fig. 7), and descriptions of individual units from the type locality are given on a previous page.

MOYA FORMATION

The term Moya formation is proposed for the massive to massively bedded and irregularly bedded to nodular limestone between the top of the Del Cuerto formation below and the base of the Bruton formation of the Fresnal group above. The Moya formation occurs widespread in central New Mexico and has been recognized in surface exposures throughout the Oscura Mountains, along the Rio Grande Valley from the Mud Springs Mountains to east of Socorro, in the Abo Canyon section, and in the Sandia Mountains area east of Albuquerque.

The name Moya is derived from Moya Spring on the east slope of the Oscura Mountains, about eight miles south of the north end of the mountain range. However, the type locality is on the northeast side of the Oscura Mountains and is the same as the type locality of the Keller group, given above.

The upper limestone of the formation forms the top of the prominent rock terrace on the northeast side of the canyon that drains northwest across the north end of the Oscura Mountains. The lower massive limestone of the formation forms the high cliff on the side of the canyon below the terrace. Most of the limestones that form the east dip-slopes throughout the Oscura Mountains are referable to the Moya formation.

At the type locality the Moya formation is about 51 feet thick. However, northward and southward from the type locality the Moya formation is thicker. The general lithology and thicknesses of individual units of the Moya are shown graphically in the accompanying illustration (Fig. 7), and descriptions of individual units of the type section have been given on a previous page. The type section of the Moya formation is composed largely of massive to massively bedded limestone, with a few thin beds of irregularly bedded to nodular limestone. Sandstones and shales are interbedded with the limestones of the Moya formation in the Los Pinos Mountains, Abo Canyon section, in the Mocking Bird Gap section, and at least as far south along the Rio Grande Valley as Mud Springs Mountains.

The fauna of the Moya is large and varied. At the type locality pelecypods and bellerophon gastropods are especially abundant in the upper limestone member, and fusulinid foraminifera are common throughout most of the section. All fusulinids so far found at the type section are referable to the genus *Triticites.*

FRESNAL GROUP

The term Fresnal group is here proposed for all sedimentary rocks that are definitely referable to the Virgil series between the top of the Keller group below and the base of the Permian Wolfcamp above. The type locality of the group is in the Fresnal Canyon along State Highway 83, east of La Luz, in the north end of the Sacramento Mountains, where the group is typically exposed. The base of the type section is about one-tenth mile west of the "Station One Mile" sign on the railroad and about 20 feet above the highway road bed. The top of the section is approximately half a mile east of this point along the road cut.

The section is mainly in the NW¼ sec. 30, T. 15 S., R. 11 E., Otero County.

At the type section the Fresnal group is 530 feet thick. At some localities in the San Andres Mountains, the group is apparently more than 1,000 feet thick. However, the lower limits of the Fresnal cannot be determined with certainty in most areas of the San Andres Mountains and the group may be much more than 1,000 feet thick in some localities. In the northern Oscura Mountains the Fresnal group is slightly more than 113 feet thick, and in Abo Canyon it is about 120 feet thick; only the lower portion of the group is present, however, in these two localities.

Rocks referable to the Fresnal are widespread in central and southern New Mexico south of Albuquerque and the Nacimiento Mountains. The Fresnal group is not known with certainty from north of these localities.

The type section of the Fresnal group is composed of argillaceous to essentially pure limestone, arkosic sandstone, conglomerates, and gray to red shale. Over 50 percent of the rocks at the type section of the Fresnal group are clastics but most of them are of marine origin. The conglomerates in the type section of the Fresnal contain large pebbles of igneous and metamorphic rocks and the original source of these pebbles is thought to have been near. In central New Mexico, the Fresnal group is composed largely of red shales, with interbedded thin nodular to irregularly bedded and highly fossiliferous limestone and arkosic sandstone. On weathered slopes this portion of the section appears to consist almost entirely of red beds.

The type section of the Fresnal is highly fossiliferous throughout, and its fauna is highly varied. However, the mega-fauna has not been studied in detail. Large fusulinid faunas also occur throughout the type section of the group and at least twenty fusulinid-bearing strata were recognized in the type section. The fusulinids from the type section of the Fresnal are highly developed forms of the genus *Triticites* and they clearly indicate an upper Virgil age for the group.

The fusulinid faunas obtained from the uppermost part of the Fresnal group in Fresnal Canyon, Mocking Bird Gap, and the Robledo Mountains are closely similar to, and presumably are closely related in age to, the fusulinids from in and from near the Brownsville limestone of Kansas. It therefore seems that the upper part of the Fresnal group of New Mexico represents a part of the Virgil that is among the youngest stratigraphic portions of the series known from North America.

Although many faunal as well as lithologic units have been recognized in the type section of the Fresnal group, no formational names will be applied to the type section at this time. How-ever, the Bruton formation is being proposed below for the lower portion of the Fresnal group in the area of the Oscura Mountains and the region to the west and north of the Oscura Mountains along the Rio Grande Valley.

The general lithology and thicknesses of the individual units of the type section of the Fresnal group are shown graphically in the accompanying illustration (Fig. 8). Descriptions of individual units of the group from the type section are as follows:

SECTION 1

Type section of the Fresnal group; Fresnal Canyon, northern Sacramento Mountains; Otero County, New Mexico.

Top		Thickness Feet
	VIRGIL SERIES	
	FRESNAL GROUP	
94	Limestone; medium gray; dense to nodular --------------------------------	1.0
93	Shale; greenish gray, alternating with purplish red-------------------------	6.5
92	Siltstone; highly calcareous; conglomeratic, with prominent pebbles chert up to one inch in diameter ---	1.5
91	Shale; greenish gray; contains scattered nodules and thin layers limestone --	2.0
90	Limestone; gray; dense and hard; lower 1.0 foot and upper 1.5 feet nodular and shaly ---	3.5
89	Shale; greenish gray; calcareous; scattered nodules limestone -----------	2.0
88	Limestone; light gray; dense; nodular in lower 1.0 foot; irregularly bedded in upper 1.0 foot ---	4.0
87	Shale; greenish gray; highly calcareous; soft ------------------------------ -	1.2
86	Limestone; light gray; dense; massive; upper 3.0 feet one bed ----------	6.0
85	Limestone; medium to dark gray; fine-grained and dense; highly argillaceous; interbedded thin streaks greenish gray shale ----------------	7.0
84	Shale; medium gray; conchoidal fracture; veinlets of gypsum -----------	2.0
83	Limestone; gray; nodular; in beds 0.1 to 0.7 foot thick; interbedded with greenish gray calcareous shale --	2.5
82	Shale; medium gray; conchoidal fracture ----------------------------------	3.0
81	Limestone; lower 2.0 feet thin-bedded and nodular; upper 4.0 feet light to medium gray, dense; forms one massive bed; fusulinids in lower portion: *Triticites* ---	6.0
80	Shale; reddish brown, grading upward into alternating gray and purple; upper 4,0 feet reddish brown, separated from lower 7.0 feet by 0.3 foot nodular limestone ---	11.5
79	Limestone; gray; argillaceous; massive; nodular-appearing beds; separated by small nodular limestone ---------------------------------------	3.5
78	Limestone; nodular; red to purple to greenish gray interbedded shale--	5.0
77	Limestone and shale; limestone highly nodular; shale highly calcareous; teeming with fusulinids: *Triticites* ----------------------------	6.5
76	Sandstone; medium-grained; alternating with red shale; lower 10.0 feet predominantly red shale; sandstone in upper portion, cross-bedded and lenticular ---	15.0
75	Conglomerate; with pebbles of chert, limestone, sandstone,	

	up to three inches in diameter. Bed 75 seems to pinch out between Beds 74 and 76	4.0
74	Shale; purplish red to brown; containing lenses and beds of siltstone, and lenticular beds of cross-bedded medium-grained sandstone; sandstone reddish brown in color	11.0
73	Limestone; medium gray; argillaceous; breaks down easily into slope	0.7
72	Shale; reddish brown; irregularly bedded; soft	3.5
71	Limestone; light gray; dense and hard; massively bedded, beds 0.5 foot to 3.0 feet thick; layers of abundant fusulinids: *Triticites*	15.0
70	Alternating gray siltstone and fine sandstone with interbedded greenish gray to brownish red shale; siltstone laminated in beds up to 1.0 foot thick; 1.5 foot bed red shale in middle portion; locally lenses of cross-bedded sandstone up to 2.0 feet in thickness at top	8.0
69	Shale; calcareous; bluish gray; conchoidal fracture; fusunids scattered in lower 3.0 feet; thin limestone in upper portion	7.0
68	Limestone; gray; dense and hard; layers of calcareous shale up to 0.1 foot thick; upper surface covered with fusulinids: *Triticites*	2.5
67	Shale; greenish gray; containing thin layers of limestone; upper portion teeming with fusulinids: *Triticites*	4.0
66	Limestone; light gray; dense and hard; massively bedded	5.5
65	Limestone; gray; highly nodular; shows slight tendency to break into irregular beds; abundant fusulinids: *Triticites*	6.0
64	Shale; greenish gray; massive; containing three prominent beds of hard dark gray siltstone in upper 1.5 feet	5.0
63	Sandstone; medium to coarse-grained; middle 4.0 *feet* massive and cross-bedded; lower 5.0 feet locally cross-bedded and conglomeratic with pebbles of chert and light gray quartzite, up to two inches in diameter; upper portion thin-bedded 13.0	
62	Shale; greenish gray, irregularly bedded; siltstone beds up to 1.0 foot thick near top and in middle	8.0
61	Limestone; light gray; lower 1.5 feet thin-bedded, remainder massively bedded; dense and hard: *Triticites*	7.0
60	Shale; massive; alternating greenish gray and purple; mottled in appearance	7.0
59	Limestone; yellowish gray; sandy in appearance	0.6
58	Shale; light greenish gray	4.0
57	Limestone; medium gray; massively bedded; abundant fusulinids: *Triticites*	2.0
56	Shale; silty; rather thin-bedded; calcareous	2.2
55	Shale; calcareous; contains small nodules limestone in lower 1.0 foot; reddish	2.0
54	Limestone; medium gray; sublithographic; becoming argillaceous and nodular in upper part	4.0
53	Shale; calcareous in lower part; bright red with small nodules of limestone in upper 3.0 feet with small inclusions green clay	4.0
52	Limestone; light gray; dense; massive; in two beds	2.3
51	Shale; highly calcareous and fossiliferous; carries nodular limestone	1.0

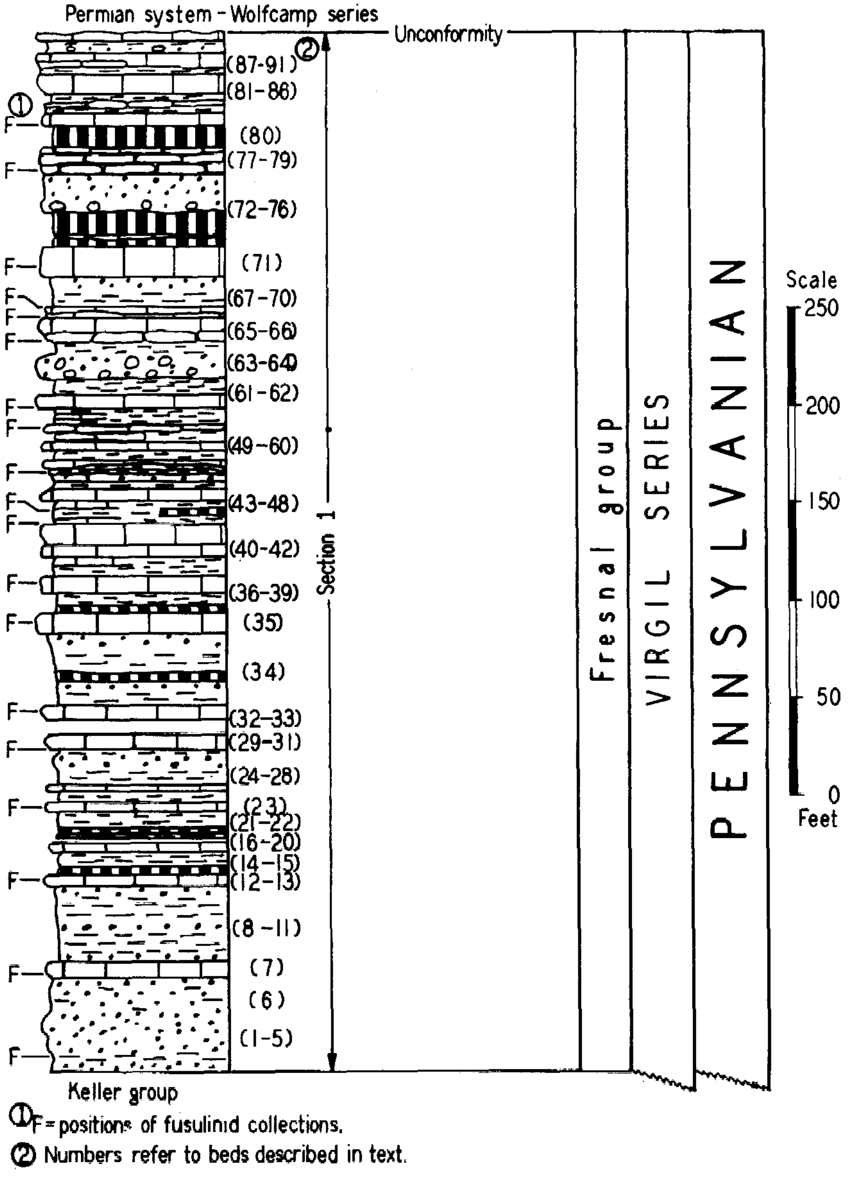


FIGURE 8 .—Diagram of the Fresnal group.

50	Shale; blocky; purplish	1.0
49	Sandstone; fine-grained; thinly laminated on weathered surfaces, with interbedded streaks silty shale	2.3
48	Alternating greenish gray shale and finely crystalline limestone	4.5
47	Limestone; light gray; dense and hard; massive; abundant fusulinids: *Triticites*	6.5
46	Shale; alternating purplish and greenish gray	1.5
45	Shale; highly calcareous; thin beds limestone throughout; fossiliferous: *Triticites*	3.0
44	Shale; greenish gray, alternating with dark red to brown shale	4.5
43	Shale; highly calcareous and fossiliferous; fusulinids: *Triticites*	1.0
42	Limestone; light gray; dense; hard; one massive bed	3.6
41	Limestone; thin-bedded; nodular; beds two inches to 1.0 foot thick; thin dark shale partings; limestone medium gray, fine-grained, dense	13.0
40	Shale; medium gray; calcareous; fossiliferous; darker gray in lower portions; thin beds limestone in upper 4.0 feet	9.5
39	Limestone; evenly bedded, in beds up to 1.0 foot thick, with gray thin-bedded shale and abundant nodules of limestone at top: *Triticites*	7.5
38	Limestone; gray; dense and hard; massive	1.5
37	Shale; medium gray; conchoidal fracture	6.5
36	Shale; purplish red; soft; contains thin streaks of yellow shale	4.0
35	Limestone; light gray; coarsely crystalline; irregularly bedded, nodular in appearance; fusulinids: *Triticites*	10.0
34	Mainly covered but shows light greenish gray shale in numerous places; thin sandstone near top of shale, with beds purple shale 0.1 to 1.0 foot thick; across canyon, 6.0 feet of cross-bedded sandstone exposed at top	37.0
33	Limestone; medium to light gray; fine-grained; dense and hard; weathers with brownish irregular surface	7.0
32	Covered	8.0
31	Limestone; medium gray; irregularly bedded and nodular; breaks down easily; abundant algae in middle portion, with numerous dendritic algae in lower 1.0 foot	4.0
30	Covered	4.0
29	Limestone; fine-grained; dense and hard; yellowish gray; fusulinids in upper part: *Triticites*	0.5
28	Shale; light greenish gray; soft	2.5
27	Sandstone; light gray; weathers dark brown on surface; lower 3.0 feet conglomeratic, with pebbles of light gray quartzite and chert; upper 2.0 feet finer-grained, more thinly bedded	7.0
26	Shale; greenish gray; soft; poorly exposed	9.0
25	Limestone; highly argillaceous; medium brownish gray in lower portion; hard in lower 2.0 feet, becoming soft and shaly in upper part; abundant fossils	3.5
24	Shale; light greenish gray; soft; calcareous	3.0
23	Limestone; gray; dense and hard	3.0

22	Shale; medium gray to light brown; soft; poorly bedded; becoming yellowish in upper portions	7.0
21	Shale; red; soft; gray streak shale 1.0 foot from base --------------------------	2.5
20	Limestone; medium gray; nodular in appearance, hard	0.8
19	Covered	3.5
18	Limestone; light gray; fine-grained; dense and hard ---------------------------	0.8
17	Covered	1.5
16	Limestone; light gray; fine-grained; massively bedded ------------------------	3.0
15	Shale; medium gray; soft; becoming lighter gray in upper part --------------	7.0
14	Shale; bright purplish red ----------------------------	3.0
13	Limestone; light gray; dense; hard; upper 1.0 foot highly crinoidal ---------	1.7
12	Limestone; irregularly bedded, in beds 0.3 to 1.0 foot thick; gray; common fusulinids: *Triticites* --	5.0
11	Sandstone; silty; thin-bedded; light greenish gray; soft; contains lenticular bed sandstone in upper part which is lithologically identical with Bed 10 ---	3.0
10	Sandstone; brown; highly cross-bedded; hard ----------------------------	1.0–1.5
9	Shale; highly silty; greenish gray; hard; blocky to conchoidal fracture; contains beds fine-grained sandstone which weather brown near middle part; several thin sandstone beds near top	33.0
8	Sandstone; highly calcareous; brown; hard -----------------------------------	0.2
7	Limestone; medium to light gray; lower 2.5 feet nodular, thin-bedded; next 1.0 foot massive; upper part thin-bedded, nodular; carries fusulinids in both nodular portions; upper 0.2 foot crinoidal: *Triticites* --	8.0
6	Siltstone; thin-bedded; alternating discontinuous bands and lenses of fine-grained hard sandstone; siltstone gray; sandstone light brownish gray ---	17.0
5	Sandstone; cross-bedded; fine to coarse-grained; more or less continuous beds of conglomerate; composed of well rounded pebbles of chert and light gray quartzite; basal 1.0 foot conglomerate; pebbles reach 0.1 foot diameter --	14.0
4	Alternating ,soft, silty sand and approximately 1.0 foot ledges medium-grained, hard sandstone; occasional layers pebbles; locally fossiliferous; badly weathered fusulinids ------------------------------------	10.0
3	Siltstone; highly sandy and highly calcareous, becoming more limy in upper portion; fossiliferous; fusulinids on upper surface: *Triticites* ------	1.0
2	Shale; gray; silty in lower portion; conchoidal fracture ---------------------	2.0
1	Sandstone; medium to coarse-grained; hard; lower ledge 1.0 foot; becomes softer and thin-bedded in upper part; finer grained in upper 3.0 feet ---	4.0

BRUTON FORMATION

The term Bruton formation is here introduced for the red shales, arkosic sandstones and conglomerates, with interbedded nodular to irregularly bedded limestones, which occur between the top of the Moya formation of the Keller group below and the base of the Permian Wolfcamp above. The name is derived from Bruton Tank on the northeast side of the Oscura Mountains, near where the formation is typically exposed. The type locality of the formation is located on the northeast side of the Oscura Mountains in the SE¼ sec. 32, T. 5 S., R. 6 E., Socorro County. The type section is a composite of several exposures close together along the side of the bluff at this locality.

The rocks of the Bruton formation are largely soft red shale, with interbedded nodular limestones, all of which break down easily into slope in almost all areas of outcrop in central New Mexico. Furthermore, at the type locality they overlie the thick Moya limestones that form prominent rock terraces out from the foothills to the northeast of the Oscura Mountains. The Bruton formation is overlain by the massive basal Permian lime-stones which support the overlying cliffs and steep slopes of Abo red beds of shales and sandstones. The Bruton formation there-fore forms the slope, at and near the type locality, between the limestone terrace below and the massive limestone cliffs above. The general lithology of the units of the type section of the Bruton formation are shown graphically in the accompanying diagram (Fig. 7), and descriptions of the individual units of the type. section are as follows:

SECTION 8

Type section of the Bruton formation of the Fresnal group; north Oscura Mountains; Socorro County, New Mexico.

Top		Thickness Feet
	VIRGIL SERIES	
	FRESNAL GROUP	
BRUTON FORMATION		113.5
45	Limestone; light greenish gray; two main beds; upper surface weathers purplish; fusulinids extremely abundant; poorly exposed: *Triticites*	2.0
44	Covered	12.0
43	Limestone; medium *gray,* mottled with light gray; upper surface shows rough weathering; fusulinids abundant; irregular chert masses scattered throughout upper ledge: *Triticites*	2.0
42	Slope. Shale; red to purplish gray, showing in places; mainly sandstone in some areas of north Oscura Mountains	15.0
41	Sandstone; arkosic; highly cross-bedded, pinkish gray; coarse-grained; dense and hard; weathers pink to brown	5.0
40	Limestone; light gray; irregular beds; many bellerophon gastropods; fine-grained, dense and hard	2.0
39	Covered	5.0
38	Clay; greenish gray; mottled with purple; abundant light gray limestone nodules; poorly exposed	3.0
37	Limestone; greenish gray; highly fossiliferous; fossils showing only in section; weathers to a rough surface	2.0
36	Slope; gray to purple shale, with numerous limestone nodular masses in lower part; upper 7.0 feet reddish brown shale, with prominent gray mottling; upper 1.0 foot purplish	20.0

35–A	Limestone; gray to light gray; coarsely crystalline; three main beds 1.0 foot thick; highly algal	5.0
35	Covered	3.0–4.0
34	Shale; greenish gray; prominent purple mottling in lower 3.0 feet; upper 4.0 feet brownish red	7.0
33	Limestone; light gray; small nodules up to 1.5 inches in diameter interbedded with bluish gray shale; mainly slope	1.5
32	Shale; lower 3.0 feet purplish to brownish gray, bluish where weathered; more purplish in upper portion	6.0
31	Limestone; light gray; dense and hard; fusulinids common in lower nodular portion; poorly exposed: *Triticites*	3.0
30	Shale; dark brownish gray in lower 5.0 feet, becoming dark brownish red in upper 5.0 feet	10.0
29	Nodular limestone; as in Bed 27	1.0
28	Slope; shows red shale in places	3.0
27	Limestone; light gray; highly nodular; many sections of brachiopods	2.0
26	Limestone; light gray; dense and hard; large fusulinids; forms low slope; poorly exposed: *Triticites*	1.5
25	Shale; bright red to dark brown in upper 1.0 foot; grading downward to dark brownish gray; soft	2.0

This formation has been studied at many localities from the east central part of the Oscura Mountains, northward through the northern hills of the Lomo de las Callas, Los Pinos Mountains, Abo Canyon, Manzano Mountains and Sandia Mountains. It has also been found at several localities along the Rio Grande Valley from Cadronito Hill southward to Mud Springs Mountains, and southwestward from Mud Springs Mountains to the region of Santa Rita and Silver City.

At the type locality the Bruton formation is about 110 feet thick. In Abo Canyon the formation is about 120 feet thick. In Mud Springs Mountains it is about 105 feet thick. In the eastern part of the Oscura Mountains the Bruton formation grades south-ward laterally into the limestones, sandstones, and shales of the lower part of the Fresnal group exposed in Mocking Bird Gap.

The stratigraphic age of the rocks here referred to the Bruton formation was discussed recently by King and Read (King, 1942, pp. 674-676). As well as I can determine from their discussion, King and Read considered the rocks here described as Bruton formation to be of Permian Wolfcamp age. Based partly on the flora and apparently partly on the fauna, these workers concluded the "several hundred feet of interbedded limestones, red and gray shales, sandstones, and arkosic conglomerates" that occur below the red non-marine Abo formation in "the Sacramento Mountains east of Alamogordo, in the San Andres and Oscura Mountains, and at Abo Canyon farther north" were referable to the Wolfcamp series of the Permian. Rocks which fit the above quoted description and which occur below the red Abo formation in the Sacramento, San Andres, and Oscura Mountains and in Abo Canyon vary in age from Pennsylvanian Virgil to middle and upper Permian Wolfcamp. The prominent red shales and arkosic conglomerates, interbedded with limestones, that I have observed in the San Andres Mountains are unconformably above a thick massive fusulinid-bearing lower Permian limestone. This lower Permian limestone in turn unconformably overlies Pennsylvanian Virgil limestones and dark gray elastics that are partially deltaic in origin.

In the central and northern part of the Oscura Mountains, beds of the same general description as given by King and Read are here referred to the Bruton formation. These rocks unconformably underlie fusulinid-bearing lower Permian Wolfcamp limestone. This Wolfcamp limestone in turn is unconformably overlain by red beds of the Abo formation. However, in some areas of the Oscura Mountains, the Abo formation rests directly on the Bruton formation, the basal Permian limestone having been removed by erosion during the time of the basal Abo unconformity. In the region northward from the Oscura Mountains to Abo Canyon the relationships between the Bruton formation, the overlying Permian limestones, and the Abo red beds are almost identical with those just described from the north portion of the Oscura Mountains.

QUESTIONABLY PENNSYLVANIAN ROCKS

The upper limits of the Pennsylvanian system can be deter-mined without question in most localities in New Mexico. The few localities in which the upper limits of the Pennsylvanian cannot be determined beyond question include the Sangre de Cristo Range and the north end of the Sacramento Mountains. In the Sangre de Cristo Range, non-fossiliferous red beds of shales, arkosic conglomerates and arkosic sandstones overlie Des Moines Pennsylvanian, as was discussed on former pages.

In Fresnal Canyon in the north end of the Sacramento Mountains, upper Virgil strata of the Fresnal group are overlain unconformably by 250 feet of strata of undetermined age. These strata are composed largely of clastic red shale, gray shale, sand-stones, and conglomerates. Although some of these rocks carry marine faunas, diagnostic fossils have not been determined. Permian fusulinids referable to the genera *Triticites* and *Schwagerina* are extremely abundant in immediately overlying strata that appear to be conformable. These fusulinids are closely similar to, and presumably are closely related in age to, fusulinids in the Foraker limestone of Kansas, the Saddle Creek limestone of Texas, and the unnamed limestone immediately over the Bruton formation of central New Mexico.

Miller (1932) studied cephalopods from shales of the clay pit at Tularosa, about 10 miles northwest of Fresnal Canyon, and concluded that the cephalopods indicated a Pennsylvanian rather than a Permian age for these shales.

The cephalopod-bearing shales in the clay pit east of Tularosa lithologically resemble more closely the strata above the Fresnal group in Fresnal Canyon than they resemble any part of the type section of the Fresnal group. However, the Pennsylvanian section is apparently changing rapidly northward toward Tularosa to non-marine and brackish-water types of rocks. It is possible that the shale of the Tularosa clay pit may be equivalent in age to a portion of the type section of the Fresnal group. The correlation between the shales in the Tularosa clay pit and the stratigraphic section exposed in Fresnal Canyon is at present a moot question.

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Geographic Map of New Mexico, scale 12 miles to 1 inch. General Land Office, Washington, D. C.	1936	.35
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