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STRATIGRAPHY AND PALEONTOLOGY OF THE PENNSYLVANIAN ROCKS OF THE RIM OF THE SANDIA MOUNTAINS, SANDOVAL AND BERNALILLO COUNTIES, NEW MEXICO

By

Paul Anthony Catacosinos

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Geology

The University of New Mexico

1962

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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TO MY WIFE AND PARENTS

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Frontispiece

The Sandia Mountains from Albuquerque,

Bernalillo County, New Mexico

Aerial view east

Photograph by courtesy of Dick Kent

Frontispiece

The Sandia Mountains from Albuquerque,

Bernalillo County, New Mexico

Aerial view east

Photograph by courtesy of Dick Kent

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ABSTRACT

The primary purpose of this investigation was to determine the presence or absence of pre-Pennsylvanian strata in the central part of the Sandia Mountains, along their western scarp. No strata older than Pennsylvanian were found by the author in this area.

The strata present in the Sandia Rim include the upper clastic member of the Sandia formation and part of the lower gray limestone member of the Madera limestone, both of Pennsylvanian age.

The Sandia formation is a predominantly clastic unit of sandstone, shale, limestone, and conglomerate which rests unconformably on a profound erosion surface formed on the Precambrian Sandia granite. The formation ranges in thickness from about 175 to 300 feet. The sediments were deposited in a transitional to epineritic environment under unstable to stable shelf conditions. A micro-paleontologic and paleontologic study of this formation indicates that the lowermost exposed units are not older than Pennsylvanian. Of interest was the discovery of a 12-foot oolitic foraminiferal limestone unit.

The part of the Madera limestone present in the area is a massive, cliff-forming limestone lying conformably upon the Sandia formation. In the area studied, it ranges in thickness from 280 to 390 feet. The sediments were deposited in an epineritic to infraneritic environment under stable shelf conditions. Of significance was the discovery of the brachiopod Rhynchopora magnicosta in the Madera limestone. This is the first reported occurrence of the genus in the Pennsylvanian of New Mexico.

INTRODUCTION

Purpose of Study

The presence of pre-Pennsylvanian Paleozoic formations in northern New Mexico has only recently been demonstrated. Since 1942, strata of pre-Pennsylvanian age have been reported from the northern and southern extremities of the Sandia Mountains and this, along with the discovery of Mississippian and possible Devonian formations in the Nacimiento Mountains to the northwest and the Sangre de Cristo Mountains to the northeast, has enhanced interest in the search for pre-Pennsylvanian strata in the central part of the Sandia Mountains.

This thesis, then, was undertaken primarily to determine the presence or absence of pre-Pennsylvanian beds in the central part of the Sandia Mountains along their western scarp. Other objectives were: to measure as accurately as possible the thickness of the strata present along the western face; to collect both megafossils and microfossils; and to define more exactly the nature of the Sandia formation in the Sandia Mountains.

Location, Extent, and Accessibility

The Sandia Mountains of New Mexico are located in Bernalillo and Sandoval Counties approximately 10 miles east of the city of Albuquerque (Fig. 1).

The area studied is bounded in the following manner: along the western face of the range extending vertically from the igneous-sedimentary contact to the rim of the mountains and extending horizontally from the western part of T. 12 N., R. 5 E. to the NW1/4 sec. 5, T. 10 N., R. 5 E. Topographically, the area is bounded by the prominent elevations of Sandia Peak on the north and South Sandia Peak on the south. The over-all length of the area is approximately 10 miles (Fig. 7).

The area is accessible from Albuquerque via U. S. Highway 66 East, State Highway 10 North, State Highway 44 West, and Sandia Crest road, a total distance of about 40 miles. Accessibility along the crest of the mountains is afforded by the Sandia Crest trail which is poorly marked, intermittent, and virtually nonexistent in the central part of the range and therefore is not shown on Figure 7.

Topography

The Sandia Range trends in a general north-south direction and is S-shaped, the northern part being convex,

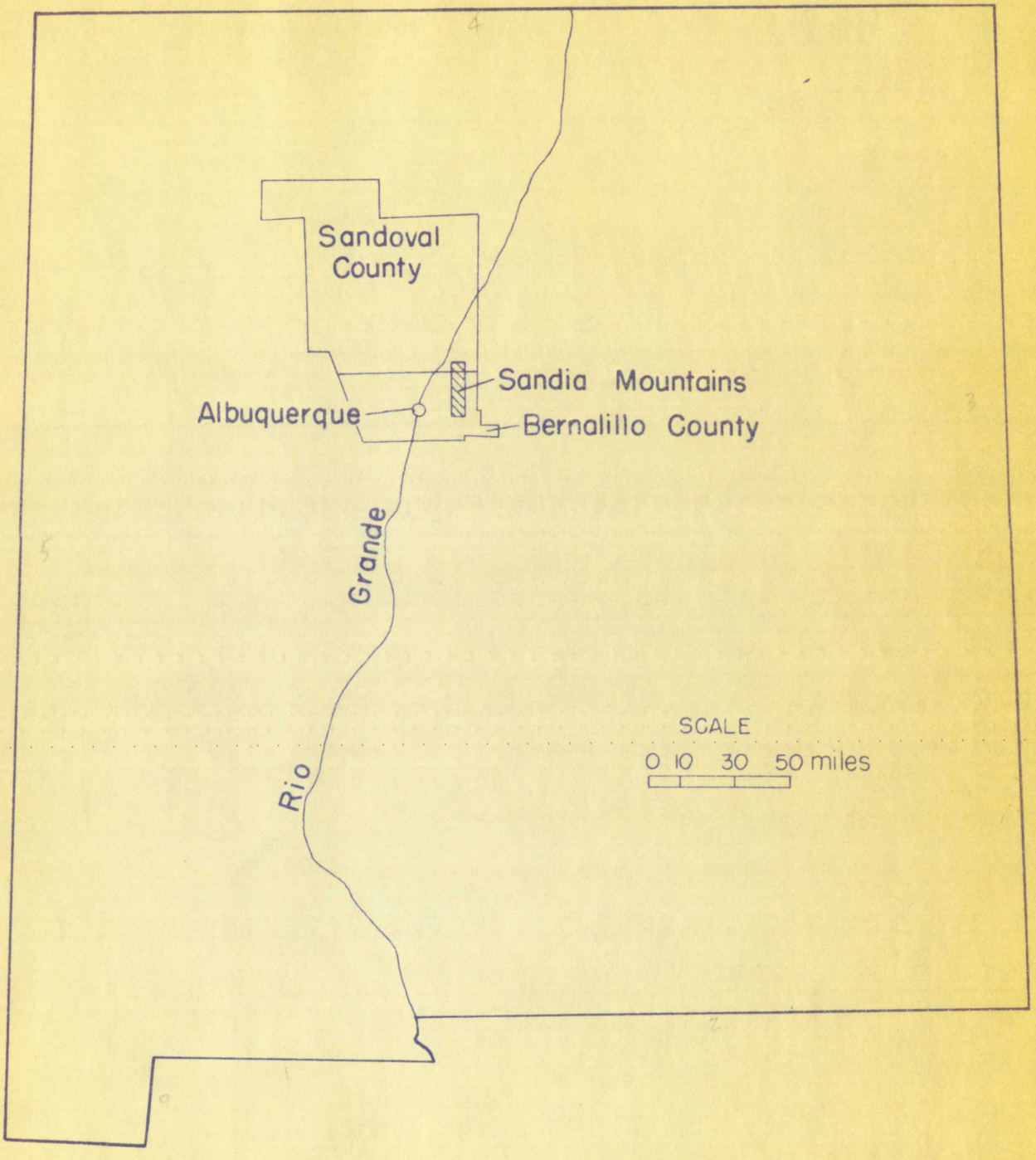

Figure 1. Index map showing area of study.

the middle part concave, and the southern part convex, toward the west (Fig. 7). This is primarily due to the combined effects of faulting and erosion in the central part of the range. The maximum relief of the mountains is on the order of 5,000 feet with the highest elevation recorded at Sandia Crest, 10,678 feet above sea level. The western face is quite rugged and supports little vegetation except along the upper 700 feet. The eastern or dip slope is heavily covered by vegetation including ponderosa pine, limber pine, white fir, Douglas fir, and blue spruce.

Wildlife in the area includes mice, squirrel, deer, bobcat, and Rocky Mountain bighorn sheep. The State Game and Fish Department estimates that there are 600 bighorns in the range (oral communication, Alan Robinson, 1961). Climbing conditions, though hazardous, were facilitated by the use of game trails and talus slopes.

Previous Investigations

Marcou (1856; 1858) was one of the earliest to make reference to the general area of the Sandia Mountains. At the village of Tijeras he collected the types of Spirifer rockymontanus and noted an abundance of horn corals both here and on the summit of the Sandias. On October 8, 1853, he wrote:

Figure 2

Northern part of the Sandia Mountains

The Madera limestone forms the prominent ledges immediately below the rim of the mountains. Underlying these ledges is the slope-forming Sandia formation. The deeply eroded Sandia granite forms the core of the range. Aerial view east.

Photograph by courtesy of Dick Kent

Figure 2

Northern part of the Sandia Mountains

The Madera limestone forms the prominent ledges immediately below the rim of the mountains. Underlying these ledges is the slope-forming Sandia formation. The deeply eroded Sandia granite forms the core of the range. Aerial view east.

Photograph by courtesy of Dick Kent

Figure 2

> "I started with my friend Dr. John Bigelow, the botanist of the expedition, to ascend the highest peak of the Sierra de Sandia * * *. The ascent of one of the most elevated summits of the Rocky Mountains,--which after all is not a very easy matter, considering the wilderness, the difficulty of the roads and the fear of the Apache Indians--was effected by Dr. Bigelow and myself the 10th of October 1853."

Later investigations were made by Ellis (1922) who discusses the geology of the Sandia Mountains, Keyes (1937) who investigated the structure of the Sandias, and Hayes (1951) who made a study of the Precambrian rocks just west and north of the present area under discussion. In the Cedro Canyon area located just south of the present area under discussion, Szabo (1953) carried out a stratigraphic and paleontologic study and reported pre-Pennsylvanian strata in Tijeras Canyon. Toomey (1953) conducted a similar study in the Placitas region at the north end of the Sandias and he too reported the presence of pre-Pennsylvanian beds. Kelley (1954; 1959) has discussed various aspects of the Sandia Mountains and Caprio (1960) made a survey of the water resources of the western slope of the Sandia Mountains. Most recently, Fitzsimmons (1961) has discussed the Precambrian rocks of the range, while Northrop (1961) has summarized the

paleontology of the Carboniferous strata of the Sandia Mountains.

Present Investigation

Field work in the Sandia Mountains was begun in the spring and completed in the fall of 1961. Sections of Pennsylvanian rocks were measured with the aid of a Brunton compass and a steel tape. Fossils were collected at the time each section was measured and also during reconnaissance trips. Petrologic samples were described, thin sections of rock samples of the Sandia formation were prepared for a micropaleontologic study, and photomicrographs were made. The maps and columnar diagrams were prepared utilizing field information and aerial photographs.

The time-stratigraphic units employed in this report are of two categories. In the more general discussions, the common geological terminology as exemplified by Pennsylvanian, Mississippian, and so forth, is used. Where it is necessary to be more specific the Midcontinent classification of Moore and Thompson (1949), slightly modified, is used. This classification is as follows:

Kawvian series	
Virgilian stage	Upper Pennsylvanian
Missourian stage	
Oklan series	
Desmoinesian stage	Middle Pennsylvanian
Atokan (Lampasan) stage	
Ardian series	
Morrowan stage	Lower Pennsylvanian
Springeran stage	

General Geologic Structure

The Sandia Mountains are the northernmost part of a system of northerly trending ranges extending some 80 miles in central New Mexico (Fig. 4). The Sandia Range is approximately 20 miles long and is bordered on the west by the Albuquerque-Belen basin which is a part of the Rio Grande depression--a major and structurally complex trough or graben. The range is bordered to the north by the Santo Domingo basin, to the east by the Tijeras and Hagan coal basins, and on the south by the Manzanita Mountains. (See Fig. 3.)

Two large, nearly parallel, north-trending faults may lie just west of the range. The westernmost one is the Hubble Springs fault (Read, Wilpolt, Andrews, Summerson, and Wood, 1944), and to the east is the Sandia fault (Fig. 3). These are high-angle normal faults with the downthrown block to the west. Kelley (1959, p. 33)

suggests that the total vertical displacement may be in excess of 11,000 feet. Joesting, Case, and Cordell (1961, p. 150) suggest 22,000 feet of displacement of the Precambrian basement rock along the Sandia front. To the north, and lying between the Hubble Springs and Sandia faults, is the La Cueva fault (Hayes, 1951, p. 28). This fault trends N. 80° E., and is a high-angle normal fault with the downthrown side to the south.

In the area studied by the author, there are a number of smaller faults present, particularly in the more central part. These faults trend in a general east-west direction, are normal, and have throws ranging from 50 to 150 feet. The downthrown sides are predominantly to the south, but some are to the north; where this has occurred, small graben-like blocks have been formed (Fig. 7). The author found and mapped a small normal fault in the vicinity of Sandia Peak which trends N. 10° E. It is downthrown to the south and has a displacement of about 50 feet.

Numerous other faults, too small to be shown on Figure 4, are also present in the central part of the area. These faults displace the strata on the order of five feet.

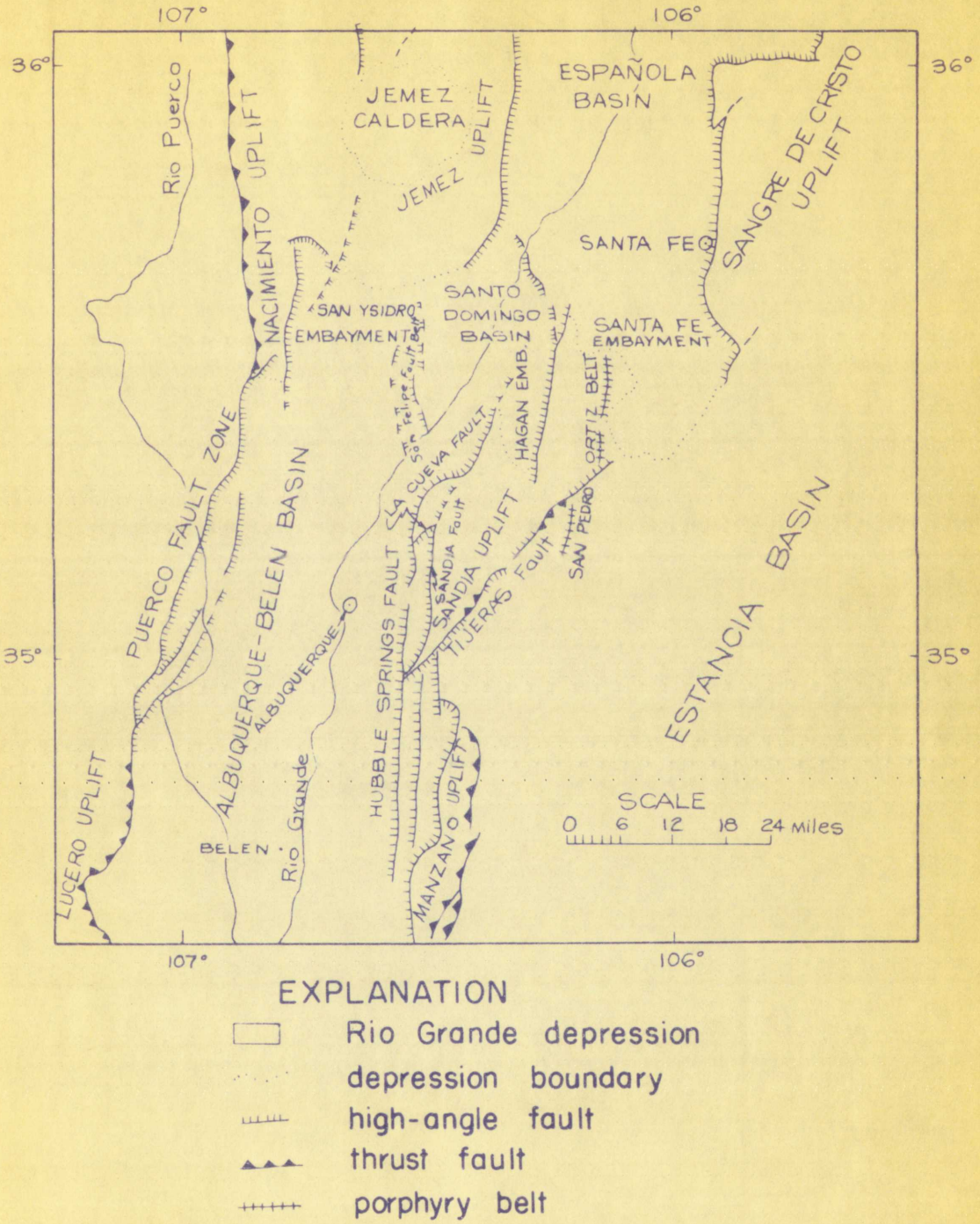

Figure 3. Tectonic map of middle Rio Grande depression (Modified from V.C. Kelley, 1954).

Acknowledgments

The author wishes to express his gratitude to Dr. Stuart A. Northrop who first suggested this study. Dr. Northrop identified the fossil specimens collected for this report; he also advised and counseled the author through certain problems encountered in the writing of the thesis.

Special thanks are due Dr. Vincent C. Kelley for his advice on the preparation of the geologic map and columnar sections, Dr. Roger Y. Anderson for his assistance in preparing the micropaleontologic section of this thesis, and Dr. Abraham Rosenzweig who allowed use of his photographic darkroom.

The writer is grateful to the New Mexico Geological Society for their grant-in-aid, to John W. Blagbrough and William G. Gustafson who assisted him on occasion in the field, Sanford Wise who prepared the photomicrographs for the author, and James L. McSwain for his criticism of the manuscript.

The author wishes finally to acknowledge the help of his wife, Joan, whose patience, understanding, and assistance made this study possible.

The author wishes to express his appreciation to Dr. Stuart A. Northrop who supervised the field operations for this report. He also wishes to acknowledge the assistance rendered by Dr. Northrop through certain problems encountered in the preparation of the thesis.

Special thanks are due to Dr. Vincent C. Kelley for his advice on the petrographic descriptions, Dr. Roger L. Peterson for assistance in preparing the illustrations for this thesis, and Dr. Mary Anne Hurley who did the photographic work.

The writer is grateful to the Geological Society for three grants-in-aid and William G. Chaney who generously assisted in the field. Thanks are also due to Dr. Charles W. Mason for the author, and James L. Kellogg for his assistance of the manuscript.

The author wishes especially to acknowledge his wife, Joan, whose patience, understanding, and assistance made this study possible.

PRECAMBRIAN ROCKS

The Precambrian rocks of the Sandia Mountains include two main rock types: the older metamorphics and the younger intrusive granite.

Metamorphic Rocks

Metamorphic rocks are present in the Placitas region of the northern Sandias (Toomey, 1953), in the Cedro Canyon area of the Manzanitas (Szabo, 1953), and in a spur of the mountains called the Rincon just west and primarily north of the area studied by the author. There are no metamorphic rocks present in the area of this report.

In his study of the Rincon, Hayes (1951, p. 7) termed all the metamorphic rocks of the Rincon the Juan Tabo sequence. On the basis of his petrographic study the entire sequence was divided into three broad groups: (1) quartzite and mica schist, (2) feldspathic and sillimanitic micaceous schist, and (3) greenstone. He considered these rocks to be the product of regional metamorphism of clastic sedimentary rocks. The thickness of the sequence was given as probably something less than 7,000 feet. Hayes considered the age of these rocks to be probably Proterozoic and possibly Archeozoic. In his

study of the Precambrian Tijeras gneiss, Lodewick (1960) determined the presence of rounded or eroded zircon and thus postulated a metasedimentary origin for the gneiss.

Sandia Granite

The main rock type which underlies entirely the sedimentary sequence of rocks present in the area of this report, and which forms the core of the Sandia Mountains, has been referred to as the Sandia granite (Reiche, 1949, pl. 5).

The rock is commonly coarse grained and has a porphyritic appearance. In the exposures visible along the approximate contact of the igneous-sedimentary rocks, the granite is so jointed and weathered as to resemble sedimentary beds. In general, there is little mineralogical variation in the Sandia granite (Fitzsimmons, 1961, p. 91). The two main mineral constituents of the granite are quartz and microcline, with lesser amounts of the plagioclase feldspars present. The common accessory minerals are biotite, sphene, apatite, magnetite, and ilmenite. Pyrite is sometimes present. The color of the granite is generally reddish, but where it has been badly weathered it is yellowish brown.

Age determinations by Aldrich, Wetherill, and Davis (1957), utilizing radioactive techniques, indicate an age

for the Sandia granite of 1,340 to 1,350 million years.

While searching for the contact between the igneous and sedimentary rocks, the author became aware of the existence of a profound erosion surface on the Sandia granite. This surface is portrayed graphically in Figure 8, which suggests a total relief of about 120 feet in 2 miles.

STRATIGRAPHY

Pre-Pennsylvanian Strata

The question of the presence of pre-Pennsylvanian Paleozoic rocks in the Sandia Mountains has been of interest to geologists for about 20 years. It had long been thought that the oldest strata of Paleozoic age present in the Sandias and for that matter, in northern New Mexico, were Pennsylvanian. In 1942, however, Thompson measured 16 feet of conglomerate and 90 feet of limestone in the northern Sandias in the vicinity of Placitas. While admitting that the age of these beds was unknown, he believed them to be of probable "lower Paleozoic age." This predominantly limestone series is underlain unconformably by Precambrian schist.

In 1951, A. K. Armstrong, an undergraduate student at the University of New Mexico, discovered megafossils of Mississippian age in the Nacimiento Mountains (Fig. 4). The formation in which they occur was subsequently named the Arroyo Penasco (Fitzsimmons, Armstrong, and Gordon, 1956, p. 1937). Prior to this, Armstrong (1955) published his observations on the Mississippian of northern New Mexico. Armstrong (1955, p. 25) shows a measured section located one mile east and south of Placitas composed of

100 feet of limestone which he correlates with the Arroyo Penasco formation. This section is underlain unconformably by Precambrian schists.

Mention should be made of the presence of a red shale unit reported both by Armstrong (1955, p. 5) and Szabo (1953, p. 17). Armstrong measured nine feet of this unit above the Arroyo Penasco formation in his Placitas section. He found it to be unfossiliferous and unconformable with the underlying Arroyo Penasco formation. He considered it equivalent to the Molas formation and correlated it with the Pennsylvanian Log Springs formation of the southern Nacimiento Mountains. Szabo measured from 4 to 17 feet of a similar unit in Tijeras Canyon at the south end of the Sandia Mountains and suggested a possible correlation with the Pennsylvanian Molas formation. Szabo, however, reported it as pre-Pennsylvanian owing to the presence of an unconformity at its top and the lack of paleontologic evidence. This unit was not found by the author in the central part of the Sandia Mountains.

Recently, in their study of the Sangre de Cristo Mountains (Fig. 4), Baltz and Read (1960) proposed two new formation names for the pre-Pennsylvanian strata there present. These are the Espiritu Santo formation for the

basal sandstone unit, and the Tererro formation for the overlying limestone. They consider the Espiritu Santo formation to be of Devonian (?) age (p. 1759), and the Tererro formation to be early Mississippian (p. 1765). Baltz and Read suggest the possibility that both formations may be correlative with the Arroyo Penasco formation, but point out (p. 1768) that:

> "Further paleontologic studies and studies of the physical stratigraphy must precede correlation, firm assignments of age, and adjustments in the terminology of the Espiritu Santo, Tererro, and Arroyo Penasco formations."

Montgomery and Sutherland (1960) published a geologic map of the upper Pecos region of the Sangre de Cristo Mountains showing the distribution of Mississippian (and older ?) beds in the area.

In their studies of the areas just north and south of the present area under discussion, Toomey (1953, p. 13) and Szabo (1953, p. 17) make reference to a white, saccharoidal, microgranular limestone or dolomite which strongly resembles marble, stratigraphically high in their pre-Pennsylvanian sections. Because of its high position in the sections and its seemingly lateral extent, one might expect it to be present in the central part of the Sandia Mountains. Accordingly, an exhaustive search was

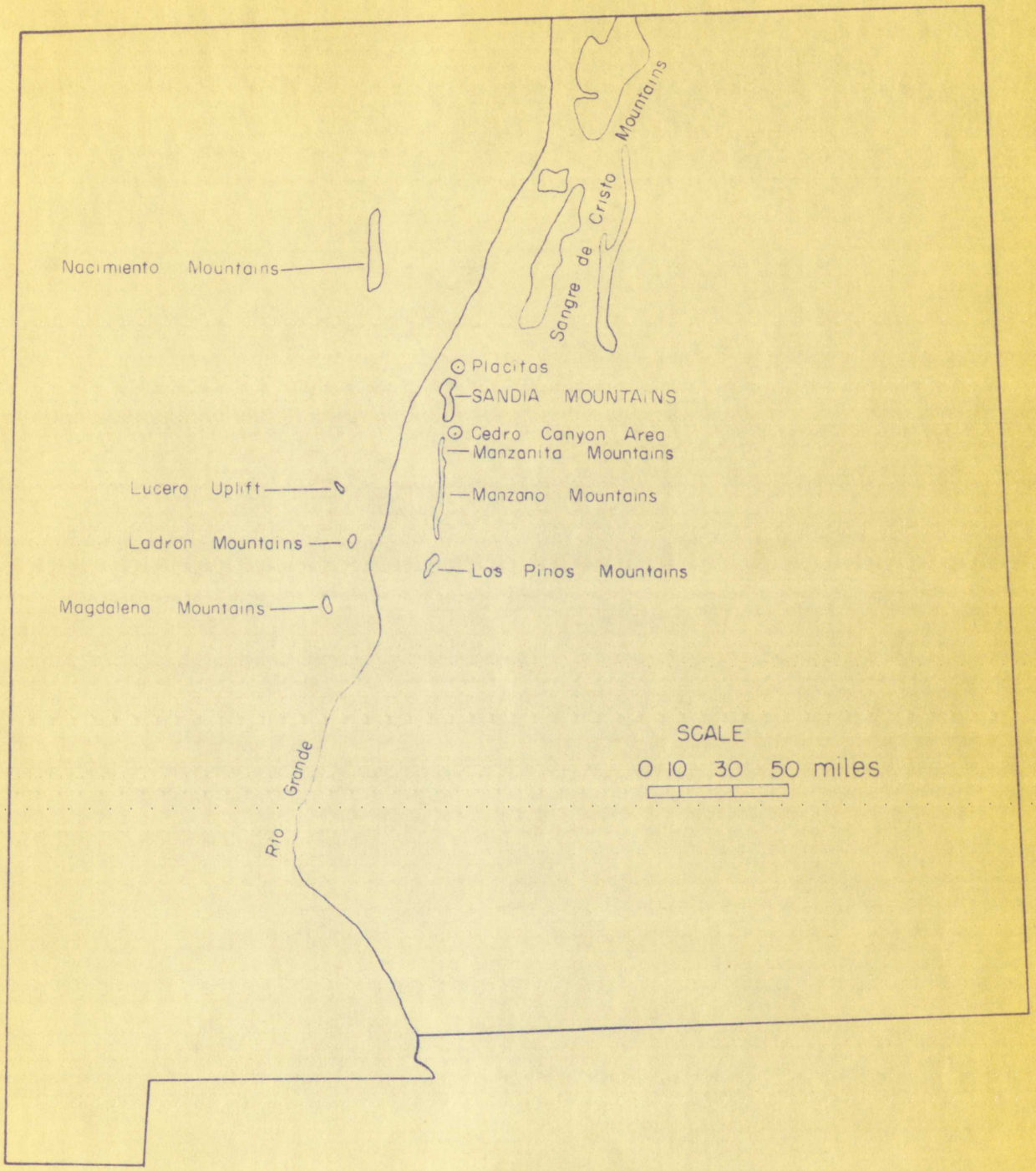

Figure 4. Map of New Mexico showing some areas referred to in this report.

made by the author for this unit or other remnants of the pre-Pennsylvanian sequence. No pre-Pennsylvanian strata were found in the area of this report.

It might be argued, with some validity, that since the stratigraphic sections measured by the author were poorly exposed, and the contact between the Sandia granite and the Sandia formation almost always obscured, pre-Pennsylvanian strata may well be present, but hidden by cover. In the Sandia Crest section (p. 30 and Fig. 8), the contact was exposed and megafossils found in limestone units SC-2-1 and SC-2-2 which indicate a definite Pennsylvanian age (p. 47, 48). Again, the microfossils found in this and other sections suggest Pennsylvanian age. Thus, while the conclusion is not absolutely proven, the evidence available to the author strongly suggests that pre-Pennsylvanian strata are absent in the central part of the Sandia Mountains. If originally present, they may have been removed by erosion during late Mississippian or early Pennsylvanian time.

Pennsylvanian System

Magdalena Group

This term was first proposed by Gordon (1907, p. 806) and was defined to include all the sedimentary rocks in

the Magdalena Mountains between the Mississippian Kelly limestone and the Permian Abo formation. The Magdalena group comprises two formations, the lowermost being the Sandia formation and the uppermost the Madera limestone. According to Kottlowski's (1961, fig. 1) isopach map of Pennsylvanian rocks in north-central New Mexico, the thickness of the Magdalena group is 1,140 feet at Placitas, 1,500 feet at Sandia Park, and 1,350 feet in Cedro Canyon.

Sandia Formation

Name.--The name Sandia formation was first proposed by Herrick (1900, p. 115) for exposures found in Tijeras Canyon. Thickness of the Sandia formation was given as 175 feet. The formation has been divided into a lower limestone member and an upper clastic member and was so mapped by Read, Wilpolt, Andrews, Summerson, and Wood (1944). The lower limestone member is now considered to be Mississippian. Only the upper clastic member was found to be present in the area of this report.

Lithology.--The Sandia formation is poorly exposed on the western face of the Sandia Mountains. It lies unconformably on the Sandia granite, and makes slopes beneath the sheer cliffs of the Madera limestone. In the area of this report the contact between the Sandia formation and

the Madera limestone was found to be almost always obscured. The author, therefore, arbitrarily chose as the contact the base of the lowermost limestone cliff of a conspicuous series of limestone cliffs.

The exposed units in the area are primarily dense limestones. They are generally medium dark gray in color and are sparsely fossiliferous. The sandstones exposed in the area are generally brownish, highly indurated, often micaceous, contain varying amounts of feldspar, and infrequently display outlines of carbonaceous residue probably originating from plant fragments. Conglomerate units are present and are well exposed in the vicinity of South Sandia Peak. The author is of the opinion that much of the covered intervals represents shale units.

The thickness of the Sandia formation ranges from about 175 feet in the Kiwanis Cabin section to about 300 feet in the Thumb Peak section. (See Fig. 7 for location of measured sections.) The variable thickness of the formation is probably due, in large part, to the irregularity of the erosion surface on which it lies (Fig. 8).

Age and Correlation.--In 1945, Northrop and Wood (p. 1185) discovered Schizophoria cf. oklahomae occurring in lower Pennsylvanian beds in Guadalupe Box Canyon, about

7 to 9 miles north of Jemez Pueblo to the east of the Nacimiento Mountains (Fig. 4). This occurrence, along with another occurrence of S. oklahomae together with Millerella in Penasco Canyon (Armstrong, 1955, p. 5), yields positive evidence of at least Morrowan age for the basal part of the formation. The upper limit has been reported as Lampasan or Atokan (Northrop and Wood, 1946). Lovejoy (1958, p. 16) suggests, on the basis of an admittedly meager fauna, that the upper limit is Lampasan (Atokan) to Desmoinesian in age. He points out, however, that this evidence is by no means conclusive.

The fossils collected by the author indicate a range in age from Atokan to Desmoinesian for the Sandia formation in the area of this report.

Fetzner (1960, p. 1377), among others, considered the Molas formation of Colorado a correlative of most of the upper clastic member of the Sandia formation of northwestern and west-central New Mexico. In the Sangre de Cristo Mountains Northrop, Sullwold, MacAlpin, and Rogers (1946) described the upper clastic member as dominantly clastic and locally carbonaceous. Northrop and Wood (1946)

mapped the Sandia formation in the Nacimiento Mountains. The upper clastic member was described as brownish sandstone and impure arenaceous limestone. The thickness varies considerably. Lovejoy (1958, p. 15) reported approximately 200 feet of the formation along the upthrown side of the Jemez fault.

In the Lucero uplift region (Fig. 4), Kelley and Wood (1946) reported the upper clastic member to be approximately 400 feet thick, some 150 feet thicker than the average found in the area of this report. Noble (1950, p. 46) found thicknesses of 642 feet and 402 feet in two measured sections in the southern Ladron Mountains (Fig. 4).

Harrison (1949, p. 21) measured 265 feet of Sandia formation approximately one and one-half miles east of Placitas. Only 172 feet of this section, however, can be considered undisputed Sandia as Harrison (1949, p. 16) equated his Basal quartzose member and Middle limestone member to the lower limestone member of the Sandia, now regarded as Mississippian. Toomey (1953, p. 45-46) showed the Sandia formation to range in thickness from 49 to 86 feet in the Placitas area. These figures seem somewhat anomalous. Szabo (1953, p. 29) measured 115 feet

of Sandia in the Cedro Canyon area.

In the area studied, the author found correlation between his measured sections to be extremely difficult, owing to the large amount of covered intervals. A gross lithologic correlation was attempted, however, and is depicted in Figure 8.

Measured Sections.--In selecting and measuring these sections of the Sandia formation, the author could find the contact between the Sandia granite and the Sandia formation, and between the Sandia formation and the Madera limestone in only one locality--the vicinity of Sandia Crest. Indeed, in the area between the Tree Springs and South Sandia Peak sections, a distance of about four miles, no section could profitably be selected owing primarily to the heavy vegetative cover, slope wash, and talus present. The measured sections are considered to be correct within a margin of error of plus or minus ten feet. Particle sizes were determined in accordance with Wentworth's (1920) recommendations. The colors and color numbers are from the Rock-color chart of the National Research Council, Washington, D. C., 1948. Bedding terms are modified from Wengerd (1957).

The sections are given in the order taken, that is, from north to south (see Fig. 7 for locations). The notation SP-1, TSS-3, and so on, indicates a petrologic sample and/or a paleontologic collection. These numbers do not correspond to interval numbers.

Sandia Peak

Interval		Feet
Madera limestone above.		
(Contact obscured)		
Sandia formation:		
12.	COVERED INTERVAL ----------	11.0
11.	CHERT, yellowish-gray (5Y 7/2) to light olive-gray (5Y 5/2), medium-bedded; weathers light browhish-gray (5YR 6/1); SP-6 ----------	3.3
10.	LIMESTONE, medium light-gray (N6), massive-bedded, dense, jointed, cherty, fossiliferous; weathers medium dark-gray (N4); SP-5 ----------	20.0
9.	COVERED INTERVAL ----------	48.0
8.	LIMESTONE, medium light-gray (N6), medium-bedded, dense, fossiliferous; weathers light-gray (N7); SP-4-2 -----	
	Limestone, dark-gray (N3), massive-bedded, dense, fossiliferous; fetid odor; weathers pale yellowish-brown (10YR 6/2); SP-4-1 ----------	9.0
7.	COVERED INTERVAL ----------	12.0

Interval		Feet
6.	LIMESTONE, very light-gray (N8), medium-bedded, clastic; subhedral particles, some containing black platy mineral; well cemented; weathers light brownish-gray (5YR 6/1); SP-3 ----------	2.5
5.	COVERED INTERVAL ----------	93.0
4.	CONGLOMERATE, light olive-gray (5Y 6/1), medium-bedded, becoming thin-bedded upwards, micaceous; quartz fragments, ranging from 2 to 4 mm; black mineral (hornblende ?); highly weathered orthoclase fragments; weathers medium-gray (N5); SP-2 ----------	2.0
3.	COVERED INTERVAL ----------	15.1
2.	SANDSTONE, yellowish-gray (5Y 7/2), massive-bedded, micaceous; quartz grains clear, unfrosted, angular; highly indurated; silica cement; weathers light olive-gray (5Y 6/1); SP-1 ----------	5.0
1.	COVERED INTERVAL ----------	35.1
	Total thickness of Sandia formation --	256.0

(Contact obscured)

Sandia granite below.

Thumb Peak

Madera limestone above.

(Contact obscured)

Sandia formation:

7.	COVERED INTERVAL ----------	95.4

Interval		Feet
6.	LIMESTONE, medium dark-gray (N4), medium-bedded, dense, fossiliferous; platy chert; trace of feldspar; well cemented; weathers light olive-gray (5Y 6/1); TP-3 ----------	11.0
5.	COVERED INTERVAL ----------	25.1
4.	LIMESTONE, medium dark-gray (N4), very thin-bedded, dense, cherty, fossiliferous; well cemented; weathers light olive-gray (5Y 6/1); TP-2 ----------	12.0
3.	COVERED INTERVAL ----------	127.6
2.	CONGLOMERATE, light brownish-gray (5YR 6/1), thin-bedded, some cross-bedding; very coarse to coarse quartz grains, subangular to subrounded; occasional large chert and feldspar particles (greater than 4 mm); some well-crystallized secondary quartz present; well cemented; weathers yellowish-gray (5Y 8/1); TP-1 ----------	14.7
1.	COVERED INTERVAL; float contains sandstone with unidentifiable fossil plant fragments ----------	12.0
	Total thickness of Sandia formation --	297.8

(Contact obscured)

Sandia granite below.

Interval

Sandia Crest

Interval		Feet
Madera limestone above.		
Sandia formation:		
16.	LIMESTONE, white (N9), medium-bedded, clastic; subrounded particles; some quartz; weathers yellowish-gray (5Y 8/1); SC-12 ----------	4.7
15.	LIMESTONE, medium light-gray (N6) to light-gray (N7), medium-bedded, becoming massive-bedded upwards, dense, extremely cherty; contains some crinoidal fragments; weathers grayish orange-pink (5YR 7/2); SC-11 ----------	30.1
	Offset 35 feet southerly	
14.	COVERED INTERVAL ----------	95.4
13.	LIMESTONE, medium light-gray (N6), medium-bedded, dense, cherty, fossiliferous; weathers light brownish-gray (5YR 6/1); SC-10 --------	15.1
12.	COVERED INTERVAL ----------	40.2
11.	SANDSTONE, pale-red (10R 6/2), medium-bedded, feldspathic, micaceous; hematitic and limonitic staining; well cemented; weathers moderate yellowish-brown (10YR 5/4); SC-9 -----	2.3
10.	COVERED INTERVAL; some shale weathering out in float ----------	4.0
9.	SANDSTONE, light olive-gray (5Y 5/2), massive-bedded, becoming thin-bedded upwards, feldspathic, micaceous; quartz grains subangular	

Interval		Feet
	to subrounded; fossils poorly preserved as a carbonaceous residue smear; thin-bedded units have extensive hematitic staining on bedding planes; weathers light olive-gray; (5Y 5/2); SC-8 ----------	4.0
8.	LIMESTONE, medium-gray (N5), medium-bedded, becoming massive-bedded upwards, crystalline, fossiliferous; coarse calcite cement; weathers light olive-gray (5Y 6/1); SC-7 -------	10.0
7.	LIMESTONE, light olive-gray (5Y 6/1), medium-bedded, crystalline; mineralized: quartz (well-crystallized), galena (average size 15 x 10 x 5 mm); some limonitic and hematitic staining; well cemented, silica cement; weathers light olive-gray (5Y 6/1); SC-6 ----------	6.0
6.	LIMESTONE, light-gray (N7), medium-bedded, becoming thin-bedded upwards, crystalline; hematitic and limonitic staining; well cemented, silica cement; weathers light-gray (N7); SC-5 --------	6.5
5.	SHALE, medium dark-gray (N4), thin-bedded, fossiliferous; poorly cemented by calcite; weathers light olive-gray (5Y 6/1); SC-4 ----------	.5
4.	LIMESTONE, medium-gray (N5), medium-bedded, crystalline, fossiliferous; some muscovite; calcareous shale stringers; weathers moderate yellowish-brown (10YR 5/4); SC-3 -----	2.7
3.	COVERED INTERVAL ----------	2.0

Interval		Feet
2.	LIMESTONE, medium-gray (N5), thin-bedded, well-crystallized, fossiliferous; some subrounded quartz fragments; locally stained red and yellow; weathers light olive-gray (5Y 6/1); SC-2-2 and SC-2-1 ----------	2.5
1.	LIMESTONE, light olive-gray (5Y 6/1), medium-bedded, clastic, feldspathic; fragments of quartz, feldspar, mica, and some calcite; well-crystallized calcite cement; weathers medium light-gray (N6); SC-1 ----------	3.3
	Total thickness of Sandia formation --	229.3

Sandia granite below.

Kiwanis Cabin

Madera limestone above.

(Contact obscured)

Sandia formation:

3.	COVERED INTERVAL; sandstone float in lower portion ----------	159.8
2.	SANDSTONE, very dusky red-purple (5RP 2/2), grading upwards to grayish orange-pink (5YR 7/2), thin-bedded, becoming medium-bedded upwards, locally arkosic, slightly micaceous; quartz grains subangular to subrounded; well indurated to friable; weathers grayish red-purple (5RP 4/2), grading to grayish-pink (5R 8/2); KC-1 ----------	9.8

Interval		Feet
1.	COVERED INTERVAL ----------	4.9
	Total thickness of Sandia formation --	174.5

(Contact obscured)

Sandia granite below.

Tree Springs

Madera limestone above.

(Contact obscured)

Sandia formation:

7.	COVERED INTERVAL ----------	17.9
6.	LIMESTONE, medium light-gray (N6), massive-bedded, cherty, fossiliferous; well cemented; weathers light olive-gray (5Y 6/1); TSS-4 ----------	9.9
5.	COVERED INTERVAL ----------	84.4
4.	LIMESTONE, medium-gray (N5), medium-bedded, becoming thin-bedded upwards, very finely crystalline, oolitic, fossiliferous; weathers light-gray (N7); TSS-3 ----------	12.7
3.	COVERED INTERVAL ----------	24.8
2.	SANDSTONE, pinkish-gray (5YR 8/1), thin-bedded, feldspathic, micaceous; coarse quartz grains, subangular to subrounded; feldspar grains about 2 mm; augite; diopside; well cemented; weathers light brownish-gray (5YR 6/1); TSS-2 ----------	3.5

Interval		Feet
1.	COVERED INTERVAL, sandstone float in lower portion ----------	79.4
	Total thickness of Sandia formation --	232.6

(Contact obscured)

Sandia granite below.

South Sandia Peak

Madera limestone above.

(Contact obscured)

Sandia formation:

17.	COVERED INTERVAL, extends upward to the rim of the Sandia Mountains ------	20.1
16.	LIMESTONE, light olive-gray (5Y 6/1), thin-bedded, becoming medium-bedded upwards; quartz and feldspar particles, granule to pebble size; poorly cemented; weathers light olive-gray (5Y 6/1); SSP-10 ----------	15.1
15.	COVERED INTERVAL ----------	7.3
14.	LIMESTONE, medium dark-gray (N4), medium-bedded, dense, fossiliferous; fragments of quartz; trace of weathered chalcopyrite; well cemented; weathers medium-gray (N5); SSP-9 ----------	2.0
13.	CONGLOMERATE, yellowish-gray (5Y 8/10) to greenish-gray (5GY 6/1), thin-bedded, calcareous; quartz and feldspar, granule to pebble size; shale or silt fragments; hematite flecks; poorly cemented, calcite cement; weathers light olive-gray (5Y 6/1); SSP-8 ----------	6.3

Interval		Feet
12.	COVERED INTERVAL ----------	10.0
11.	LIMESTONE, medium light-gray (N6), thin-bedded, crystalline, fossiliferous; poorly cemented; weathers light-gray (N7); SSP-7 ----------	10.0
10.	CONGLOMERATE, yellowish-gray (5Y 8/1), thin-bedded, cross-bedded, calcareous; green quartz fragments, 2 to 4 mm; some mica; poorly cemented, calcite cement; weathers yellowish-gray (5Y 8/1); SSP-6 -------	5.0
9.	COVERED INTERVAL ----------	21.7
8.	SANDSTONE, light olive-gray (5Y 6/1), medium-bedded, becoming thin-bedded upwards, cross-bedded, calcareous; quartz grains, medium size, sub-angular; feldspar; mica; well cemented, calcite cement; grades into a noncalcareous conglomerate towards top; weathers pale red (10R 6/2); SSP-5 ----------	27.4
7.	CONGLOMERATE, yellowish-gray (5Y 8/1), medium-bedded, becoming thin-bedded upwards; granule to pebble size particles, subangular to rounded; some feldspar, some green quartz (?); muscovite; well cemented, weathers light olive-gray (5Y 6/1); SSP-4 -----	5.0
6.	LIMESTONE, greenish-gray (5GY 6/1), thin-bedded, arenaceous, micaceous; scattered black shale and green mud-stone particles throughout; weathers light olive-gray (5Y 6/1); SSP-3 -----	3.2
5.	COVERED INTERVAL ----------	48.2

Interval		Feet
4.	SANDSTONE, grayish-pink (5R 8/2), medium-bedded, becoming thin-bedded upwards, arkosic; quartz grains, medium to coarse in size, subangular to subrounded; muscovite; highly weathered feldspar; occasional quartz pebbles included; well cemented, weathers pale-red (5R 6/2); SSP-2 ----------	5.0
3.	COVERED INTERVAL ----------	45.2
2.	LIMESTONE, light olive-gray (5Y 5/2), thin-bedded, becoming medium-bedded upwards, clastic, fossiliferous; feldspar, quartz; possible gypsum; slightly micaceous; quartz pebbles and granules included towards top; poorly cemented; weathers pale-brown (5YR 5/2); SSP-1 ----------	25.1
1.	COVERED INTERVAL ----------	15.1
	Total thickness of Sandia formation --	271.7

(Contact obscured)

Sandia granite below.

Madera Limestone

Name.--The term Madera limestone was first proposed by Keyes (1903, p. 48) for the thick limestone sequence overlying the Sandia formation near the village of La Madera in the eastern foothills of the Sandia Mountains. Various investigators have subdivided the formation into two or three members. At the present time, the two most commonly

used divisions are the lower gray limestone and upper arkosic limestone members.

Lithology.--In the area studied, the Madera limestone overlies conformably the Sandia formation. Darton (1928) commented on the gradational nature of the contact between the Sandia formation and the Madera limestone and noted that the transitions from one formation to the other differ in different localities. On the west face of the Sandia Mountains, the Madera limestone forms a succession of sheer cliffs commonly 30 feet high. Although these cliffs appear to be continuous they are not, owing to the effects of erosion and cover. The limestone is commonly dense, cherty, and locally fossiliferous. The covered intervals represent limestone, probably shale, and possibly sandstone units, but no exposed sandstone units were found by the author in any of the measured sections. The thickness of the Madera limestone along the western face of the Sandia Mountains ranges from about 280 feet in the Tree Springs section to about 390 feet in the Sandia Peak area.

Age.--Northrop (1961, p. 111) indicates a range in age for the Madera limestone in the Sandia country from Desmoinesian to Virgilian. The fossils collected by the

Figure 5

Central part of the Sandia Mountains

Localities included in this southeast aerial view of the rim are Sandia Crest at the extreme left, Kiwanis Cabin left of center, and Tree Springs near upper right corner.

Photograph by courtesy of Dick Kent

Figure 5

Central part of the Sandia Mountains

Localities included in this southeast aerial view of the rim are Sandia Crest at the extreme left, Kiwanis Cabin left of center, and Tree Springs near upper right corner.

Photograph by courtesy of Dick Kent

Figure 5

author indicate a Desmoinesian age for that part of the Madera limestone exposed along the western face of the Sandia Mountains.

Measured Sections.--Only that part of the lower gray limestone member of the Madera limestone, from the contact with the Sandia formation to the rim of the Sandia Mountains, was measured. A summary of megafossils collected is given in the section on Paleontology. See Figure 7 for the locations of the measured sections.

Sandia Peak

Interval	Feet
Upper part of the Madera limestone not measured.	
(Rim of the Sandia Mountains)	
Lower part of the Madera limestone:	
21. LIMESTONE, light-gray (N7), medium-bedded. Contains fossils but these are poorly preserved; on the dip slope of the rim numerous large crinoid columnals replaced by red silica are present; cherty nodules; well cemented; weathers light olive-gray (5Y 6/1); SP-13 ----------	31.1
20. LIMESTONE, medium-gray (N5), massive-bedded, dense, crinoidal; brachiopods abundant; weathers yellowish-gray (5Y 8/1); SP-12-1 and SP-12-2 ----------	30.1

Interval		Feet
19.	COVERED INTERVAL ----------	35.1
18.	LIMESTONE, medium-gray (N5), thin-bedded, fossiliferous; interbedded with shaly limestone; well cemented; weathers yellowish-gray (5Y 8/1); SP-11 ----------	32.1
17.	LIMESTONE, medium-gray (N5), dominantly thin-bedded, crinoidal; well cemented; weathers very pale-orange (10YR 8/2); SP-10 ----------	30.1
16.	LIMESTONE, medium light-gray (N6), massive-bedded, sparsely fossiliferous; white chert stringers, 1-6 inches in thickness; weathers yellowish-gray (5Y 8/1) to light olive-gray (5Y 6/1); SP-9 ----------	26.1
15.	COVERED INTERVAL ----------	130.5
14.	LIMESTONE, light-gray (N7), massive-bedded, dense, fossiliferous; weathers yellowish-gray (5Y 7/2); SP-8-2 ----------	40.2
13.	LIMESTONE, medium dark-gray (N4), medium-bedded, becoming thin-bedded upwards, dense, fossiliferous; fetid odor; red chert particles; interbedded with calcareous shale; well cemented; weathers yellowish-gray (5Y 7/2); SP-8-1 ----------	35.1
	Total thickness of exposed Madera limestone ----------	390.4

(Contact obscured)

Sandia formation below.

Thumb Peak

Upper part of the Madera limestone not measured.

(Rim of the Sandia Mountains)

Lower part of the Madera limestone:

Interval		Feet
16.	LIMESTONE, medium-gray (N5), thin-bedded, becoming medium-bedded upwards, dense, extremely cherty, sparsely fossiliferous; weathers grayish-orange-pink (5YR 7/2); TP-8 ----------	58.2
15.	COVERED INTERVAL ----------	10.0
14.	LIMESTONE, light olive-gray (5Y 5/2), massive-bedded, becoming medium-bedded upwards, dense, sparsely fossiliferous; some chert; weathers very light-gray (N8); TP-7 ----------	35.1
13.	LIMESTONE, medium light-gray (N6), medium-bedded, becoming thin-bedded upwards, dense, cherty, fossiliferous; fetid odor; weathers yellowish-gray (5Y 7/2); TP-6 ----------	36.1
12.	COVERED INTERVAL ----------	73.3
11.	LIMESTONE, light-gray (N7), massive-bedded, dense, cherty; contains some crinoidal fragments; weathers light olive-gray (5Y 6/1); TP-5 ----------	21.1
10.	COVERED INTERVAL ----------	45.2
9.	LIMESTONE, very light-gray (N8), massive-bedded, dense, fossiliferous; weathers light olive-gray (5Y 6/1); TP-4-2 ----------	36.1

Interval		Feet
8.	LIMESTONE, medium-gray (N5), medium-bedded, becoming thin-bedded upwards, dense, fossiliferous; fetid odor; interbedded with calcareous shale; weathers very pale-orange (10YR 8/2); TP-4-1 ----------	25.1
	Total thickness of exposed Madera limestone ----------	340.2

(Contact obscured)

Sandia formation below.

Sandia Crest

Upper part of the Madera limestone not measured.

(Rim of the Sandia Mountains)

Lower part of the Madera limestone:

26.	LIMESTONE, medium-gray (N5), thin-bedded, becoming medium-bedded upwards, dense, cherty nodules; weathers light olive-gray (5Y 6/1); SC-18 ----------	19.4
25.	COVERED INTERVAL ----------	35.1
24.	LIMESTONE, light-gray (N7), thin-bedded, becoming medium-bedded upwards, dense, fossiliferous; weathers grayish orange-pink (5YR 7/2); SC-17 ----------	75.3
23.	COVERED INTERVAL ----------	15.1

Interval		Feet
22.	LIMESTONE, very light-gray (N8), medium-bedded, becoming massive-bedded upwards, dense, extremely cherty; chert stringers; weathers grayish orange-pink (5YR 7/2); SC-16	15.1
21.	COVERED INTERVAL	20.1
20.	LIMESTONE, very light-gray (N8), medium-bedded, dense; some chert; weathers light-gray (N7); SC-15	11.0
19.	COVERED INTERVAL	40.2
18.	LIMESTONE, light-gray (N7), massive-bedded, dense, fossiliferous; weathers grayish orange-pink (5YR 7/2); SC-14	25.1
	Offset 40 feet northerly	
17.	LIMESTONE, medium-gray (N5), medium-bedded, becoming thin-bedded upwards, dense, fossiliferous; interbedded with clastic limestone; weathers yellowish-gray (5Y 8/1); SC-13	41.2
	Total thickness of exposed Madera limestone	297.6

Sandia formation below.

Kiwanis Cabin

Upper part of the Madera limestone not measured.

(Rim of the Sandia Mountains)

Lower part of the Madera limestone:

Interval		Feet
17.	LIMESTONE, medium light-gray (N6), thin-bedded, becoming medium-bedded upwards, dense, cherty, abundantly fossiliferous; weathers yellowish-gray (5Y 8/1); KC-10	46.8
	Offset 150 feet northerly	
16.	LIMESTONE, medium-gray (N5), dominantly massive-bedded, dense; nodular chert; weathers light-gray (N8); KC-9	88.8
15.	COVERED INTERVAL	5.9
14.	LIMESTONE, light-gray (N7), thin-bedded, becoming medium-bedded upwards, dense, fossiliferous; white cherty stringers irregularly bedded throughout; weathers grayish orange-pink (5YR 7/2); KC-8	24.5
13.	COVERED INTERVAL	7.9
12.	LIMESTONE, medium-gray (N5), ranges from thin-bedded at base to massive-bedded to medium-bedded at top; dense, cherty towards top, abundantly fossiliferous; weathers yellowish-gray (5Y 8/1); KC-7	34.3
11.	COVERED INTERVAL	7.4
10.	LIMESTONE, medium light-gray (N6), medium-bedded, becoming massive-bedded upwards, dense, cherty; weathers light olive-gray (5Y 6/1); KC-6	28.0
9.	LIMESTONE, white (N9), medium-bedded, well-crystallized; calcite angular to subrounded; fairly well cemented; weathers light olive-gray (5Y 6/1); KC-5	5.0

Interval		Feet
8.	COVERED INTERVAL ----------	9.8
7.	LIMESTONE, medium light-gray (N6), massive-bedded, becoming medium-bedded upwards, dense, extremely cherty at base, fossiliferous; gastropods and corals at top; weathers yellowish-gray (5Y 8/1); KC-4 ----------	26.5
	Offset 60 feet northerly	
6.	COVERED INTERVAL ----------	49.0
5.	LIMESTONE, light-gray (N7), massive-bedded, dense, extremely cherty; weathers yellowish-gray (5Y 8/1); KC-3 ----------	23.9
	Offset 20 feet northerly	
4.	LIMESTONE, medium dark-gray (N4), thin-bedded, becoming medium-bedded upwards, dense, cherty, fossiliferous; weathers light olive-gray (5Y 6/1); KC-2 ----------	22.1
	Total thickness of exposed Madera limestone ----------	379.9

(Contact obscured)

Sandia formation below.

Tree Springs

Upper part of the Madera limestone not measured.

(Rim of the Sandia Mountains)

Lower part of the Madera limestone:

Interval		Feet
12.	LIMESTONE, light-gray (N7), thin-bedded, becoming medium-bedded upwards, dense, cherty, fossiliferous; weathers medium-gray (N5); TSS-7 ----------	104.2
	Offset 40 feet southerly	
11.	COVERED INTERVAL ----------	9.9
10.	LIMESTONE, greenish-gray (5GY 6/1), ranges from thin-bedded at base to massive-bedded to medium-bedded at top, cherty; weathers yellowish-gray (5Y 7/2); TSS-6 ----------	24.8
9.	COVERED INTERVAL ----------	74.5
8.	LIMESTONE, dark-gray (N3), ranges from medium-bedded at base to massive-bedded to medium-bedded at top, dense, extremely cherty, fossiliferous; chert in irregular masses; well-indurated shaly lenses, about 2-inch bedding; weathers yellowish-gray (5Y 8/1); TSS-5 -------	70.0
	Total thickness of exposed Madera limestone ----------	283.4

(Contact obscured)

Sandia formation below.

PALEONTOLOGY

Sandia Formation

Megafossils

The megafossils were identified by Dr. S. A. Northrop (memorandum, March 11, 1962). This section should be considered, in essence, as a direct quotation from the memorandum. The author has taken the liberty of editing and rearranging slightly the order of presentation. The notations TP-2, SC-13, and so on, refer to the sample number within the appropriate measured section. The localities where collections were made from float are indicated on Figure 7.

Thumb Peak Section

TP-2

Fenestelloid bryozoan
Spirifer cf. *occiduus*

TP-3

Rhomboporoid bryozoan
Phricodothyris perplexa
Crinoid columnals

Sandia Crest Section

SC-2-1

Spirifer occiduus
Crinoid columnals

SC-2-2

Spirifer occiduus
Crinoid columnals

SC-3

Fenestelloid bryozoan
Spirifer sp.
Crinoid columnals

SC-4

Tetracoral
Composita? sp.
Spirifer rockymontanus
Crinoid columnals

SC-7

Rhomboporoid bryozoan
Composita? sp.
Spirifer occiduus

Sandia Crest Float Locality

Spirifer occiduus

Microfossils

The author restricted his micropaleontological investigation to the Sandia formation. A total of 21 thin sections were prepared; of these, 12 were found to be significant and are herein described. The best examples of both limestone texture and fauna are included in Plates 1 to 7, and these represent seven of the twelve thin sections described.

One unit, TSS-3, deserves special comment. This limestone sample has an oolitic texture in hand specimen. In thin section, the oolites are seen to be formed around many kinds of fossils, including Foraminifera, bryozoan fragments, and others (Pl. 3). The vertical and lateral extent of this unit is not known as it was not seen in any of the other measured sections.

Sandia Peak Section

SP-4-1

Texture typical "fossil hash"; brachiopod valves, productoid spines, crinoid fragments, fusulinids, trepostome bryozoan; (Pl. 6, fig. 1; Pl. 7, figs. 3 and 4).

SP-4-2

Texture typical "fossil hash"; cryptostome bryozoan, Rhombopora? sp., bryozoan fragments, fusulinids, arenaceous Foraminifera, Textularia? sp., crinoid fragments, brachiopod valves, productoid spines; (Pl. 1, figs. 1 and 2; Pl. 4, fig. 1; Pl. 5, fig. 3; Pl. 6, figs. 2 and 3).

SP-5

Many replaced and partially replaced fossil fragments.

Thumb Peak Section

TP-2

"Spiny" texture; bryozoan fragments, fenestelloid bryozoan; (Pl. 7, fig. 2).

TP-3

Texture typical "fossil hash"; crinoid fragments, bryozoan fragments, fusulinids, Endothyra? sp., other Foraminifera; (Pl. 2, figs. 1 and 2).

Sandia Crest Section

SC-2-2

Texture typical "fossil hash"; quartz and feldspar grains; bryozoan fragments, crinoid fragments, fusulinids, Fusulinella? sp.; (Pl. 4, fig. 2; Pl. 5, fig 2).

SC-3

Texture typical "fossil hash"; bryozoan fragments, crinoid fragments, productoid spines.

SC-4

Shale, calcite cement; crinoid fragments, productoid spines, brachiopod valves, trepostome bryozoan.

SC-10

Ooze texture; replaced productoid brachiopod spine; (Pl. 7, fig. 1).

Tree Springs Section

TSS-3

Oolitic texture; oolites suspended in sparry calcite cement; productoid spines, arenaceous Foraminifera, bryozoan fragments, crinoid fragments, all of which are contained within the oolites; (Pl. 3, figs. 1 and 2; Pl. 5, fig. 1).

TSS-4

Productoid and other(?) spines, replaced by chert.

South Sandia Peak Section

SSP-9

Quartz grains; bryozoan fragments, crinoid fragments, fusulinids.

Summary

Following is a list of the fauna collected from the Sandia formation.

Phylum Protozoa

Endothyra? sp.
Fusulinella? sp.
Textularia? sp.
Fusulinids; several genera and species probably present
Arenaceous Foraminifera

Phylum Coelenterata

Tetracoral

Phylum Bryozoa

Rhombopora? sp.
Cryptostome bryozoan
Fenestelloid bryozoan
Rhomboporoid bryozoan
Trepostome bryozoan
Bryozoan fragments

Phylum Brachiopoda

Composita? sp.
Phricodothyris perplexa
Spirifer occiduus
S. cf. occiduus
S. rockymontanus
S. sp.
Productoid spines
Productoid and other(?) spines
Brachiopod valves

Phylum Echinodermata

Crinoid columnals
Crinoid fragments

Phylum Unknown

Many replaced and partially replaced fossil fragments

Toomey (1953) reports 12 species of invertebrates from the Sandia formation of the Placitas area, including Spirifer occiduus and S. rockymontanus, and also 5 species of plants. Szabo (1953) cites 9 species from the Sandia formation of Tijeras Canyon, including Phricodothyris perplexa, Spirifer occiduus, and S. rockymontanus.

This is admittedly a meager fauna. However, it seems to be of Atokan to early Desmoinesian age. Thompson (1942, p. 49) assigned the Sandia formation to the lower part of his Armendaris group, and in turn, to the lower part of the Des Moines series.

Madera Limestone

Megafossils

The fossil specimens were collected only from that part of the lower gray limestone member of the Madera limestone exposed along the western face of the Sandia Mountains.

Sandia Peak Section

SP-8-1

Tetracoral
Desmoinesia? sp.
Neospirifer dunbari alatus
Crinoid columnals

SP-8-2

Desmoinesia cf. *missouriensis*

SP-11

Kozlowskia splendens
Phricodothyris perplexa

SP-12-1

Antiquatonia coloradoensis
Spirifer occiduus
Ditomopyge sp.; pygidium

SP-12-2

Antiquatonia coloradoensis
Spirifer occiduus
Crinoid columnals

Sandia Peak Float Locality

Tetracorals; several genera and species; one is 1 inch in diameter
Rhombopora cf. lepidodendroides
Fenestelloid bryozoans; several genera
Ramose forms of bryozoans; up to 5 mm in diameter and 50 mm long
Antiquatonia coloradoensis; mostly small; one is 3 inches wide
Composita elongata
Echinaria semipunctata
Hustedia mormoni
Kozlowskia splendens; common
Linoproductus platyumbonus
Neospirifer dunbari alatus
Orbiculoidea sp.
Phricodothyris perplexa; common
Rhynchopora magnicosta; common; first reported occurrence of the genus in New Mexico Pennsylvanian
Crinoid columnals; mostly small; one is 17 mm in diameter

Sandia Crest Section

SC-13

Desmoinesia cf. muricatina
Crinoid columnals

SC-14

Antiquatonia sp.

Kiwanis Cabin Section

KC-2

Spirifer cf. rockymontanus

KC-4

Antiquatonia cf. coloradoensis
Crinoid plate and columnals

KC-7

Phricodothyris perplexa
Crinoid columnals
Orthonychia parva

KC-8

Phricodothyris perplexa
Crinoid columnals

KC-10

Rhombopora? sp.
Chonetinella cf. *flemingi*
Kozlowskia? sp.
Spirifer sp.
Crinoid columnals

Kiwanis Cabin Float Locality

Rhomboporoid bryozoan
Antiquatonia coloradoensis
Neospirifer dunbari
Phricodothyris perplexa
Crinoid columnals; and a globular calyx 35 mm in diameter, genus undetermined

Tree Springs Section

TSS-5

Phricodothyris perplexa
Crinoid columnals

TSS-7

Linoproductus? sp.
Spirifer sp.
Crinoid columnals

Summary

Following is a list of the fauna collected from the Madera limestone.

Phylum Coelenterata

Tetracorals; several genera and species

Phylum Bryozoa

Rhombopora cf. lepidodendroides
R.? sp.
Fenestelloid bryozoans; several genera and species
Rhomboporoid bryozoan
Ramose bryozoans

Phylum Brachiopoda

Antiquatonia coloradoensis
A. cf. coloradoensis
A. sp.
Chonetinella cf. flemingi
Composita elongata
Desmoinesia cf. missouriensis
D. cf. muricatina
D.? sp.
Echinaria semipunctata
Hustedia mormoni
Kozlowskia splendens
K.? sp.
Linoproductus platyumbonus
L.? sp.
Neospirifer dunbari
N. dunbari alatus
Orbiculoidea sp.
Phricodothyris perplexa
Rhynchopora magnicosta
Spirifer occiduus
S. cf. rockymontanus
S. sp.

Phylum Echinodermata

Crinoid calyx, plate, and columnals

Phylum Mollusca

Orthonychia parva

Phylum Arthropoda

Ditomopyge sp.

The most interesting megafossil collected in this study is *Rhynchopora magnicosta*. Specimens were collected by Dr. Northrop and the author in the summer of 1961 from the Sandia Peak float locality (Fig. 7). This is the first reported occurrence of the genus in the Pennsylvanian of New Mexico. *Rhynchopora magnicosta* is restricted to the Morrowan in Arkansas and Oklahoma and to either the top of the Strawn (upper Desmoinesian) or base of the Canyon (lower Missourian) near Strawn, Texas.

The ranges of many of these species, as determined from the Midcontinent region (Moore and others, 1944) are often quite restrictive. The Atokan and Desmoinesian are characterized by nonfasciculate spirifers, such as *Spirifer occiduus*, *S. opimus*, and *S. rockymontanus*, which do not range higher. *Desmoinesia missouriensis* and *D. muricatina* are restricted to the Desmoinesian. *Kozlowskia splendens* appears in the Desmoinesian and ranges upward into the

Missourian. In the Midcontinent, small specimens of Phricodothyris perplexa are locally very common in Desmoinesian beds. See Table 1 for the geologic ranges of certain species occurring in the Madera limestone of the central Sandia Mountains and elsewhere.

The lower part of the Madera limestone that is exposed along the western scarp of the Sandia Mountains is probably of middle to late Desmoinesian age.

Area of this report	Midcontinent [1]		Placitas [2]		Cedro Canyon [3]	
	Desmoinesian	Missourian	Desmoinesian	Missourian	Desmoinesian	Missourian
Antiquatonia coloradoensis (may = A. portlockiana)	X	X	X	X	X	?
Chonetinella cf. flemingi	X	X				X
Composita elongata		X	X		?	X
Desmoinesia cf. muricatina	X		X		X	
Echinaria semipunctata		X		X		X
Kozlowskia splendens	X	X		X	X	X
Linoproductus platyumbonus		X		X		X
Neospirifer dunbari	X	X			X	X
N. dunbari alatus		X		X		?
Orbiculoidea sp.	X	X	X		X	
Phricodothyris perplexa	X	X	X	X	X	X
Rhynchopora magnicosta	X	?				
Spirifer occiduus	X		X		X	
S. cf. rockymontanus	X		X		X	
Orthonychia parva			X		X	X
Ditomopyge sp.			X		X	X

[1] mostly from Dunbar and Condra (1932)

[2] from Toomey (1953)

[3] from Szabo (1953)

Table 1. Ranges of some Pennsylvanian species occurring in the Madera limestone of the rim of the central Sandia Mountains.

Figure 6

Aerial view of vicinity of Kiwanis Cabin

Kiwanis Cabin (K. C.) is located on the rim of the V formed by the two prominent cliffs in the upper center of the photograph. Immediately behind it lies a relatively treeless meadow, one of the favorite grazing grounds of the Rocky Mountain bighorn sheep.

Photograph by courtesy of Dick Kent

Figure 6

Aerial view of vicinity of Kiwanis Cabin

Kiwanis Cabin (K. C.) is located on the rim of the V formed by the two prominent cliffs in the upper center of the photograph. Immediately behind it lies a relatively treeless meadow, one of the favorite grazing grounds of the Rocky Mountain bighorn sheep.

Photograph by courtesy of Dick Kent

Figure 6

PENNSYLVANIAN ENVIRONMENTS

Paleoecology

The fossiliferous beds of the Pennsylvanian sequence exposed on the western face of the Sandia Mountains are primarily limestones. The faunas are represented mainly by brachiopods and crinoids. The crinoids occur in greatest individual abundance, chiefly as columnals. The brachiopods are next, with a total of 12 genera collected. Bryozoans are common to a lesser extent. Corals, gastropods, trilobites, and Foraminifera are also present. A few, poorly preserved, unidentifiable plant fossils were found in the sandstone of the lower part of the Sandia formation.

In modern seas (Moore, 1929, p. 467-470), most corals live at depths of less than 150 feet and at temperatures of 73°-78°F, with 68°F being the lower limit for reef corals. Bryozoans are most abundant in moderately warm, shallow waters where there is a shell or rock bottom. Brachiopods are most often found in shallow water, with only a few ranging beyond the edge of the continental shelf to depths of more than 600 feet. The fauna collected thus suggests a warm, shallow sea environment. The author wishes to point out that the interpretation of paleoecology is based on the assumption that fossil plants and animals

represented in the geologic column lived largely in the same environments as the corresponding classes of organisms today. Elias (1937, p. 422-423), among others, has noted that unless this assumption is accepted there is little on which to base an approach to the problem of environments.

Lithology

The main rock types of the Sandia formation exposed in the area are limestone, sandstone, and conglomerate. Shale is probably present in large amounts, but most likely is hidden by talus, slope wash, and dense vegetative cover. Utilizing the tectono-environmental classification of Krumbein, Sloss, and Dapples (1949, p. 1876-1877) as a basis for analysis, the lower part of the Sandia formation represents the transitional to epineritic environment on an unstable shelf. This is suggested by the presence of poorly preserved plant fossils, limestone texture, the micaceous feldspathic sandstone, and the feldspathic limestone.

The middle and upper parts of the formation suggest an epineritic environment with unstable to stable shelf conditions. The limestones found here are typically dense and of the fossiliferous-fragmental type. In

studying the author's thin sections, Dr. R. Y. Anderson (written communication, 1962) noted:

> "These are typical fragmental "fossil hash" or "calcarenite" limestones. Only one showed quiet water "ooze" type of deposition--perhaps a fleeting lagoon. All others show evidence of strong wave or current action above wave base."

That part of the Madera limestone exposed on the western face of the Sandia Mountains is composed almost entirely of a sequence of dense, cherty limestones ranging in color from light gray to medium dark gray. This lithologic character, along with the variety of benthonic invertebrates, suggests an epineritic to infraneritic environment on a stable shelf.

Positive areas lying to the east, north, and south--the Uncompahgre axis, the Penasco axis, and the Joyita axis, respectively--supplied most of the clastic sediments for this area (Read and Wood, 1947, p. 227).

CONCLUSIONS

The author could find no pre-Pennsylvanian Paleozoic strata in the central part of the Sandia Mountains.

The Pennsylvanian formations present along the western face are the Sandia formation and a portion of the lower gray limestone member of the Madera limestone.

The Sandia formation rests unconformably on a profound erosional surface formed on the Precambrian Sandia granite. The formation ranges in thickness from about 175 feet to 300 feet and is predominantly clastic. It represents deposition of sediments in a transitional to epineritic environment under unstable to stable shelf conditions. The formation is sparsely fossiliferous.

That part of the Madera limestone exposed in the area lies conformably on the Sandia formation. In this area, the formation ranges in thickness from 280 feet to 390 feet and it reflects deposition of carbonate sediments in an epineritic to infraneritic environment under stable shelf conditions. The formation is locally fossiliferous.

Of significance was the discovery of the brachiopod Rhynchopora magnicosta in float from the Madera limestone. This is the first reported occurrence of the genus in the Pennsylvanian of New Mexico.

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PLATE 1

Foraminifera

Figure

1. Textularia? sp. X 80.

   SP-4-2

2. Same as above. X 25.6.

   Note typical "fossil hash" texture composed of bryozoan fragments, crinoid fragments, brachiopod valves, and productoid spines.

   SP-4-2

PLATE 1

Foraminifera

Figure

1. Textularia? sp. X 80.

   SP-4-2

2. Same as above. X 25.6.

   Note typical "fossil hash" texture composed of bryozoan fragments, crinoid fragments, brachiopod valves, and productoid spines.

   SP-4-2

Plate I

1

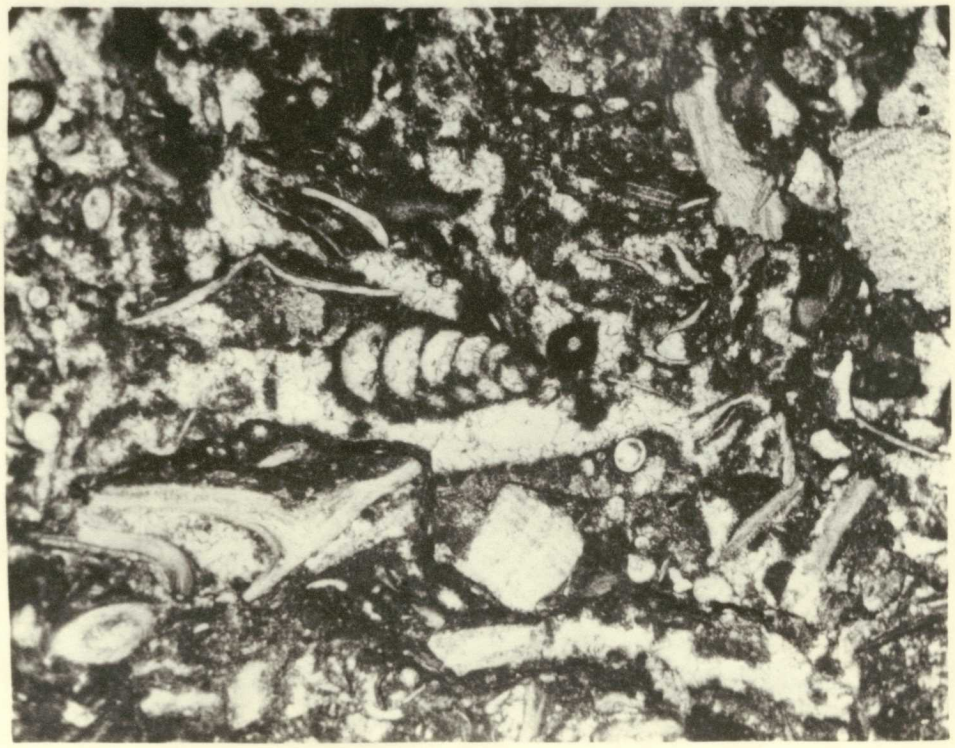

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PLATE 2

Foraminifera

Figure

1. Fusulinid, sagittal section. X 80.

   Crinoid columnal in lower left corner.

   TP-3

2. Endothyra? sp. X 80.

   TP-3

PLATE 2

Foraminifera

Figure

1. Fusulinid, sagittal section. X 80.

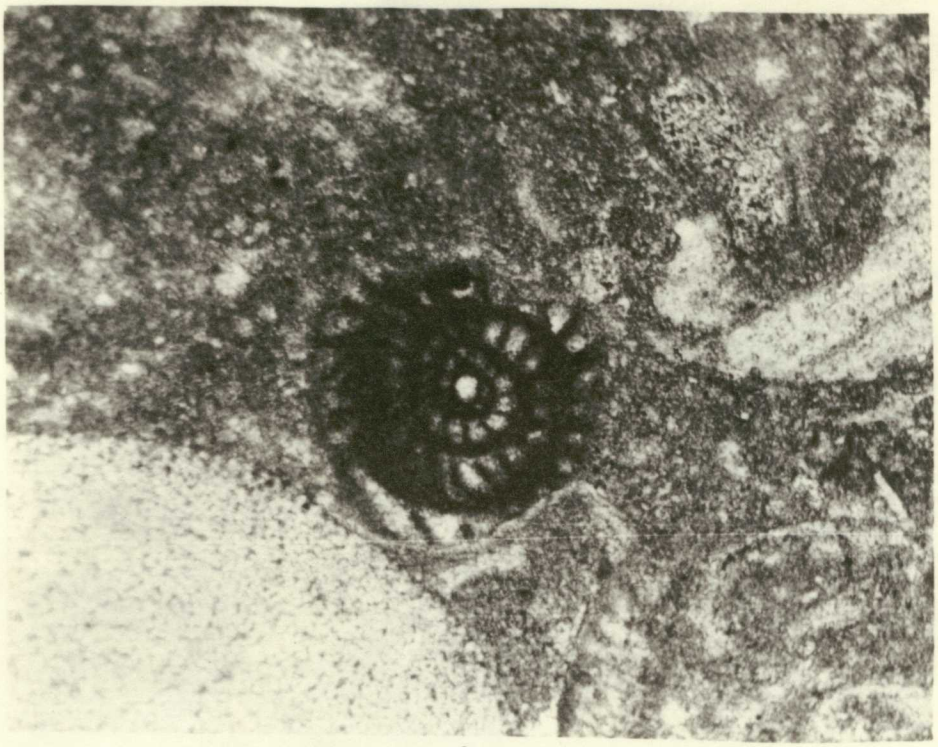
   Crinoid columnal in lower left corner.

   TP-3

2. Endothyra? sp. X 80.

   TP-3

Plate 2



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2

PLATE 3

Oolites

Figure

1. Arenaceous Foraminifera. X 80.
   Note nearby oolites.
   TSS-3

2. Same as above. X 25.6. All fossils are enclosed in oolites. Oolites are suspended in sparry calcite cement.
   TSS-3

PLATE 3

Oolites

Figure

1. Arenaceous Foraminifera. X 80.

   Note nearby oolites.

   TSS-3

2. Same as above. X 25.6. All fossils are enclosed in oolites. Oolites are suspended in sparry calcite cement.

   TSS-3

Plate 3

1

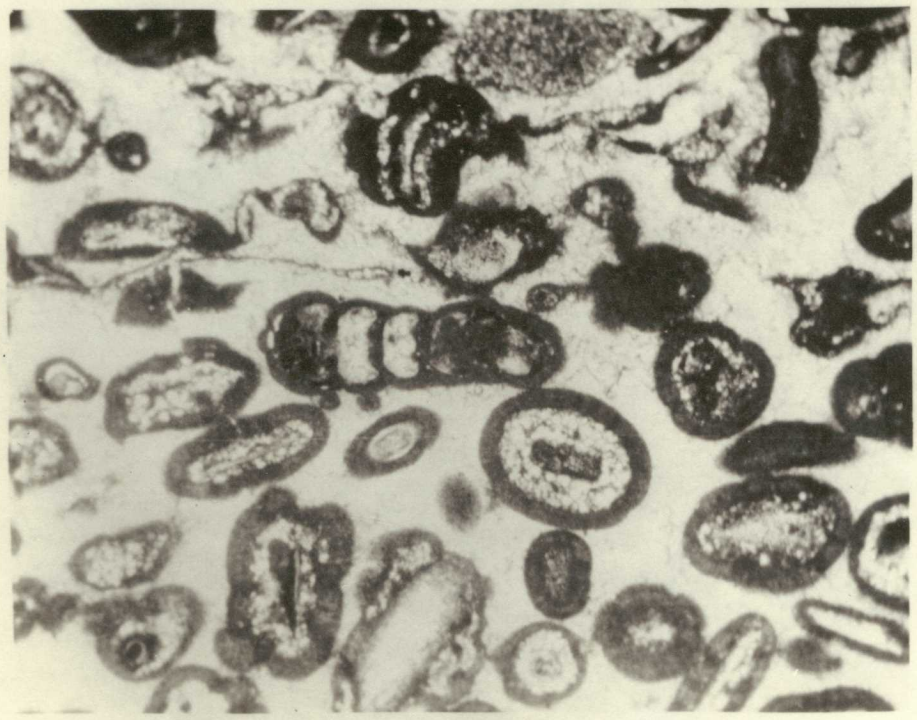

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PLATE 4

Foraminifera

Figure

1. Fusulinid. X 80.

   SP-4-2

2. Fusulinella? sp. X 80.

   SC-2-2

PLATE 4

Foraminifera

Figure

1. Fusuliniid. X 80.

   SP-4-2

2. Fusulinella? sp. X 80.

   SC-2-2

Plate 4

1

2

PLATE 5

Foraminifera

Figure

1. Unknown coiled fossil. X 80. Enclosed in oolite.

   TSS-3

2. Fusulinid. X 80.

   SC-2-2

3. Fusulinid. X 80. Note productoid spines.

   SP-4-2

PLATE 5

Foraminifera

Figure

1. Unknown coiled fossil. X 80. Enclosed in oolite.

   TSS-3

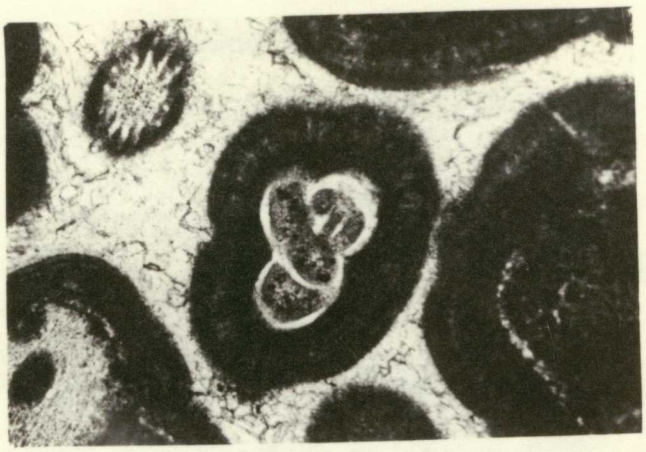
2. Fusulinid. X 80.

   SC-2-2

3. Fusulinid. X 80. Note productoid spines.

   SP-4-2

Plate 5



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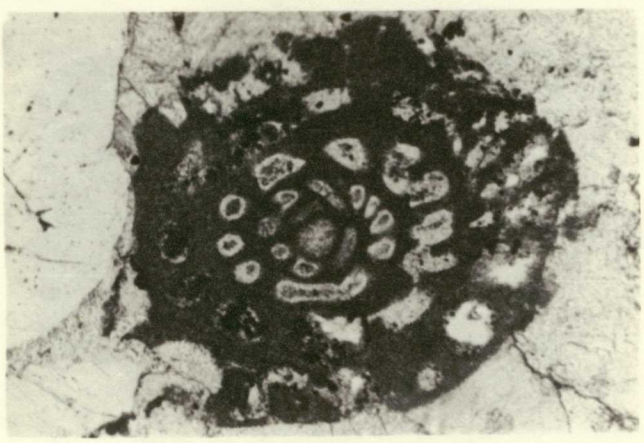

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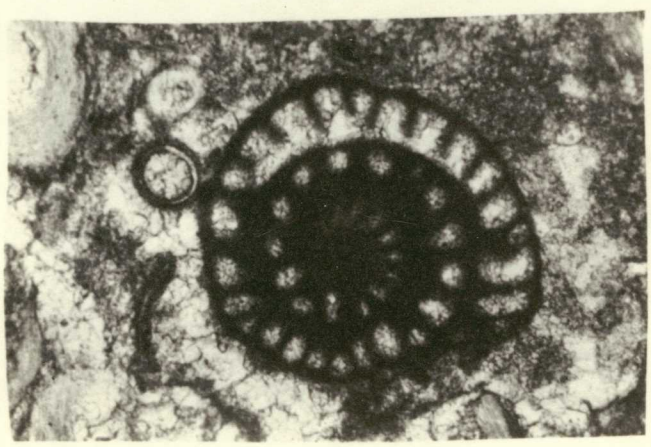


3

PLATE 6

Bryozoa

Figure

1. Trepostome bryozoan. X 25.6.

   SP-4-1

2. Rhombopora? sp. X 80.

   SP-4-2

3. Cryptostome bryozoan. X 80.

   SP-4-2

PLATE 6

Bryozoa

Figure

1. Trepostome bryozoan. X 25.6.

SP-4-1

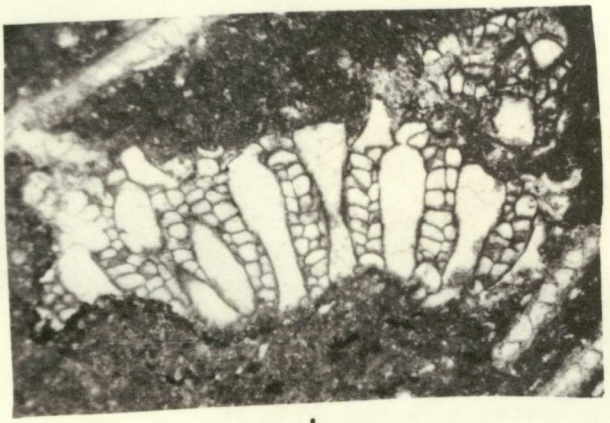
2. Rhombopora? sp. X 80.

SP-4-2

3. Cryptostome bryozoan. X 80.

SP-4-2

Plate 6



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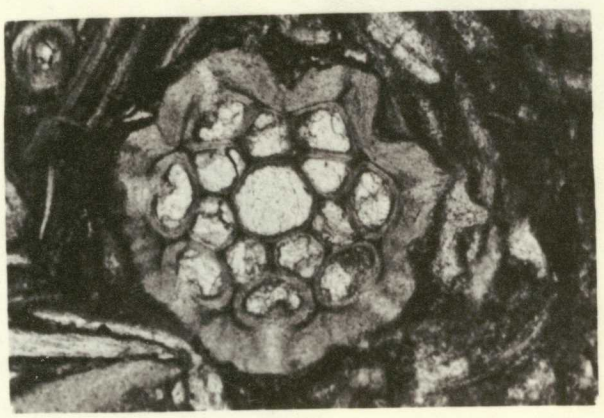

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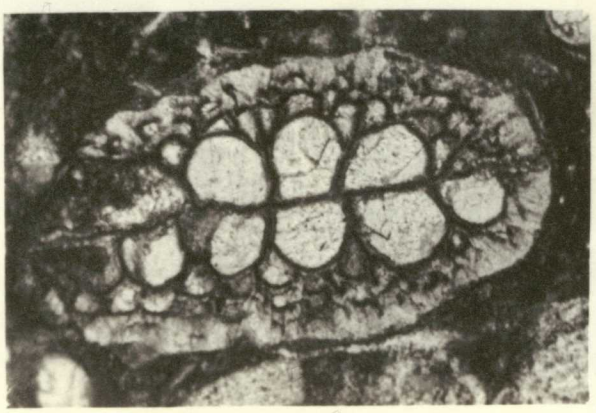

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PLATE 7

Bryozoa and Brachiopoda

Figure

1. Replaced productoid brachiopod spine. X 25.6.

   Ooze type of texture.

   SC-10

2. Fenestelloid bryozoan. X 25.6.

   Note "spiny" texture of matrix.

   TP-2

3. Bryozoan fragments. X 25.6.

   Typical "fossil hash" texture.

   SP-4-1

4. Bryozoan fragments. X 25.6

   SP-4-1

PLATE 7

Bryozoa and Brachiopoda

Figure

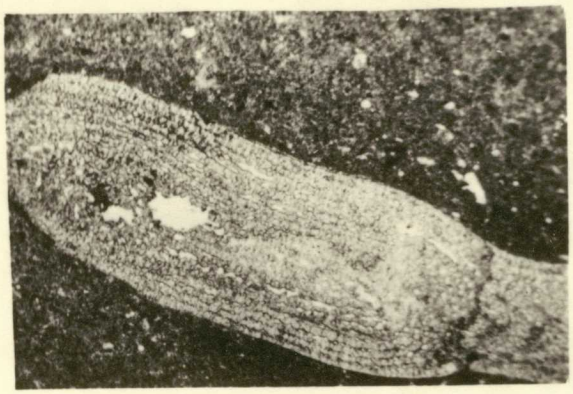
1. Replaced productoid brachiopod spine. X 25.6.
   Ooze type of texture.
   SC-10

2. Fenestelloid bryozoan. X 25.6.
   Note "spiny" texture of matrix.
   TP-2

3. Bryozoan fragments. X 25.6.
   Typical "fossil hash" texture.
   SP-4-1

4. Bryozoan fragments. X 25.6
   SP-4-1

Plate 7



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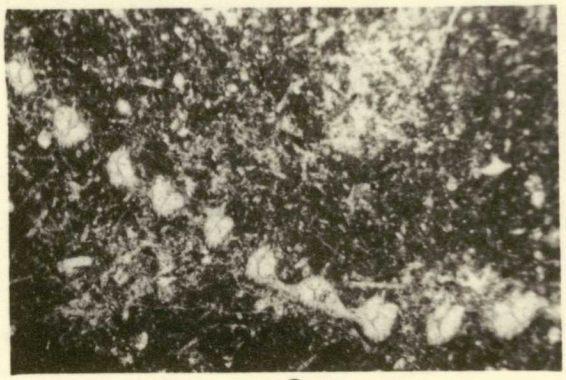
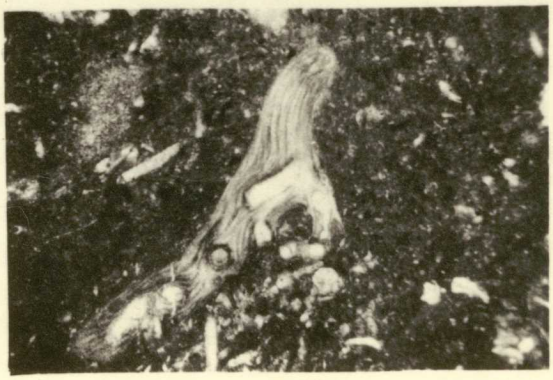


2

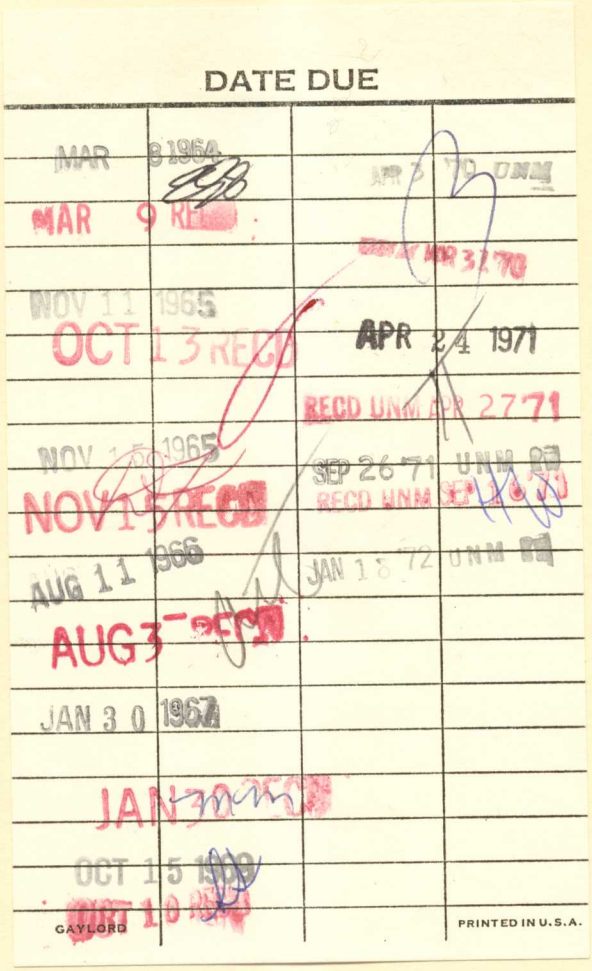
3



4

IMPORTANT!

Special care should be taken to prevent loss or damage of this volume. If lost or damaged, it must be paid for at the current rate of typing.



2 maps