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Geology of the Pedernal Hills Area Torrance County, New Mexico

John F. Fallis

PEDERNAL HILLS AREA - FALLIS

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GEOLOGY OF THE PEDERNAL HILLS AREA

TORRANCE COUNTY, NEW MEXICO

By

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A Thesis

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ABSTRACT

The Pedernal Hills of north-central New Mexico form a prominent ridge between the Estancia Basin on the west and the Pecos River drainage of the Great Plains on the east. They are remnants of an ancient Paleozoic highland.

The Precambrian core which forms the area of greatest relief (the Pedernal Hills) consists of, from oldest to youngest: interbedded quartzite and phyllite, with quartzite predominating, sericite-chlorite schist, greenstone, and granite. The prevailing strike is N 40° E with an average dip of 30° to the southeast. The schistosity parallels the dip and strike. The quartzite, phyllite, schist, and greenstone are apparently conformable with each other. They represent approximately 10,000 feet of sandstones, siltstones, shales, and basic flows or sills intruded by granite.

Numerous environmental changes have resulted in a regional metamorphism that has altered the Precambrian rocks to their present metamorphic state. A vast igneous reservoir, the source of the granite intrusions, is probably the cause of the regional metamorphism.

Deep wells surrounding the Pedernal uplift penetrate a section of clastic sedimentary rocks up to 5,000 feet thick, Over 3,000 feet of this section is Pennsylvanian in age and represents sediments derived from a highland (the Pedernal uplift) which came into being during early or middle Pennsylvanian time. This Pedernal uplift, in conjunction with other Pennsylvanian structural elements, divided the Penn-

sylvanian seas into connected basins. The basin (southern extension of the Rowe-Mora basin) to the west of the Pedernal uplift is probably the result of a large fault or faults along the west side of the Pedernal uplift.

Lapping onto the Precambrian core are rocks of the Yeso formation of Permian age, which were deposited in a saline epicontinental sea. The Glorieta sandstone, San Andres formation, and Bernal formation of Permian age represent another marine cycle. The Triassic Santa Rosa sandstone is a result of a continental environment. Jurassic and Cretaceous rocks are absent in the area, probably as a result of a later cycle of erosion.

During Laramide or late Tertiary time, a period of uplift and faulting resulted in a zone of faults and dikes along the western side of the Pedernal Hills. This may be due to further movement along the great Pennsylvanian fault.

In latest Tertiary or early Quaternary time, the area was subjected to extensive erosion which developed a prominent pediment surface. This pediment may merge with the Great Plains surface to the east.

INTRODUCTION

Location and Accessibility

The area included in this report is in the north-central part of Torrance county, central New Mexico. The area is bounded on the north by U. S. Highway 66, on the east by U. S. Highway 285, on the south by U. S. Highway 60, and on the west by the approximate eastern edge of the Estancia basin. Clines Corners on U. S. Highway 66 forms the northeast corner of the area. The mapped area contains approximately 230 square miles.

Most of the area is readily accessible from any of the highways mentioned above. County and section line roads cover most of the area.

Easiest access to the area is obtained by a dirt road running south from U. S. Highway 66 approximately 6.5 miles west of Clines Corners. This road runs south for 6.5 miles and then east across the Pedernal Hills to junction with U. S. Highway 285 some 14 miles south of Clines Corners. From this same road at the old North Lucy schoolhouse site, a section line road runs south to U. S. Highway 285 traversing the southern part of the area.

Purpose

The Pedernal Hills area has been of considerable scientific and economic interest for a number of years. This interest stems mainly from speculation as to the influence of the Pedernal axis and other positive elements of New Mexico on the sedimentation and stratigraphy of the Upper

INTRODUCTION

Location and Accessibility

The area [illegible] central part of [illegible] County, New Mexico. [illegible] area is bounded on the north by U. S. [illegible] east by U. S. Highway [illegible] on the south by [illegible] 60, and on the west by [illegible] Rio [illegible] Salinas [illegible] Canyon [illegible] the northeast corner of the area. [illegible] approximately 270 square miles.

Most of the area is [illegible] highways mentioned above. [illegible] cover most of the area.

Easiest access to the area [illegible] running south [illegible] U. S. Highway [illegible] west of [illegible] and then [illegible] across the [illegible] U. S. Highway [illegible] From this [illegible] a section line road [illegible] entering the southern part of the area.

Purpose

The [illegible] interest [illegible] of the [illegible] Mexico on the [illegible]

Paleozoic. Despite this interest, there has been no detailed mapping in the area.

The Precambrian exposures in the area were mapped in as much detail as megascopic examination would allow. This was done not only to determine a possible source of Paleozoic sediments but to attempt to unravel some of the geologic events of the Precambrian. The surface exposures of the Permian sediments and their relation to the Precambrian were studied in detail.

In conjunction with the field mapping, the writer examined the samples from four wells adjacent to the mapped area to study the effects of the Pedernal positive element on the sedimentation locally.

Previous Work

Johnson (1902, p. 57) speculated on the character of the Precambrian rocks of the area. Meinzer (1911, p. 11-12), in his description of the Estancia Valley, mentioned the Pedernal Hills briefly. Darton (1928, p. 283-284) outlined the geology of the area in his study of the "redbeds" of the state. Read and Wood (1944) included the eastern and northern portions of the area in their map. Thompson (1942, p. 12-14) discussed the effect of the Pedernal landmass on Pennsylvanian strata of New Mexico, as did Read and Wood (1947, p. 225).

Present Work

Field work

The area included in this report was mapped by the

[illegible]. Perhaps [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] was confined only to [illegible] [illegible] [illegible] [illegible] [illegible] zone as well [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] levels [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] were studied in detail.

In addition to the field studies, [illegible] [illegible] [illegible] [illegible] the samples [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] to study the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] sedimentation locally.

Previous Work

Johnson (1902, p. 57) [illegible] [illegible] [illegible] the Pennsylvanian [illegible] of the area. Wanless (1931, p. [illegible]), in his description of the [illegible] [illegible], mentioned the [illegible] [illegible] [illegible]. [illegible] (1938, p. [illegible]) [illegible] the geology of the area in his study of the [illegible] of the [illegible]. Weller and Wood (1944) [illegible] the [illegible] [illegible] northern [illegible] [illegible] [illegible] [illegible] [illegible] (1946, p. 12-14) [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Pennsylvanian [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] (1947, p. 22).

[illegible]

Field Work

The [illegible] [illegible] [illegible] [illegible] was [illegible] by the

writer during the months of March through June, 1957, in preparation for his Master's Degree.

The mapping was done on aerial photos. Stratigraphic sections were measured with a Brunton compass.

Laboratory work

During the preparation of this report, the author described the samples from the following wells: Petrol # 1 State, Cardinal # 1 State, Sanders # 1 State, and the Randall # 1 Estancia (Plate II).

Map compilation

The map (Plate I) was compiled from aerial photographs at a scale of 1:63,360.

The geology was transferred by inspection from the aerial photos to U. S. Soil Conservation Service photomozaics and reduced to the desired scale. All control was supplied by the mosaics.

Acknowledgments

The writer is indebted to Dr. V. C. Kelley and Dr. J. P. Fitzsimmons of the University of New Mexico who acted as faculty advisors. The personnel of the Fuels Branch of the U. S. Geological Survey were especially helpful in allowing the use of their equipment. Special thanks are due R. B. O'Sullivan of the U. S. Geological Survey for his constructive criticism and encouragement.

GEOGRAPHY

Physiography

Topography

The Pedernal Hills lie along the boundary between the Great Plains and the Basin and Range provinces. To the east are found the gently dipping, moderately dissected strata of the Great Plains. To the west are the Estancia basin and the tilted fault block of the Sandia and Manzano Mountains. The outstanding topographic features are the Pedernal Hills standing above less resistant and gently dipping sedimentary strata. Pedernal Peak rises several hundred feet above the surrounding country to an elevation of 7,580 feet. West of Pedernal Peak, two lines of hills (the Pedernal Hills) of low to moderate relief trend northerly and extend to the southern border of the area.

Along the western edge of the Pedernal Hills, the Yeso sandstones form an east-facing cuesta which has been dissected in several places.

South of U. S. Highway 66, in the northern portion of the area, is the southern termination of Glorieta Mesa. This is a prominent, flat-topped, monoclinal feature that rises from the Estancia basin to an elevation of approximately 7,000 feet.

Along U. S. Highway 285, in the eastern portion of the area and just north of the Pedernal Hills, the most prominent topographic feature is a Tertiary-Quaternary pediment surface

which bevels the underlying strata and above which rise the Pedernal Hills. This surface has been dissected by the streams of the area and exists in places only as remnants.

Drainage

The Pedernal Hills form a drainage divide between the Pecos River on the east and the enclosed Estancia basin on the west. All the streams of the area are intermittant and flow only during periods of heavy rainfall.

Most of the streams were consequent upon the Tertiary-Quaternary pediment surface and have dissected this surface. Several subsequent streams flow along the strike of the sedimentary rocks at the contact with the Precambrian. The general stream pattern is dendritic.

Several small streams in the northern portion of the area drain into sinkholes. These have developed as a result of solution of underlying gypsum or limestone layers.

Climate and Vegetation

The climate of the Pedernal Hills is typical of the semiarid southwestern United States. Summers are generally mild with warm days and cool nights. Because of the elevation, winter months are rather cold with some snowfall.

The rainfall in the area measures from ten to fifteen inches per year. Aside from winter snowfall, most of the precipitation falls during the summer months as localized thundershowers of short duration.

Most of the area is rather sparsely covered with veg-

which [illegible], the [illegible] [illegible] [illegible]

Federal [illegible] [illegible] [illegible] [illegible]

strong [illegible] area and [illegible] [illegible] may be [illegible].

<u>Drainage</u>

The general [illegible] [illegible] [illegible] [illegible] the

Pecos River on [illegible] [illegible] [illegible] [illegible]

the west [illegible] [illegible] [illegible] [illegible] and

flow only [illegible] periods and heavy [illegible].

Most of the streams [illegible] [illegible] [illegible] [illegible]

the [illegible] [illegible] [illegible] [illegible] [illegible].

Several [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible].

general drainage pattern is [illegible].

Several small streams [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] of underlying [illegible] [illegible] layers.

Climate and Vegetation

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[illegible] [illegible] [illegible] [illegible]. [illegible]

mild with [illegible] [illegible] [illegible] [illegible]

[illegible], winter [illegible] are [illegible] [illegible].

The rainfall in [illegible] [illegible] [illegible]

teen inches per year. [illegible] [illegible] [illegible]

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[illegible] [illegible] [illegible] [illegible].

Most of the [illegible] [illegible] [illegible] [illegible]

etation. This cover in the lowlands is typically rangeland , consisting mainly of grass, yucca, sagebrush, and several varieties of cacti. The higher elevations of the Pedernal Hills are almost barren bedause of the absence of a soil mantle. The southern termination of Glorieta Mesa in the northern part of the area is covered by a dense stand of pinon, juniper, and ponderosa pine. Stands of pinon and juniper also occur in some of the canyons of the Pedernal Hills.

Inhabitants and Industry

The Pedernal Hills are sparsely settled. The principal occupation is the raising of sheep and cattle with some dry farming attempted during years of good rainfall. The village of Clines Corners, consisting of a service station and restaurant, is a busy stop for travellers on both U. S. Highway 66 and U. S. Highway 285. Encino, a ranch town of some 700 inhabitants, lies just off the southeast corner of the mapped area.

Prospect pits are scattered over most of the Precambrian outcrop area. One of these, listed in the guidebook for the seventh field trip of the Roswell Geological Society as the Bedford Mine, appears to have been mined although no record of the mines activities could be located.

station. This crop [illegible]

considerable [illegible]

varieties of grass [illegible]

hills [illegible]

months. The southern [illegible]

northern part of the area is [illegible]

plots, [illegible] and [illegible]

juniper [illegible]

hills.

Inhabitants and Industries

The Pajarito [illegible] is [illegible]. The principal occupation is the [illegible] of [illegible], and [illegible] dry farming [illegible]. The villages [illegible] and [illegible] Highway [illegible] and [illegible] one [illegible] the [illegible] area.

[illegible] the Pajarito [illegible] the [illegible] the [illegible], [illegible] report [illegible].

STRATIGRAPHY

Precambrian Rocks

General statement

The Precambrian of the Pedernal area consists of several thousand feet of metasediments and igneous rocks. Very little is known of the events of the Precambrian era but the quartzite and sericite-chlorite schist of the Pedernal Hills represent a considerable thickness of sedimentary strata which have been regionally metamorphosed. The granite, at least in places, is considered to be intrusive into the metasediments. The greenstones probably are the metamorphic equivalents of basalts or gabbros.

From a scaled horizontal distance and an average dip, it would appear that there is at least 10,000 feet of Precambrian rocks exposed in the area. The possibility of isoclinal folding makes this figure completely arbitrary.

In this report, the rocks will be described in stratigraphic order from oldest to youngest as follows: (1) quartzite, (2) phyllite, (3) sericite-chlorite schist, (4) greenstones, and (5) granite.

Stark and Dapples (1946, p. 1127), in the Los Pinos Mountains to the southwest of the Pedernal area, recognized quartzites, schists, rhyolites and granites in the Precambrian. With the exception of the rhyolite, all of these rock types were recognized in the Pedernal area. Although the writer makes no attempt at correlation, it is believed

that further detailed petrographic studies of the Precambrian of both areas might uncover some correlative features.

Quartzite

The Precambrian quartzite forms the most imposing outcrop in the area. It comprises the northern one third of the Precambrian outcrop area, including Pedernal Peak and most of the surrounding Pedernal Hills. The steeply dipping quartzite crops out in a series of northeast trending hills. The bedding seems to be quite distinct and regular and varies from thin to massive. The dip also varies considerably but generally averages 30° to the south. This quartzite represents a considerable thickness of metamorphosed sandstone.

The quartz grains making up the quartzite vary from extremely fine- to coarse-grained. Recrystallization appears to be complete as most of the specimens have a massive crystalline appearance. Sericite is locally abundant and is concentrated along bedding planes, giving them a silky sheen. The color varies from white to reddish brown. Occassional dark specks of magnetite are present.

One ten-foot layer of quartzite conglomerate is present in the quartzite series. It contains subangular pebbles up to one and a half inches in diameter. The matrix is quartzite as previously described. As no faulting was evident, and no sedimentary structures were observed, the writer assumes this to be a metamorphosed conglomeratic sandstone in its normal position.

Phyllite

Interbedded with the quartzite are layers of phyllite

from five to thirty feet thick. They are composed mainly of quartz with abundant sericite along the bedding beds. The thinly schistose cleavage is well developed in some cases and is parallel to the bedding. These phyllites are generally a pale red in color. They represent the finer-grained (siltstone) portion of the sandstone sequence.

Sericite-chlorite schist

Just south of the quartzite sequence described above, and apparently lying conformably upon it, is a 200- to 300-foot layer of sericite-chlorite schist. It crops out in the vicinity of the old North Lucy schoolhouse.

The main constituents are sericite and chlorite with the sericite giving the rock a silky appearance. The color ranges from gray to grayish green. Small (less than one mm) porphyroblasts of garnet are common. Quartz veins and lenses, generally parallel to the schistosity, are common.

Greenstone

South of the quartzite sequence of the Precambrian outcrops is a series of dark green rocks which will be lumped together as greenstones. They are poorly exposed in a series of low-lying hills. The strike of these schists is generally more easterly than that of the quartzites and sericite-chlorite schist. However, the greenstones appear to be conformable upon the chlorite-sericite schist.

The schistosity varies considerably and in places appears to be almost absent, the schist then resembling a basic igneous rock. The fabric varies from finely granular to

microcrystalline. Because of the small size of the crystals, the individual mineral constituents are hard to determine. Plagioclase and amphibole appear to be the major constituents. Epidote was recognized in the well samples. Scattered grains of magnetite occur. Quartz veins, varying from a few inches to several feet in thickness, are common.

This thick sequence of greenstones is assumed by the writer to be a metamorphosed sequence of basic flows or sills or both. It might also be a metamorphosed sequence of marl or dolomitic marl.

Granite

Granite outcrops are abundant in the Pedernal area, especially to the south along U. S. Highway 285. One isolated exposure occurs surrounded by quartzite in the extreme northern end of the Precambrian outcrop. Because of its irregular outcrop pattern and lack of any well defined trend, the granite is believed to be intrusive in character. The contact of the granite with the other Precambrian rocks was not observed.

The granites in general are coarse-grained (some feldspar crystals are two to four millimeters in length), equigranular rocks composed mainly of anhedral to subhedral crystals of quartz, pink feldspar (orthoclase or microcline), and biotite. Some plagioclase is present, as albite twinning occurs. The overall color of the granite is pink.

In some areas, there is a marked gneissic foliation. The dark minerals, particularly biotite, are concentrated

in irregular bands with quartz and feldspar as phenocrysts.

Metamorphism of the Precambrian rocks

All the Precambrian sediments show the effects of a regional metamorphism of low to moderate intensity which transformed the sandstones, siltstones, and shales to quartzites and schists. Stark and Dapples (1946, p. 1141) suggest that in the Los Pinos Mountains, a large granite mass would be a logical source of heat for metamorphism. This could easily be the situation in the Pedernal area.

Pennsylvanian-Permian Strata

General statement

No Pennsylvanian rocks outcrop within the area of this report. Pennsylvanian strata will be discussed as they occur in the well samples examined by the writer. However, because of a lack of fossil and lithologic boundaries, Pennsylvanian and lower Permian strata will be treated as one unit under the heading Pennsylvanian-Permian. This will include rocks normally classified in three divisions: the Magdalena group, the Bursum formation, and the Abo formation.

The term Magdalena group has become the general term for Pennsylvanian strata in New Mexico. The name was first applied by Gordon (1907, p. 805-816). First named by Wilpolt et al (1946), the Bursum is generally regarded to be of early Permian age although it may be of Pennsylvanian age in places. The Abo formation (Lee, 1909, p. 12) is, at least in part, definitely Permian (Fig. 1).

	SERIES			SANDIA, MANZANO AND LOS PINOS MOUNTAINS	ESTANCIA VALLEY	SANGRE DE CRISTO MOUNTAINS
PERMIAN	LEONARD			YESO FORMATION	YESO FORMATION	YESO FORMATION
PENN-PERM	WOLFCAMP			ABO FORMATION	ABO FORMATION	SANGRE DE CRISTO FORMATION
PENNSYLVANIAN	VIRGIL	MAGDALENA GROUP	Madera Limestone	Arkosic Limestone Member	Arkosic Limestone Member	
PENNSYLVANIAN	MISSOURI	MAGDALENA GROUP	Madera Limestone	Arkosic Limestone Member	Arkosic Limestone Member	Arkosic Limestone Member / Arkose & Arkosic ls.
PENNSYLVANIAN	DES MOINES	MAGDALENA GROUP	Madera Limestone	Gray Limestone Member	Gray Limestone Member	Gray Limestone Member / dark shale limestone & sandstone
PENNSYLVANIAN	ATOKA	MAGDALENA GROUP		SANDIA FORMATION	SANDIA FORMATION	SANDIA FM. / sandstone & shale
				?	?	?
				PRECAMBRIAN	PRECAMBRIAN	PRECAMBRIAN

FIGURE 1 NOMENCLATURE OF PENNSYLVANIAN ROCK UNITS IN NORTH-CENTRAL NEW MEXICO
After Read and Wood (1947)

Pennsylvanian rocks are widespread in New Mexico, being absent only in such positive areas as the Pedernal Hills and the Zuni Mountains.

Relation to adjacent formations

The Pennsylvanian rocks generally lie unconformably on Precambrian crystalline rocks or Paleozoic sediments. However, this contact was not seen in the well samples.

The Pennsylvanian-Permian contact is the subject of some debate, but it is generally regarded as being everywhere unconformable (Thompson, 1942, p. 20). Read and Wood (1947, p. 223) stated that the continental arkose and red-beds of the Abo and Sangre de Cristo formations may rest conformably, disconformably, and unconformably on the marine strata of the Magdalena group.

In the subsurface of the Pedernal area, there is no observable depositional break between Pennsylvanian and Permian strata, hence the writer's use of the term Pennsylvanian-Permian. There seems to have been continuous sedimentation during Pennsylvanian and Permian time.

The base of the Yeso formation is arbitrarily placed at the first occurrence of angular rock fragments and mica. This break is clearcut in most cases. For example, the base of the Yeso formation is some 200 feet below a dolomitic gypsum layer in both the Sanders # 1 State and the Umbarger # 1 State (Plate II).

Character and thickness

The Magdalena group is generally a marine sequence of

limestones, sandstones, arkoses, and shales, with the limestones predominating. Thicknesses range from 500 feet in the Nacimiento Mountains to over 3,500 feet in the Sangre de Cristo Range (Thompson, 1942, p. 18).

The Bursum formation of Wilpolt, et al (1946) is a series of limestones, sandstones, conglomerates, and shales transitional between the dominantly marine Pennsylvanian and the continental Abo formation. It is 250 feet thick at the type locality. The Abo formation (Lee, 1909, p. 12) is a dark red, coarse-grained sandstone with various amounts of conglomerate. Neither the Bursum formation nor the Abo formation were recognized in the subsurface by the writer.

The Pennsylvanian-Permian sediments seen in the well samples form a predominantly clastic sequence of arkosic sandstone, graywacke, siltstone, red and gray shales, and a few thin limestones. This section is thought to be, at least in part, marine.

Probably the most important and interesting well is the Randall # 1 Estancia. In this well, the Pennsylvanian-Permian section is at least 3,900 feet thick. The well was drilling in sandstones of Madera age when abandoned (Read and Wood, 1944). The Pennsylvanian-Permian section consists of interbedded reddish brown to dark greenish gray sandstones, siltstones, arkosic sandstones, and graywackes with subordinate amounts of shale and limestone. The sandstones are poorly sorted, fine- to coarse-grained, and are composed of angular quartz and quartzite fragments with three to fifteen percent feldspar. The graywackes contain up to 50

percent dark green rock fragments. The limestones are pale brown to greenish gray, microcrystalline, and nonporous. Common accessory minerals are pyrrhotite and magnetite.

The samples from 3,600 to 3,900 feet contain limestone, black shale, and dark gray siltstone. Several Pennsylvanian ostracods were found in this interval. Because it more nearly resembles the marine Pennsylvanian of New Mexico, this interval is regarded by the writer as being definitely marine.

Samples from the Sanders # 1 State, although lithologically similar to the samples from the Randall # 1 Estancia, have a greater percentage of arkosic sandstone. This sandstone is composed mainly of fresh angular quartz, orthoclase (probably microcline), and granite fragments, with up to ten percent biotite. Dark green rock fragments are abundant near the bottom of the well. Magnetic minerals (chiefly pyrrhotite) are common, as is a trace of pyroboles. The section in this well is at least 2,700 feet thick.

The lithology of the Cardinal # 1 State seems to be almost identical with that of the Randall # 1 Estancia, although the samples were incomplete. The total depth of this well is 2,363 feet including 1,100 feet of Pennsylvanian-Permian strata below the base of the Yeso formation.

These sediments contain abundant clastic material, possibly deposited in a subsiding basin. Because of the angularity, size of the particles, and presence of labile minerals, the distance over which the sediments were transported must have been short. This would indicate a source area immediately adjacent to the depositional area, a re-

quirement fulfilled by the Pedernal axis.

The composition of the sediments indicates a source terrane comprised of quartzitic, granitic, and dark green metamorphic rocks which are the rock types exposed on the surface in the Precambrian of the Pedernal area.

Age and correlation

The Pennsylvanian-Permian of New Mexico should include strata of Morrow (Northrop and Wood, 1946) through a part of Leonard time (Bates et al, 1947, p. 28). Whether the clastic sequence of the Pedernal area represents this whole time interval or just a part is questionable until more information is available.

Permian Strata

General statement

The Permian of northern New Mexico includes, in ascending order, the Bursum formation, Abo formation, Yeso formation, Glorieta sandstone, San Andres formation, and the Bernal formation.

Neither the Bursum nor the Abo formations crop out within the area mapped, and the writer was unable to distinguish them from Pennsylvanian rocks in the well samples. Certainly Bursum and Abo time are represented by some portion of the red-bed sequence encountered in the wells, but just what part was not determined.

Yeso formation

Type locality and distribution - First described by

Lee (1909, p. 12) as a member of the Manzano group, the Yeso formation was redescribed by Needham and Bates (1943, p. 1657-1661) in order to give the formation a more precise definition. The name derived from the Mesa del Yeso, a prominent landmark twelve miles northwest of Socorro.

Four members are included in the Yeso formation: these are, in ascending order, the Meseta Blanca sandstone (Northrop and Wood, 1946), the Torres member (Wilpolt *et al*, 1946), the Canas gypsum, and Joyita sandstone (Needham and Bates, 1943, p. 1657-1661). The Meseta Blanca sandstone member was included as a part of the Abo formation by Needham and Bates, but it is now considered to belong in the Yeso formation because it is believed to be a marine sandstone (Bates *et al*, 1947, p. 28). The Torres member contains the interbedded sandstone, siltstone, limestone, and gypsum that make up the main part of the formation.

The Yeso formation makes up a large part of the exposed strata in the Pedernal area. It crops out along both sides and across the northern end of the Precambrian exposures.

Relation to adjacent formations - The Yeso formation lies unconformably upon the Precambrian.

Lithology - In the Pedernal area, the Yeso formation consists of a lower zone of fine- to medium-grained, pale yellowish orange sandstone. This zone grades upward into a zone of moderately reddish orange to pale reddish brown siltstones and sandstones with thin limestone and gypsum beds.

The sandstones are generally thin to medium, regularly

bedded, and are composed mainly of angular quartz. There are thin siltstone zones in the sandstones. Well rounded, medium to coarse quartz grains are common. The limestones are medium gray to olive-gray, finely crystalline, nonporous, with a rugose weathered surface. Coarse quartz grains are sometimes found.

At the Permian-Precambrian contact, the lower sandstones and limestones of the Yeso formation contain angular quartzite fragments as much as one foot in diameter. Where this contact was observed, the Yeso sandstones contain up to 30 percent of these fragments. However, the matrix is still fine- to medium-grained. These fragments are observed only within one-half mile of the Precambrian.

The writer correlates the lower sandstone zone with the Meseta Blanca sandstone. The overlying siltstones, sandstones, limestones and gypsum comprise the Torres member. In the well samples, the four members were not easily distinguished. However, the lithology encountered in the well samples was similar to that of the surface sections, although it was considerably thicker.

Thickness - At the type locality, the Yeso formation, as now defined, is 696 feet thick. It thickens to over 2,350 feet in the subsurface of the southeastern part of the State.

In the Pedernal area, no complete section of the Yeso formation is available. A composite thickness of approximately 275 feet was obtained two to three miles from the Precambrian outcrop area. Hence the Yeso formation ranges from a feather edge at the contact with the Precambrian to approximately 275

feet within the mapped area.

In the Randall # 1 Estancia well, approximately eight miles west of the Precambrian outcrop, the Yeso formation appears to be at least 1,000 feet thick (Plate II). To the north in the Sanders # 1 State, the Yeso formation is 730 feet thick. In the Cardinal # 1 State northeast of the Precambrian outcrop, the Yeso formation is 780 feet thick.

The samples from the Petrol # 1 State are similar to those previously described. This well penetrated only a few hundred feet of sediments, mostly Yeso. Worthy of note is the presence of several beds containing up to 50 percent specular hematite.

Age and correlation - No diagnostic fossils were found in the Yeso formation in the Pedernal area. However, because of the lithology and stratigraphic position, the Yeso formation is easily recognized over a large area. Needham and Bates (1943, p. 1666) believed it to be equivalent to the lower part of the Bone Spring limestone of the Delaware basin and to part of the De Chelly sandstone of northeastern Arizona. Hence it is considered to represent a part of lower Leonard time.

Glorieta sandstone

Type locality and distribution - The following is quoted from Needham and Bates (1943, p. 1662) in which they defined the Glorieta sandstone.

"The name Glorieta was first used by Keyes (1915, p. 2, 7), who applied it to the main body of the Dakota sandstone (Cretaceous) around the south end of the Rocky Mountains. Although Keyes gave no type locality, presumably the sand-

stone was named from Glorieta Mesa in Santa Fe and San Miguel Counties, New Mexico, or from the town of Glorieta at the north end of the Mesa. Cretaceous formations do not crop out at either of these places. Common usage has determined the Glorieta to be the prominent sandstone, well developed and exposed on Glorieta Mesa, that separates the Yeso and San Andres formations.

The Glorieta was first designated Permian by Hager and Robitaille (1919)..."

In U. S. Geological Survey usage, the Glorieta sandstone is a member of the San Andres formation. However, the writer will treat the Glorieta sandstone as a separate formation, as is the practice of the New Mexico Bureau of Mines and Mineral Resources.

The Glorieta sandstone is present in New Mexico in the same areas as the underlying Yeso formation. It is especially prominent in northern New Mexico. The Glorieta sandstone crops out in a band across the northern part of the Pedernal area. It forms the escarpment which is considered to be the southern termination of Glorieta Mesa. The width of the outcrop area varies from a few hundred feet on Glorieta Mesa to approximately three miles where it crosses U. S. Highway 285.

Relation to adjacent formations - The Glorieta sandstone is believed to lie conformably on the Yeso formation (Needham and Bates, 1942, p. 33). Bates et al (1947, p. 33) found tongues of the Yeso formation in the lower part of the Glorieta sandstone. These were thought to indicate alternating transgression and regression of the Yeso seas from the south.

Lithology - The Glorieta sandstone is a white to very pale orange, clean, siliceous, quartz sandstone. It weathers a moderately yellowish brown to reddish brown. The grains

are well sorted, medium-grained and subangular. Other distinguishing features are the thin to massive regular bedding, and iron concretion zones. Varying from hard to friable, it is generally a cliff former. On weathered surfaces, shiny quartz faces give it a sugary appearance.

In the subsurface, it is easily recognized because of its clean appearance and iron staining. Some of the well samples contain up to two percent magnetic minerals.

Thickness - The Glorieta sandstone attains its greatest thickness in northern New Mexixo. This thickness ranges from 12 feet in the northern Sacramento Mountains to 278 feet at Willard in Torrance County and 136 feet at the type locality (Needham and Bates, 1943, p. 1664). In the Pedernal area, the Glorieta is approximately 210 feet thick. This section was measured up a cliff, the top of which was covered with limestone float. However, the actual Glorieta-San Andres contact was not observed.

In the subsurface, the Glorieta sandstone ranges from 280 feet thick in the Sanders # 1 State to an approximate 400 feet in the Cardinal # 1 State.

Age and correlation - According to Needham and Bates (1943, p. 1664), the Glorieta sandstone is equivalent to the upper part of the De Chelly sandstone of northeastern Arizona and the San Angelo sandstone of north and central Texas. These writers believe it to be identical with the Hondo sandstone.

San Andres formation

Type locality and distribution - First defined by Lee

(1909, p. 12) from the San Andres Mountains in southern New Mexico, the San Andres formation was redefined by Needham and Bates (1943, p. 1664-1667). The U. S. Geological Survey includes the Glorieta sandstone as the lower sandstone member of the San Andres formation, but the term San Andres formation as used in this report consists of just the limestone member of the San Andres formation of the U. S. Geological Survey.

The San Andres formation crops out rather widely over northern and southeastern New Mexico. From thin and discontinuous exposures in the northern part of the state, it thickens toward the southeast with large exposures capping Chupadera Mesa, the Sacramento Mountains, and the Guadalupe Mountains.

The San Andres formation is exposed only as erosional remnants and float capping the mesa in the northern part of the Pedernal area and in the monoclinal fold along the western side of this mesa. Exposures are poor.

Relation to adjacent formations - The San Andres-Glorieta sandstone contact is generally regarded as conformable, and in some places may be gradational (Bates, et al, 1947, p.34). Needham and Bates (1943, p. 1666) stated that they have seen sandstones resembling Glorieta sandstone some distance above the base of the San Andres limestone. These were regarded as belonging in the San Andres despite the difference of lithology.

In the Pedernal area, the San Andres-Glorieta contact is covered everywhere. There were places where sandstones

resembling the Glorieta seemed to occur stratigraphically above limestone considered to be San Andres. This alternating sandstone-limestone sequence is the relationship described above as noted by Needham and Bates.

Lithology - According to Needham and Bates (1943, p. 1665), the San Andres has a remarkable uniformity of composition. It consists predominantly of limestone with occasional dolomite and gypsum beds. To the southeast in the subsurface, the San Andres includes a thick section of alternating limestones, gypsums and red-beds.

Within the mapped area, no detailed lithologic sections could be measured because of poor exposures. However, where seen, the San Andres is a dark gray, finely crystalline, nonporous limestone. It appears to be massively bedded and has a rugose weathered surface which is due to the silica content. Some massive white gypsum was observed in the San Andres interval but its stratigraphic position could not be determined because of the poor exposures.

Thickness - Thicknesses of the San Andres range from 15 feet in northern New Mexico to an average of 1,200 feet in the subsurface along the west side of the Permian Basin. In the Pedernal area, no good exposures are available. An interval of 247 feet, mostly covered, was measured.

Age and correlation - The San Andres formation is considered by Needham and Bates (1943, p. 1666) to constitute the upper part of the Leonard series and thus to be equivalent to the upper part of the Bone Spring limestone of the Delaware basin. Lloyd (1949, p. 16) placed the San Andres

in the Guadalupe series.

Bernal formation

Type locality and distribution - Long considered the upper clastic member of the San Andres, the name Bernal formation was first published by Bachman (1953).

The type locality is near the village of Bernal and Chapelle, San Miguel Counties. The Bernal formation has been recognized over much of central and northwestern New Mexico. In the Pedernal area, it crops out as a slope former beneath the Santa Rosa sandstone cliff just north of Highway 66 in the vicinity of Clines Corners.

Relation to adjacent formations - Disconformable relations between the Bernal formation and the underlying San Andres formation have been observed in other parts of central New Mexico (Bachman, 1953). The contact in the Pedernal area is covered.

Lithology - At the type locality, the Bernal formation consists of interbedded, brownish red siltstone and fine-grained sandstone. In the Pedernal area, it is made up of thinly bedded, pale red to moderately reddish orange, fine-grained sandstones. The sand grains are predominantly subangular quartz. Although generally regularly bedded, some short corss-beds are seen. Despite the fact that the sandstones are well cemented, they are slope formers.

Thickness - The Bernal formation averages 100 feet in thickness in north-central New Mexico. A thickness of 156 feet was measured in the Pedernal area.

Age and correlation - The Bernal formation probably correlates with parts of the Chalk Bluff formation of southeastern New Mexico (Bachman, 1953).

Triassic Strata

General statement

In eastern New Mexico, the Triassic system is represented by a red-bed sequence which is equivalent to the Dockum group of western Texas. The Dockum group in New Mexico includes the Santa Rosa sandstone and the overlying Chinle formation. In the Pedernal area only the Santa Rosa sandstone is exposed.

Santa Rosa sandstone

Type locality and distribution - The name Santa Rosa was first used by Darton (1922, p. 183) in describing prominent sandstone exposures in the vicinity of the town of Santa Rosa. No exact type locality was given. The sandstone crops out extensively in eastern New Mexico especially around Santa Rosa and along the Canadian and Concho Rivers.

Within the mapped area, the Santa Rosa sandstone caps the ridge just north of and paralleling Highway 66 along the northern border.

Relation to adjacent formations - The Santa Rosa sandstone lies disconformably on the Bernal formation. Although it does not occur within the mapped area, the contact with the overlying Chinle formation seems to be conformable elsewhere (Bachman, 1953).

Lithology - In general, the Santa Rosa sandstone is a series of irregularly bedded, red-brown sandstones, siltstones, and conglomeratic sandstones. In the Pedernal area, the measured section consists of a light yellow-brown, sandy conglomerate grading into a light yellow-brown, medium- to coarse-grained sandstone which weathers to a dark brown. The coarse material of the conglomerate ranges from coarse-grained sand to pebbles one inch in diameter. The pebbles are predominantly quartzite and chert and vary from subangular to subrounded. Some cross-bedding is seen. In the sandstone, the coarser material is concentrated along the cross-beds. The whole unit is a well consolidated cliff former.

Thickness - The thickness of the Santa Rosa sandstone varies considerably. Near Ocate in Mora County, Bachman (1953) reported 425 feet. Dobrovolny et al (1946) measured a maximum of 300 feet in northwestern Quay County. Around Santa Rosa, it averages 100 feet. In the Pedernal area, only 13 feet was measured in partial section to the top of a cliff, the top being a stripped surface on the sandstone-conglomerate interval.

Age and correlation - Both the Santa Rosa sandstone and the overlying Chinle formation are believed to be late Triassic in age (Bachman, 1953). The Santa Rosa occupies the stratigraphic interval of the Shinarump conglomerate of northeastern Arizona and the Agua Zarca formation of northwest New Mexico.

Cenozoic Rocks

General statement

The Cenozoic era is represented by caliche and gravel,

alluvium, and igneous intrusive rocks. The caliche and gravel, and the alluvium were mapped as separate units because they are of different ages and represent different erosion cycles.

Caliche and gravel

Darton, on the state map (1928), showed extensive Miocene-Pliocene deposits along the eastern flank of the Pedernal Hills. These were thought to be the Ogallala formation of the Great Plains (Darton, 1928, p. 28). However, this term was not used in this report because there was not sufficient evidence on which to base a correlation with the Ogallala formation.

In the Pedernal area, the deposits are widespread, forming an almost level surface along the eastern side and across the northern end of the Pedernal Hills. Along the west side, the surface is dissected and the caliche and gravel deposits exist only as scattered remnants.

Near the Precambrian outcrops, the deposits are almost wholly made up of gravels. The gravels contain angular fragments of Precambrian quartzite, granite, and schist up to three inches in diameter and loosely consolidated with a caliche cement. Farther away from the Precambrian, the amount of gravel decreases to scattered pebbles and the deposit is predominantly caliche. The caliche, which resembles a sandy marl, is generally well consolidated and ranges in color from white to grayish orange-pink. The

bedding and structure of the deposit is irregular, resulting in a nodular weathered surface. Quite commonly the slope below the deposit is covered with white caliche debris. The maximum thickness observed within the mapped area was approximately 15 feet.

The caliche-gravel deposit is unconformable on the underlying rocks. It is Tertiary-Quaternary in age.

Alluvium

Although at least half of the area is covered by alluvium and soil of different types, alluvium was mapped only where it is well developed in some of the major dry washs and in sinkholes. This alluvium consists of unconsolidated fluviatile sands, silts, and gravels.

Intrusive rocks

Northwest of the Pedernal Hills are several parallel dikes. These are five to ten feet thick and are composed of diabase.

STRUCTURE

General Statement

The major structural elements within the Precambrian of the Pedernal area are (1) the predominantly southeastward dipping metasediments, and (2) the granite intrusions. The structural elements of the post-Precambrian sediments include (1) the unconformable contact between the Precambrian basement and the overlying strata, and (2) the normal faults of the Pennsylvanian and Permian strata. Regionally, the most imposing feature is the Pedernal axis, a positive area that existed during Pennsylvanian and Permian time.

Precambrian Basement

The Precambrian basement is composed of several thousand feet of quartzite, schist, and greenstone intruded by granite. The strike and dip are fairly consistent with an average strike of N 40° E and a dip of 35° to the southeast. Toward the south, in areas of very poor exposures, the strike appears to swing around to a more general easterly direction with the dip steepening slightly.

This series of metasediments has apparently been subjected to at least one and possibly two granitic intrusions. The granite comprises the main part of the Precambrian outcrops in the southern half of the mapped area. In the granite, there is an occassional, irregular flow pattern. The contact of the granite and the metasediments was not observed, but within the granite area there are outcrops of

a basic or intermediate rock which are regarded to be the greenstone after being subjected to a degree of contact metamorphism. The lack of narrow, elongated exposures suggests that these outcrops are not lamprophyre dikes.

Quartz veins are common in the Precambrian. These are especially noticeable in the dark green schists where they occur along the planes of schistosity and also in a vertical position. The vertical veins generally trend in a northerly direction across the strike. They range from a few inches up to ten feet in thickness. Quartz veins in greenstones are believed to be derived from the wall rock by a process of carbonatization and chloritization and are localized along shear zones (Boyle, 1955).

Little or no evidence of folding or faulting was found. Within the quartzites and schist, small drag folds are evident, representing some deformation. However, as a rule, the attitude of the beds is remarkably uniform.

One exception to the above statement is a prominent zone striking N 15° W across the west side of Pedernal Peak. This zone supports more vegetation than the surrounding terrain and is easily seen on the aerial photos. This is regarded to be a high angle fault but whether the movement was normal or reverse could not be determined.

Within the Precambrian, a rather well-developed joint system is present. It is especially prominent within the quartzite. The first and best developed set of joints has a strike of N 25° W and a dip of 75° to the southwest. This set makes an angle of 50 to 55° with the strike of the beds.

The second set of joints is oriented along the strike of the beds (N 30° E) and generally dips at right angles to the plane of the bedding. The third and least well-developed set of joints strikes in an easterly direction and also dips at right angles to the bedding planes. If only two of the sets of joints are developed, a rock fragment may have a rhombohedral appearance; if all three are developed, it may have a hexagonal outline. Although this system of joints resembles shear fractures, the structural geology of the Precambrian is not well enough understood to venture an opinion on the origin of the joints and the forces involved.

Paleozoic and Mesozoic Structure

The structure of the Pennsylvanian, Permian, and Triassic rocks is quite simple and uniform. They lap unconformably onto the Precambrian core. The dip is generally two to five degrees away from the Precambrian. In places, the basal beds of the Yeso formation have an undulating surface, probably due to irregularities in the basement rocks.

Along the west side of the Precambrian, two faults are visible. The major fault trends in a northerly direction and appears to connect with the monoclinal fold along the west side of the southern termination of Glorieta Mesa. This appears to be a normal fault with the west side downthrown. Maximum displacement seems to be on the order of 150 to 200 feet. The trace of this fault disappears to the south in areas of poor exposures. Maximum dip adjacent to the plane of the fault is 75 to 80°, flattening within a few hundred feet to the more normal two- to five-degree dip. The second

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fault occurs east of the major one in the vicinity of the dikes. The east side of this fault is the downthrown side.

The dip in the Glorieta sandstone along the monocline varies from eight to thirty degrees as it disappears under the alluvium. This dip appears to flatten out rapidly, as the Glorieta crops out again immediately outside the western boundary of the mapped area.

The strata of Glorieta Mesa apparently at one time lapped directly against the Precambrian and have been eroded back to their present position.

Parallel to, and probably associated with, the faults described above is a set of five dikes. These are all within three miles of the zone of faults and on the east side of it. These dikes represent intrusions along planes of weakness caused by the same forces that caused the fault. The faults and dikes may represent a zone of fractures caused by relaxation of previous compressional forces.

Regional Structure

The Precambrian of the Pedernal area is the surface exposure of a buried land mass that existed in middle Pennsylvanian times, the so called "Ancestral Rockies" (Fig. 2). The Pedernal uplift trends northward into the southeastern part of the Sangre de Cristo Mountains. To the south, it extends through the Gallinas, Sacramento and Guadalupe Mountains.

On the west, the Pedernal uplift is bounded by a sedimentary basin over 5,000 feet deep, as evidenced by the thick

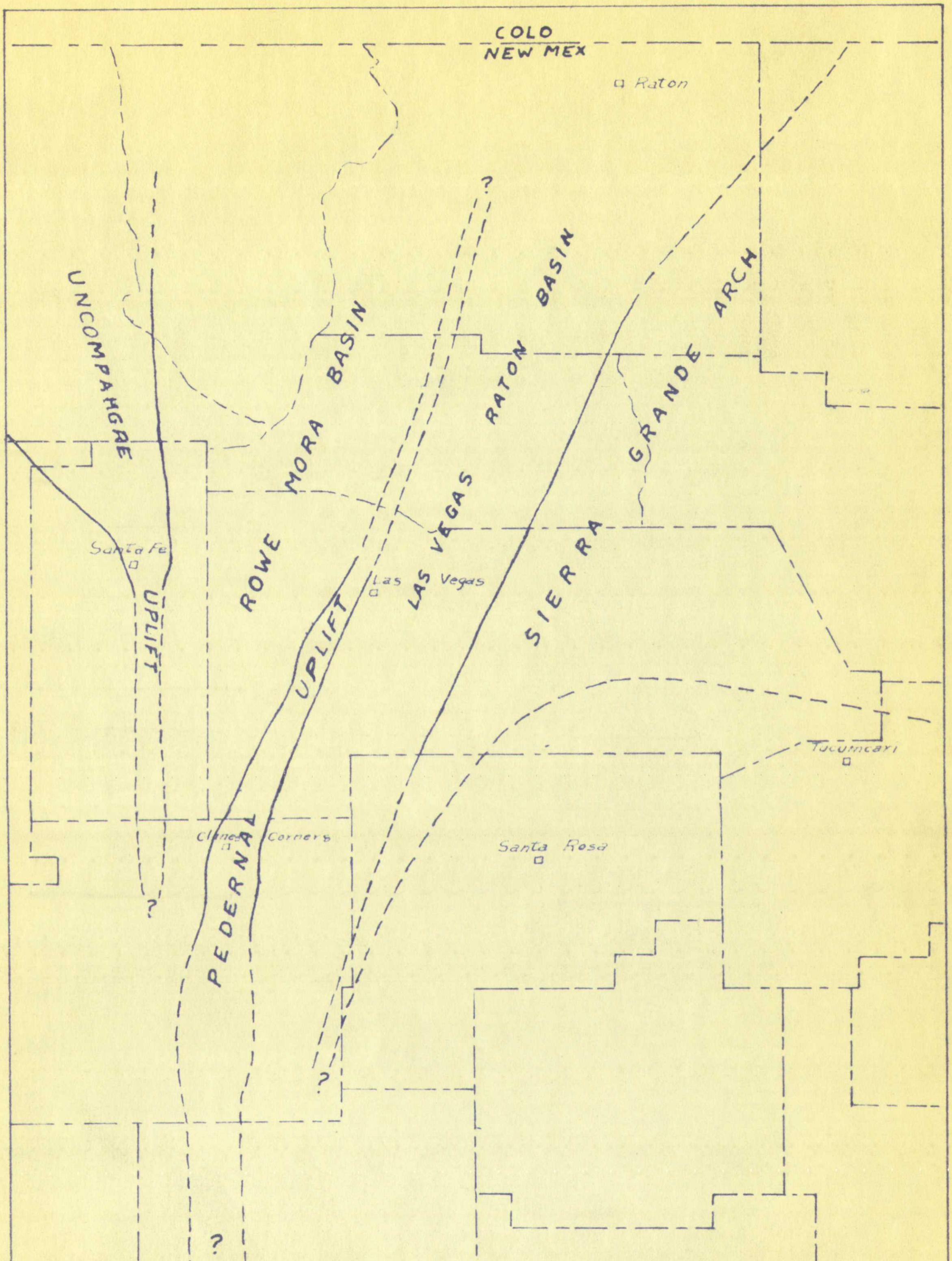

FIGURE 2 OUTLINE OF PRINCIPAL STRUCTURAL FEATURES DURING PENNSYLVANIAN TIME

section of the Randall # 1 Estancia. As the dip of the Pre-cambrian rocks is to the southeast rather than into the basin, there is the possibility of a fault along the western edge of the Pedernal uplift with the basin being downthrown. This basin connects to the north with the Rowe-Mora basin and to the south under Chupadera Mesa with the Tularosa basin (Fig. 3).

Along the west side of the Pedernal uplift, it is probable that another subsurface basin exists between the Pedernal uplift and the Sierra Grande arch. The thick clastic sections of the Sanders # 1 State and the Cardinal # 1 State would indicate this. This basin may extend northward into the Las Vegas-Raton and Trinidad basins. The Sierra Grande arch continues northeastward into Colorado where it is known as the Las Animas arch.

Thus by middle Pennsylvanian time, the regional structural elements of northern New Mexico included the following: the Uncompahgre, Pedernal, and Sierra Grande uplifts separated by the Rowe-Mora and Las Vegas-Raton basins. These features have a general northerly trend that would indicate that they resulted from east-west compressional forces. This is theoretical, as little is actually known of these basins and uplifts.

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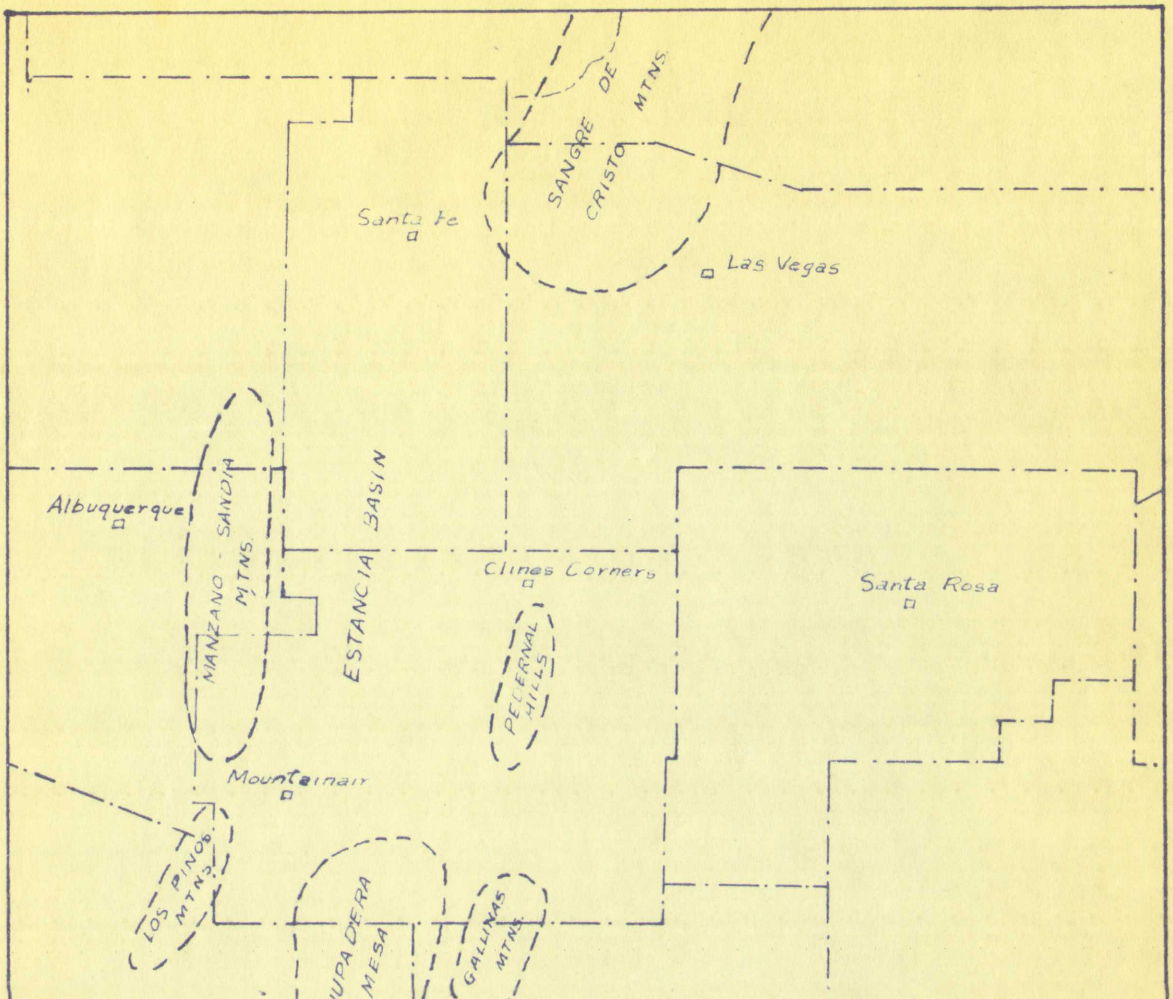

FIGURE 3 PRINCIPAL PHYSIOGRAPHIC FEATURES OF CENTRAL NEW MEXICO

GEOLOGIC HISTORY

Events of the Precambrian

The events of the Precambrian era of New Mexico in general are poorly understood because of a lack of detailed work on the Precambrian exposures of the state. From the exposures of the Pedernal Hills, the following events can at least be inferred.

The first recorded event in Precambrian time was the deposition of several thousand feet of sands, silts and muds. These were then lithified and uplifted. If the greenstones are assumed to be metamorphosed igneous rocks, then a considerable thickness of igneous rocks, probably as sills and flows, was added. The next event was the tilting and possible folding of the strata with accompanying regional metamorphism. This metamorphism altered the sedimentary rocks to their present metamorphic equivalents. The last recorded event of the Precambrian was the intrusion of the pre-existing rocks by large masses of granite.

Paleozoic and Mesozoic History

The geologic history of northern New Mexico in early Paleozoic time is largely speculative. Outcrops of Mississippian and Devonian age have been found. However, most of northern New Mexico is believed to have been a high, positive area subject to extensive erosion during most of early Paleozoic time.

During early Pennsylvanian time, widespread marine transgression occurred with the deposition of the Sandia

formation, a dominantly clastic formation which, because of its transgressive nature, may vary in age regionally. The seas continued to be widespread during Des Moines time although local highs may have been present. During Des Moines time, the lower gray limestone member of the Madera formation was deposited.

It appears that the orogenic movements which were to shape the structural elements of New Mexico during the Pennsylvanian period began during Des Moines time. The Pedernal uplift was beginning to form with the appearance of more clastics in the adjoining sedimentary basins. These movements continued through Missouri and Virgil time with more and more clastics being deposited. The earlier widespread Pennsylvanian sea had been divided by Virgil time into the separate basins (e. g. Rowe-Mora basin), with the intervening highlands (e. g. Pedernal uplift) shedding vast amounts of clastic material. This clastic sequence seems to have been the cause of local regression. The amount of sediments exceeded subsidence, thus forcing the sea to retreat. The continental Sangre de Cristo formation and the clastic sequence of the Randall # 1 Estancia well are examples of the material deposited. During latest Pennsylvanian time, this regression of the Pennsylvanian sea became general.

According to Read and Wood (1947, p. 223), the Pennsylvanian of northern New Mexico makes up a major sedimentary cycle consisting of a marine and a continental phase. The marine phase includes a suite of trangressive sediments (Sandia Formation) and a suite of marine sediments repre-

senting maximum marine transgression. The Madera formation is representative of this group. Overlying this marine suite are sediments of alternating marine and continental deposits which are unevenly distributed. The Bursum formation is a good example of this alternating environment.

The continental sediments which are, at least in part, of Permian age have not been broken down into minor units. They have been called the Sangre de Cristo and the Abo formations. These continental sediments represent the final phase of geosynclinal sedimentation and of geanticlinal maturity and old age (Read and Wood, 1947, p. 223).

It should be remembered, in considering the Pennsylvanian-Permian contact, that during late Pennsylvanian time, northern New Mexico consisted of separate basins and highlands which were at the same time partly or intermittently connected. Each separate basin may have its own characteristics to the point that broad generalizations concerning unconformities may not be true for the whole area. The absence of an unconformity in some localitites may indicate continuous sedimentation. In general, the top of the Magdalena formation represents the upper limit of marine sedimentation in any given area.

During early Leonard time, most of northern and eastern New Mexico was covered by a saline epicontinental sea which deposited the Yeso formation. Needham and Bates (1943, p. 1661) state that the alternating sandstones, siltstones, limestones, and gypsums are evidence of the cyclical deposition of this formation. Most of the sediments of the Yeso formation were derived from the high areas which came

into being during Pennsylvanian time. Probably by middle Permian time, most of these source areas had been reduced to near base-level.

During middle Permian time, the sea once again transgressed northward and deposited the San Andres limestone. The underlying Glorieta sandstone is believed to be an extensively developed beach deposit formed as the sea transgressed (Bachman 1953). The source of this extensive sandstone is somewhat of a mystery. King (1945, p. 10) maintained that the Glorieta was derived from islands in the Permian sea. These would be the remnants of the Pennsylvanian high areas.

The Bernal formation suggests marine or lagoonal conditions during late middle Permian time (Bachman, 1953).

No rocks of late Permian or early and middle Triassic are present in the Pedernal area, probably because of nondeposition. It is believed that during this period of time that, although the area was of very low relief, it was probably still shedding some sediments. McKee (1954, p. 25) believes that the Uncompahgre uplift and other high areas supplied sediments to the Moenkopi formation of Arizona, Utah and Colorado during early and middle Triassic time although the whole area was of very low relief. Continental conditions existed during late Triassic time, with the Santa Rosa sandstone and Chinle formation representing floodplain or fluviatile environments.

Jurassic and Cretaceous rocks are not present within the area. As rocks of Jurassic and Cretaceous age crop

out in areas adjacent to the Pedernal Hills, they may have at one time extended completely across the Pedernal uplift and have been removed by post-Cretaceous erosion. Late Cretaceous time marks the last marine transgression of New Mexico.

The Laramide orogeny of late Cretaceous-early Tertiary time produced folding and complex faulting in what is now the Sangre de Cristo Range of northern New Mexico and in the Los Pinos Mountains southwest of the mapped area. Although there is no evidence of extensive Laramide orogeny in the Pedernal area, it is possible that the Pedernal axis was rejuvenated slightly at this time.

Cenozoic History

During middle and late Tertiary time, uplift and normal faulting occurred widely over New Mexico, as evidenced by the Sandia and Manzano fault blocks to the west. The faulting and emplacement of the dikes, along the western edge of the Pedernal Hills, probably occurred at this time.

During latest Tertiary or early Quaternary time, the Pedernal area was subjected to an extensive cycle of erosion with the development of a pediment surface and gravel-caliche cap rock, dipping gently away from the Pedernal Hills which stood as erosional remnants above this pediment surface. As the relief on this surface must have been low, the erosion cycle is believed by the author to have reached a mature or old-age phase. The gravels were deposited by streams which rapidly lost their velocity on the increasingly

gentle slope. The caliche was probably formed by evaporation of ground-waters.

Darton (1928, p. 53) mapped this caliche-gravel caprock as the Ogallala formation of the Great Plains and stated that the pediment surface was the same one that formed the Llano Estacado. Fiedler and Nye (1933, p. 14) named the higher of two erosion surfaces on the eastern slope of the Sacramento Mountains, the Sacramento Plain. Nye suggested that this surface originally continued eastward to the surface of the Great Plains. In other ground water reports this surface was projected northward to the broad upland surface that extends from the Capitan Mountains northward to Glorieta Mesa. It also extends eastward to merge with the outliers of the Great Plains west of the Pecos River in the vicinity of Ft. Sumner and Santa Rosa (U. S. Geol. Survey, 1941).

C. B. Read of the U. S. Geological Survey (personal communication) stated that the surface of Glorieta Mesa seems to project upward and merge with some of the pediment surfaces preserved in the higher elevations of the Sangre de Cristo Range.

At any rate, by latest Tertiary time, the Pedernal Hills and surrounding area were of low relief and in an advanced cycle of erosion, with a pediment surface stretching eastward toward the Great Plains.

During Pleistocene time, the great Estancia salt lake developed in the Estancia basin just west of the area.

The present day topography is a result of a recent rejuvenation of the streams of the area. The old pediments

are dissected and remain as remnants of a previously extensive pediment surface.

CONCLUSIONS

The principal conclusions of this report are as follows:

1. The Precambrian of the Pedernal Hills consists mainly of a thick sequence of quartzite, schist, greenstone, and granite. No complex faulting is present.

2. The Pedernal uplift is bordered on the west by the southern tip of the Rowe-Mora basin which, since middle Pennsylvanian time, has accumulated over 5,000 feet of sediments.

3. The great depth of this basin may be due to a fault along the west side of the Pedernal uplift.

4. The thickness of clastic sediments on the east side of the Pedernal uplift suggests another depositional basin which may be the southern end of the Las Vegas-Raton basin.

5. The Pedernal uplift was reduced to low relief by Yeso time and supplied very little sedimentary material from then on.

6. Late Permian and early and middle Triassic strata are absent in the area, probably because of nondeposition.

7. During late Tertiary-Quaternary time, the Pedernal Hills area underwent a cycle of erosion. An extensive pediment surface was developed which is now preserved as erosional remnants capped by caliche and gravel.

MEASURED SECTIONS

Section # 1 - Glorieta sandstone measured on the southern end of Glorieta Mesa (Sec. 2, T. 8 N., R. 11 E.)

		thickness (feet)
Glorieta sandstone		
1.	Sandstone, yellowish brown on weathered surface, yellowish white on fresh, fine- to medium-grained, well consolidated, thin to medium bedded, forms cliff, predominantly clean, subangular quartz sand.....	210
	total	210

Section # 2 - Yeso formation (Sec. 11, T. 8 N., R. 11 E.)

Yeso formation		
14.	Siltstone, red-brown, forms slope.......	22.8
13.	Gypsum, white to gray, massive..........	6.0
12.	Limestone, olive-gray, finely crystalline, rugose weathered surface................	3.0
11.	Sandstone, orange-red-brown, very fine- to fine-grained, subangular quartz, slope former.................................	20.0
10.	Siltstone, red-brown, forms slope.......	est40.0
9.	Gypsum, white, massive..................	est 6.0
8.	Siltstone, red-brown, forms slope.......	est70.0
7.	Limestone, dolomitic, medium gray, microcrystalline, dense, some very fine vuggy porosity................................	5.0
6.	Sandstone, calcareous, yellow-gray, very fine-grained, medium bedded............	4.0
5.	Sandstone, dark yellow-orange, very fine-grained, thin bedded grading into unit above..................................	4.0
4.	Sandstone, reddish brown, very thin bedded..................................	21.1
3.	Sandstone, grayish orange to dark yellow-orange, thin bedded, slope former, predominantly quartz, grades into unit above.	8.0
2.	Sandstone, moderate yellowish orange to dark brown, medium-grained, predominantly subangular quartz, thin irregular bedding, forms slope............................	5.0
1.	Sandstone, yellowish orange, medium-grained, massive bedded, forms cliff....	est70.0
	total	284.9

Section # 3 - Yeso formation measured in canyon, (Sec. 6, T. 7 N., R. 13 E.) on the east side of the Pedernal Hills.

		thickness (feet)
	<u>Tertiary-Quaternary gravel and caliche</u>	
6.	Caliche, pinkish tan to white, sandy with quartzite pebbles, 1 to 4 inches in diameter, irregularly bedded, nodular, caps mesa..........................	10
	total	10
	<u>Yeso formation</u>	
5.	Sandstone, reddish brown with light gray spots, very fine- to fine-grained, thin to medium bedded..........................	97.0
4.	Sandstone, grayish orange, thin to medium bedded, forms ledge, predominantly subangular quartz..........................	4.0
3.	Sandstone, pale yellowish orange, thin to medium bedded, fine- to medium-grained with some coarse grains near top, some siltstone zones with nodular weathering.	74.0
2.	Limestone, medium gray, weathers yellow-brown, microcrystalline, nonporous, has scattered quartz granules and pebbles...	6.0
1.	Sandstone, pale yellowish orange, very fine- to medium-grained, thin to medium bedded, contains abundant angular quartzite pebbles..........................	49.0
	total	230.0

Section # 4 - Bernal formation and Santa Rosa sandstone measured near Highway 66 (Sec. 13, T. 9 N., R. 11 E.).

	<u>Santa Rosa sandstone</u>	
3.	Sandstone, yellow-brown to dark brown, predominantly subangular to subrounded quartz, medium bedded, forms upper half of cliff..........................	5.0
2.	Conglomerate, sandy, light yellow to dark brown, predominantly chert and quartzite pebbles up to one inch in diameter, some cross-bedding, grades into sandstone above, forms lower half of cliff........	8.0
	total	13.0
	<u>Bernal formation</u>	
1.	Sandstone, pale red to moderate reddish orange, very fine- to fine-grained, predominantly subangular quartz, thin bedded with some short cross-beds, forms slope, lower half largely covered.............	156.0
	total	156.0

REFERENCES CITED

Bachman, G. O., 1953, Geology of a part of northwestern Mora County, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM 137.

Bates, R. L., Wilpolt, R. H., MacAlpin, A. J., and Vorbe, Georges, 1947, Geology of the Gran Quivira Quadrangle, New Mexico: New Mexico Bur. of Mines and Min. Res. Bull. 26.

Baker, C. L., 1920, Contributions to the stratigraphy of eastern New Mexico: Am. Jour. Sci., 4th ser., v. 49, p. 99-126.

Boyle, K. W., 1955, Geochemistry and origin of the gold bearing quartz veins and lenses of the Yellow Knife greenstone belt: Econ. Geology, v. 50, no. 1, p. 51-66.

Darton, N. H., 1922, Geologic structure of parts of New Mexico: U. S. Geol. Survey Bull. 726, p. 173-275.

_____ 1928a, Red beds and associated formations in New Mexico: U. S. Geol. Survey Bull. 794.

_____ 1928b, Geologic map of New Mexico: U. S. Geol. Survey.

Dobrovolny, E., Summerson, C. H., and Bates, R. L., 1946 Geology of northwestern Quay County, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM 62.

Fiedler, A. G., and Nye, S. S., 1933, Geology and ground water resources of the Roswell artesian basin, New Mexico: U. S. Geol. Survey Water-Supply Paper 639.

Gordon, C. H., 1907, Notes on Pennsylvanian formations in the Rio Grande Valley, New Mexico: Jour. Geology, v. 15, p. 805-816.

Hager, Dorsey, and Robitaille, A. E., 1919, Geologic report on oil possibilities in eastern New Mexico (unpublished). Cited by Wilmarth, M. Grace, 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896. p. 831.

Heaton, R. L., 1933, Ancestral Rockies and Mesozoic and late Paleozoic stratigraphy of the Rocky Mountains region: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 2, p. 109.

Johnson, D. W., 1902, Notes of a geological reconnaissance in eastern Valencia County, New Mexico: Am. Geologist, v. 29, p. 87.

Kelley, V. C., 1956, Thickness of strata: Jour. of Sed. Petrol., v. 26, no. 4, p. 289-300.

Keyes, C. R., 1915, Foundation of exact geologic correlation: Iowa Acad. Sci., v. 22, p. 249-267.

King, P. B. 1942, Permian of West Texas and southeastern New Mexico: Am Assoc. Petroleum Geologists Bull., v. 26, p.535-763.

Lang, W. B., 1937, Permian formations of the Pecos Valley of New Mexico and Texas: Am. Assoc. Petroleum Geologists Bull., v. 21, p. 833-898.

Lee, W. T., and Girty, G. H., 1909, The Manzano group of the Rio Grande Valley, New Mexico: U. S. Geol. Survey Bull. 389.

Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., 1910, The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68.

Lloyd, E. R., 1949, Pre-San Andres stratigraphy and oil producing zones in southeastern New Mexico: New Mexico Bur. of Mines and Min. Res. Bull. 29.

McKee, E. D., 1951, Sedimentary basins of Arizona and adjacent areas: Geol. Soc. America Bull., v. 62, no. 5, p. 481-506.

_____ 1954, Stratigraphy and History of the Moenkopi formation of Triassic Age: Geol. Soc. America, Mem. 61.

Meinzer, O. E., 1911, Geology and water resources of the Estancia Valley, New Mexico: U. S. Geol. Survey Water-Supply Paper 275.

Needham, C. E., and Bates, R. L., 1943, Permian type section in central New Mexico: Geol. Soc. America Bull., v. 54, no. 11, p. 1653-1668.

New Mexico Geological Society, 1952, Guidebook of the Rio Grande Valley, central New Mexico: 3rd. Field Conf.

_____ 1956, Guidebook of southeastern Sangre de Cristo Mountains, New Mexico: 7th Field Conf.

Northrop S. A., and Wood, G. H., 1946, Geology of the Nacimiento and San Pedro Mountains and adjacent plateaus: U. S. Geol. Survey Oil and Gas Inv. Map OM 57.

Read, C. B., and Wood, G. H., et al, 1944, Geologic map and stratigraphic sections of Permian and Pennsylvanian rocks of parts of San Miguel, Santa Fe, Sandoval, Bernalillo, Torrance, and Valencia Counties, north-

Kelley, V. C., 1955, [illegible]
[illegible], v. 25, no. 4, p. [illegible]

Keyes, C. R., 1923, [illegible]
Iowa Acad. Sci., v. [illegible]

King, P. B., 1942, Permian of west Texas and southeastern
New Mexico: Am. Assoc. Petroleum Geologists Bull., v.
26, p. 535-763.

Lang, W. T. B., 1937, [illegible]
of New Mexico and Texas: Am. Assoc. Petroleum Ge-
ologists Bull., v. 21, [illegible]

Lee, W. T., and Girty, G. H., 1909, The Manzano group of the
Rio Grande valley, New Mexico: U. S. Geol. Survey Bull.
389.

Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., 1910,
The ore deposits of New Mexico: U. S. Geol. Survey
Prof. Paper 68.

Lloyd, E. R., 1949, Pre-San Andres stratigraphy and oil-
producing zones in southeastern New Mexico: New Mexico
Bur. of Mines and Min. Res. Bull. 29.

McKee, E. D., 1951, [illegible]
mentary [illegible] Geol. Soc. America Bull., v. 62,
p. 481-[illegible].

____ 1954, [illegible]
Formation of [illegible]

Meinzer, O. E., 1911, Geology and water resources of Es-
tancia Valley, New Mexico: U. S. Geol. Survey Water-
Supply Paper 275.

Needham, C. E., and Bates, R. L., 1943, Permian type sections
in central New Mexico: Geol. Soc. America Bull., v. 54,
no. 11, p. 1653-1668.

New Mexico Geological Society, [illegible]
[illegible]

____ 1956, [illegible]
[illegible], New Mexico [illegible]

Northrop, S. A., and Wood, G. H., 1946, Geology of Naci-
miento and San Pedro Mountains and [illegible]
U. S. Geol. Survey Oil and Gas Inv. [illegible]

Read, C. B., and Wood, G. H., et al., 1944, [illegible]
stratigraphic sections of [illegible]
rocks of parts of San Miguel, Santa Fe, Sandoval,
Bernalillo, Torrance, and Valencia Counties, [illegible]

central New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM 21.

Read, C. B., and Wood, G. H., 1947, Distribution and correlation of Pennsylvanian rocks in late Paleozoic sedimentary basins of northern New Mexico: Jour. Geology, v. 55, no. 3, p. 220-236.

Roswell Geological Society, 1952, The Pedernal positive element and the Estancia basin: Guidebook of the 7th Field Trip.

Stark, J. T., and Dapples, E. C., 1946, Geology of the Los Pinos Mountains, New Mexico: Geol. Soc. American Bull., v. 57, no. 12, p. 1121-1172.

Thompson, M. L., 1942, The Pennsylvanian system in New Mexico: Bur. of Mines and Min. Res. Bull. 17.

U. S. Geol. Survey, 1941, Unpublished report on water resources of the Pecos River basin, New Mexico.

Wilpolt, R. H., MacAlpin, A. J., Bates, R. L., and Vorbes, Georges, 1946, Geologic map and stratigraphic sections of Paleozoic rocks of Joyita Hills, Los Pinos Mountains, and northern Chupadera Mesa, Valencia, Torrance, and Socorro Counties, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM 61.

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