NEW MEXICO
BUREAU OF MINES AND MINERAL RESOURCES
A DEPARTMENT OF THE SCHOOL OF MINES

E. C. ANDERSON
Director

BULLETIN 29

Pre-San Andres Stratigraphy and Oil-Producing Zones in Southeastern New Mexico

A PROGRESS REPORT

By
E. RUSSELL LLOYD

SOCORRO
1949

CONTENTS*P*

CONTENTS

PLATES

FIGURES

THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

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

EXPLANATORY NOTE

By

E. C. ANDERSON

The four years since the release of Bulletin No. 23, a preliminary report compiled by Robert E. King, have seen much work done and great progress made in the search for oil at depth in southeastern New Mexico. Many wells have been drilled, many producers have been brought in, and several new fields developed. Much new information on the stratigraphy and producing zones of the pre-San Andres formations has been accumulated.

The Bureau deemed it desirable that a new report be compiled and published that would include all the information, new and old, available as of July 1, 1949—that a "Progress Report" be made to replace Mr. King's "Preliminary Report".

To do the job properly it was essential that a person familiar with what has been done in the area be persuaded to undertake the work. It was not only essential that this person be familiar with the progress made in the development of the deep fields, he must also enjoy the full confidence and respect of the operating personnel, as well as his professional associates.

In persuading Mr. Russell Lloyd to undertake the preparation of this report, we feel that this Bureau, as well as the petroleum fraternity, are indeed fortunate. It seems generally agreed that a better qualified person could not have been found for the job.

We hope that Bulletin 29, "Pre-San Andres stratigraphy and oil-producing zones in southeastern New Mexico—A Progress Report," will serve the industry well.

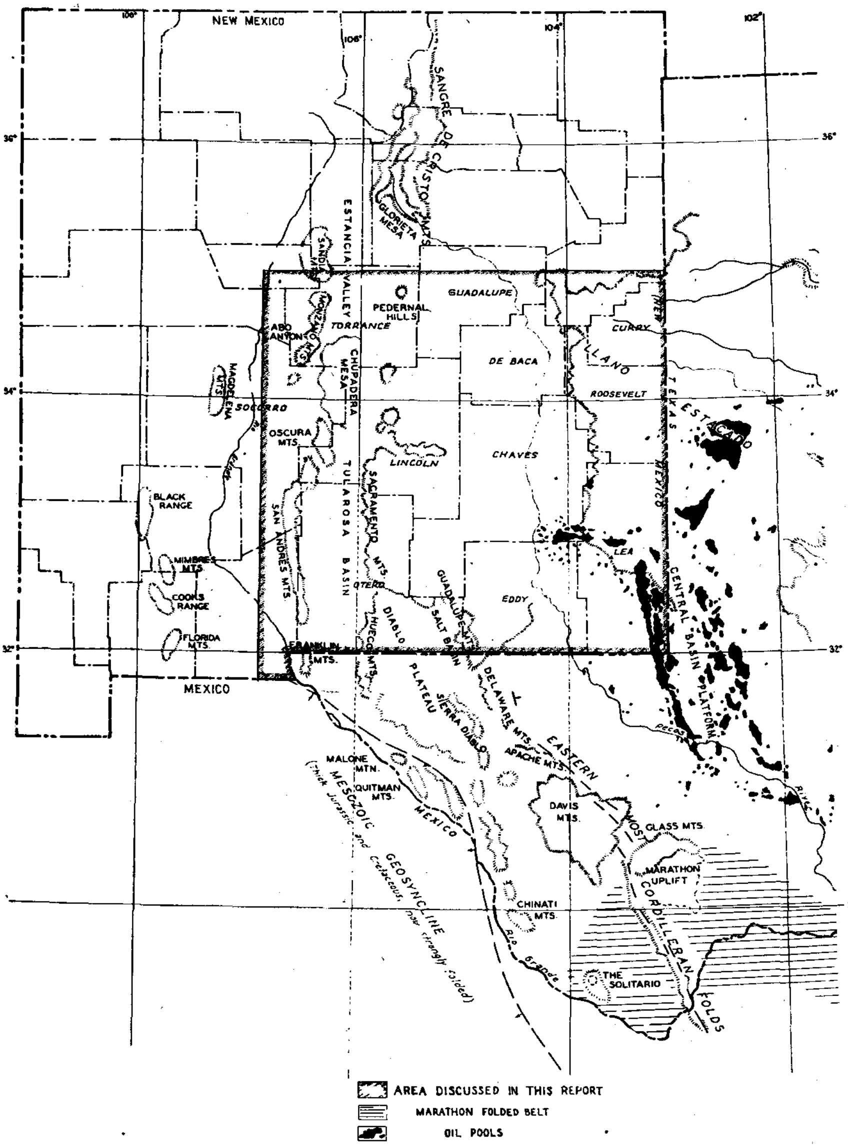

FIGURE 1. Outline map of New Mexico and part of Texas showing area discussed in this report.

Pre-San Andres Stratigraphy and Oil-Producing Zones in Southeastern New Mexico

A PROGRESS REPORT

By

E. RUSSELL LLOYD[1]

INTRODUCTION

The first discovery of commercial oil or gas in New Mexico in rocks older than the San Andres actually took place late in 1943 with the drilling of R. Olsen Oil Company's Langlie well in sec. 11, T. 25 S., R. 37 E., Lea County. Gas was discovered in what was later called the Justis pool, but the well was not officially completed until April 18, 1944. Later in 1944 the Dublin (Ellen-burger) , Drinkard (lower Yeso) and Cass (Pennsylvanian) pools were discovered, and the search for "older" pays has been active since that time.

In 1945 the New Mexico Bureau of Mines and Mineral Resources published Bulletin No. 23, a report by Robert E. King entitled "Stratigraphy and oil-producing zones of the pre-San Andres formations of southeastern New Mexico." This was a "Preliminary report," and the present work is designed as a progress report to supplement the work of King in the light of numerous wells that have been drilled since 1945.

Southeastern New Mexico is an indefinite area. The accompanying base map (pl. 1) covers the part of the state south and east of Albuquerque (fig. 1) . Present interest, however, is largely in the southeastern counties, Lea, Eddy, Chaves, and Roosevelt, and actual production of oil or gas from pre-San Andres formations is confined to Lea County. Most of the producing formations are exposed in the Sacramento, San Andres, and other mountains where they have been studied and described in more or less detail. A comparison of these described surface sections with the correlative sections in producing areas and in numerous exploratory wells has been one of the primary objects of the present studies. Much is yet to be learned, and future studies and data to be revealed by future wells will undoubtedly necessitate important revisions and additions to correlations and interpretations herein presented.

The report is primarily an attempt at regional stratigraphic interpretation. Some consideration of the major structural features is necessary in an interpretation of the stratigraphy, but no detailed structural studies have been undertaken. The strati-

[1]Consulting geologist, Midland, Texas.

graphic settings of the several oil and gas pools producing from rocks of pre-San. Andres age are presented, and some general structural features are shown by outline cross sections.

The purpose of King's report as expressed in his introduction was "to attempt standardization of names and correlations of the older subsurface units in southeastern New Mexico, and to compare the names used with those established for the surface outcrop sections in the state." The correlations and interpretations presented by King are accepted in the present report with only a few exceptions. The formation names used by King and in the present report are largely those established by surface work in the mountains of southern New Mexico. Some of them are not in general use, and in other cases there is a diversity in usage among geologists working in the area.

Many geologists use the names Clear Fork and Wichita correlated from groups of Permian formations. exposed in north central Texas. In the writer's opinion, however, the common correlations of these groups are not well established, and their use in New Mexico is inadvisable. The name "Tubb sand" is firmly established among subsurface geologists in the Permian Basin, but unfortunately has never been described in geological literature. The Drinkard sandy member of the Yeso formation, adequately described by R. E. King, is probably the same strati-graphic unit and, because it is well defined, should be more widely recognized.

The standard series names for subdivisions of the Pennsylvanian are preferred to the more local Texas units, although the latter are in common use. Recently defined or re-defined Mississippian formations, the Helms and Rancheria are used for subsurface units in preference to "Barnett" and "Mississippian limestone."

ACKNOWLEDGMENTS

The present report is a compilation based on published reports, logs from sample cuttings, electrical and radioactivity logs, paleontological and insoluble residue studies, and detailed studies by a number of geologists. Descriptions of sample cuttings from most of the critical Wildcat wells have been kindly furnished for use in preparing this report by W. W. West of the Permian Basin Sample Laboratory. Electrical and radioactivity logs were obtained from the West Texas Electrical Log Service. R. V. Hollingsworth and Harold Williams of the Paleontological Laboratory have been particularly helpful in furnishing fusulinid determinations without which the subdivisions of the Pennsylvanian and lower Permian would be impossible. Much valuable data have been furnished by E. W. Vanderpool of the Residue Research Laboratory.

Detailed surface sections of the Yeso and Abo formations

were measured in the Sacramento Mountains for this report by Richard C. Northup and Lloyd C. Pray. A similar section iri the Oscura Mountains was kindly furnished by Walter C. Warren with permission from the Standard Oil Company of Texas. A detailed measured section of the Pennsylvanian system in the Sacramento Mountains with fusulinid determinations of the series subdivisions was kindly furnished by M. L. Thompson. Some structural interpretations, particularly the outline of the old Pedernal Mountains, were guided in part by gravity surveys furnished by Hart Brown.

Many valuable suggestions and corrections were furnished by a number of geologists who have read the manuscript either in whole or in part. Particular thanks are due to John Emery Adams, Carl F. Barnhart, Carl C. Branson, Ralph D. Chambers, Hugh N. Frenzel, John M. Hills, Theodore S. Jones, Richard C. Northup, Dana M. Secor, R. C. Spivey, John W. Skinner, Georges Vorbe, and W. A. Waldschmidt. The report was prepared under the supervision of E. C. Anderson, Director of the Bureau of Mines and Mineral Resources.

Many suggestions and corrections by these geologists have been incorporated in the text, but there are still differences of opinion which cannot be reconciled. The writer must accept full responsibility for all statements, but his associates may claim full credit for much of the material incorporated in the report and may properly disavow any statements with which they do not agree.

PRINCIPAL STRUCTURAL FEATURES

GENERAL

Surf ace features east of the Pecos Valley in New Mexico furnish little evidence of the subsurface structure. Farther west, however, many structural features have been mapped on the surface and have determined the locations of a number of test wells.

The Sacramento and Guadalupe mountains are cuestas with gently sloping eastern flanks and faulted western scarps which separate them from the Tularosa and Salt basins respectively. The Hueco Mountains lie east of the southern part of the Tularosa Basin and form the western scarp of the Diablo Plateau. The highest part, structurally, of the Hueco Mountains lies west of the main west facing scarp and extends north along a line of low lying hills to the Jarilla Mountains at Oro Grande. The main structural uplift of the Sacramento Mountains dies out to the south in the Otero Mesa which is the northern continuation of the Diablo Plateau.

North of the Sacramento Mountains late Tertiary intrusions of igneous rocks form the Sierra Blanca, Capitan Mountains, Jicarilla Mountains, Gallinas Mountains, and other smaller peaks

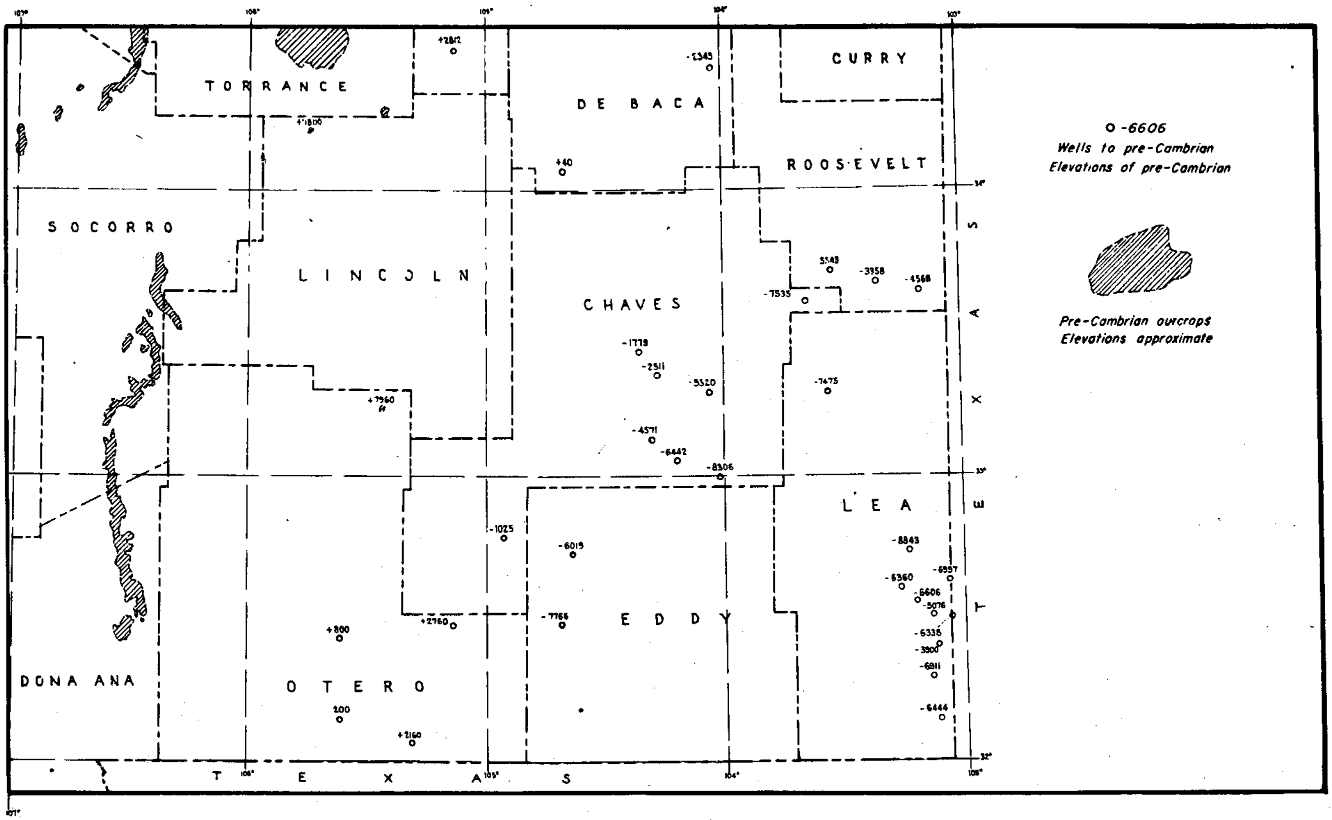

FIGURE 2. Pre-Cambrian elevations in southeastern New Mexico.

and ranges. Farther north along the same general trend, the Pedernal Hills consist of comparatively low lying outcrops of pre-Cambrian igneous rocks, gneisses and schists.

Farther west the Oscura, Los Piños, and Manzano mountains consisting of pre-Cambrian, Pennsylvanian, and Permian rocks are cuestas sloping to the east with abrupt, faulted western scarps. South and a little west of the Oscura Mountains are the San Andres Mountains, also a cuesta but sloping steeply to the west and with an abrupt, faulted eastern scarp facing the Sacramento Mountains across Tularosa Basin. The San Andres Mountains form a narrow range extending over 70 miles from north to south and expose rocks of all Paleozoic systems except the Cambrian. The same trend is continued south through the Organ and Franklin mountains to El Paso, Texas.

The common designations of structural units in the area east of the mountains, such as the Central Basin Platform, the Delaware Basin, and Northwestern Shelf area, are based primarily on structural and stratigraphic features of the Permian rocks and in general do not reflect the pre-Permian uplifts and basins. Some of the older positive areas can be outlined, but for, the most part their limits can be mapped in only a general way. The most prominent are the Pedernal Mountains, the Matador uplift, and the Eunice uplift, but there are others of lesser extent and prominence, and undoubtedly still others will be found by future drilling. The area of most nearly continuous deposition was probably in southern Eddy County and southwestern Lea County, but this is, as yet, essentially unexplored territory and may include some older positive areas of which there is at present little indication.

The top of the pre-Cambrian has been reached in a number of wells in southeastern New Mexico. Elevations of this horizon, above or below sea level, are shown on fig. 2 both in wildcat wells and in some localities where it is exposed at the surface. No attempt is made to interpret these points by structural contours because data are lacking over wide areas, and in these areas a structural interpretation would be largely guesswork. The present structural position of the pre-Cambrian represents the algebraic sum of structural movements since the beginning of the Cambrian except in limited areas where part of the pre-Cambrian has been removed by erosion.

PEDERNAL MOUNTAINS

The Pedernal Mountains were described by Thompson (1942, p. 12) as the Pedernal Land Mass, a southern branch of the Ancestral Rocky Mountains. The name is from the Pedernal Hills of Torrance County where pre-Cambrian gneisses, schists, and igneous rocks are exposed in low hills and are overlain by red and variegated shales and sandstones of the Yeso and Abo formations. Outlying knobs to the north, east, and south consist of similar pre-Cambrian rocks and the pre-Cambrian has been found at shallow depths in a number of wells. The principal outcrops of the pre-Cambrian in this and other areas are shown on p1. 1.

Pajarita Peak in T. 12 S., R. 15 E., Otero County, on the eastern slope of the Sacramento cuesta, is composed in part of igneous rock which is reported to be pre-Cambrian,[2] overlain by the Abo formation. Similar conditions have been reported just west of Capitan Mountains, Lincoln County (Thompson, 1942, p. 12) . A well drilled by Stanolind Oil and Gas Company near Picacho, Lincoln County, (sec. 10, T. 12 S., R. 18 E.) found coarse arkosic sandstone at 2310 feet underlain at 2550 feet by "granite wash" which in turn grades downward into igneous rock, the exact top of which is difficult to determine. Similar conditions were found in Humble's State No. 1-N (Manning Dome) well 15 miles farther south in sec. 35, T. 14 S., R. 17 E. in Chaves County. In both wells the arkosic sandstone and "granite wash" correspond in stratigraphic position with the Abo formation. The "granite" reported by Darton (1928, pp. 231-232) in a well near Picacho is probably "granite wash" grading downward into pre-Cambrian igneous rock.

The occurrence of thick beds of coarse elastics in areas surrounding the old Pedernal Mountains furnish some measure of its extent and prominence. Because of the probable elevation and extent of the uplift the name mountains is preferred to "land mass." The coarse sandstones and conglomerates are found in numerous beds from lower Atoka to the top of the Pennsylvanian as well as in the lower part of the Permian. They are conspicuous in the Sacramento, Oscura, Los Piños, and mountains farther north and also in numerous wells east of the mountains. The thickness and abundance of these coarse elastics indicate contemporaneous mountains of considerable magnitude. The first uplift apparently took place about the beginning of Atoka time, but probably the major uplift was early in the Permian. No coarse elastics have been found in beds older than the Pennsylvanian, but the present known northern occurrence of any pre-Pennsylvanian sediments in southeastern New Mexico is south of latitude 34° in the southern Oscura Mountains and in a well in southern Roosevelt County. It is logical to assume that southeastern New Mexico north of latitude 34° was a land area of low relief throughout earlier Paleozoic time.

The probable extent of the Pedernal Mountains in Pennsylvanian time is shown 'on fig. 4. The areal extent is predicated partly on the known absence of Pennsylvanian rocks and partly on gravity surveys furnished by Hart Brown. Three wells in southern Otero County found the Pennsylvanian missing, so it is possible that during Pennsylvanian time there was a continuous land area across Otero County into Hudspeth County, Texas.

[2]Some geologists who have studied Pajarita Peak believe that the igneous rock may be a Tertiary intrusive.

The present map, however, shows only local areas of uplift in Otero County.

MATADOR UPLIFT

Beds of Permian age (Wolfcamp) rest on the pre-Cambrian in one well in southern Roosevelt County, Shell's Harwood No. 1 in sec. 27, T. 7 S., R. 35 E. This is commonly interpreted as the western extension of the Matador uplift which is a prominent subsurface feature extending westward from the Electra arch of north central Texas across the South Plains area of Texas. In some wells the pre-Cambrian is directly overlain by Permian rocks, but in other wells beds of Virgil (upper Pennsylvanian) age rest on the pre-Cambrian indicating a pre-Virgil uplift. This is the case in Shell's Saunders-Federal test in sec. 5, T. 8 S., R. 37 E. where 100 feet of limestone and shale of Virgil age is present over the pre-Cambrian.

Some geologists think that the Matador uplift is a continuous ridge, while others think of it as a general alignment of isolated peaks. Data available to the writer on this question are inconclusive. There was probably some recurrence of structural uplift at various times throughout the Pennsylvanian culminating about the beginning of the Permian. No extensive coarse elastics have been reported in either Pennsylvanian or Permian rocks on the flanks of the Matador uplift, so we can assume. the absence of any high or extensive area of pre-Cambrian rocks.

The alignment of the Matador uplift has suggested a possible connection with the Capitan Mountains of central Lincoln County and with the east-west trending dikes in Chaves County. These mountains and dikes, however, are formed by late•Tertiary igneous intrusions, and their connection with a pre-Permian structural uplift is very doubtful. Another possible connection is with a structural feature found by drilling east and a little north of Roswell. In this area De Kalb's Lewis No. 1 well found only 200 feet of limestone and shale of Virgil age with a basal "granite wash" overlying the pre-Cambrian. Much thicker Pennsylvanian and older rocks were found in wells a few miles to the southeast indicating a ridge similar in character to the Matador uplift. Gravity data indicate that this ridge had a northeast-southwest trend but does not indicate any direct connection with the Matador uplift. Such a connection might have been by a few isolated peaks.

EUNICE UPLIFT

The Eunice uplift in eastern Lea County is well known because of its numerous oil pools and the large number of wells that have been drilled on and around the flanks of the main uplift. Only some broad outlines of the stratigraphy, structure and oil development are presented in this report.

The higher part of the uplift covers 15 to 20 square miles and in this area, the Abo formation of Leonard (Permian) age

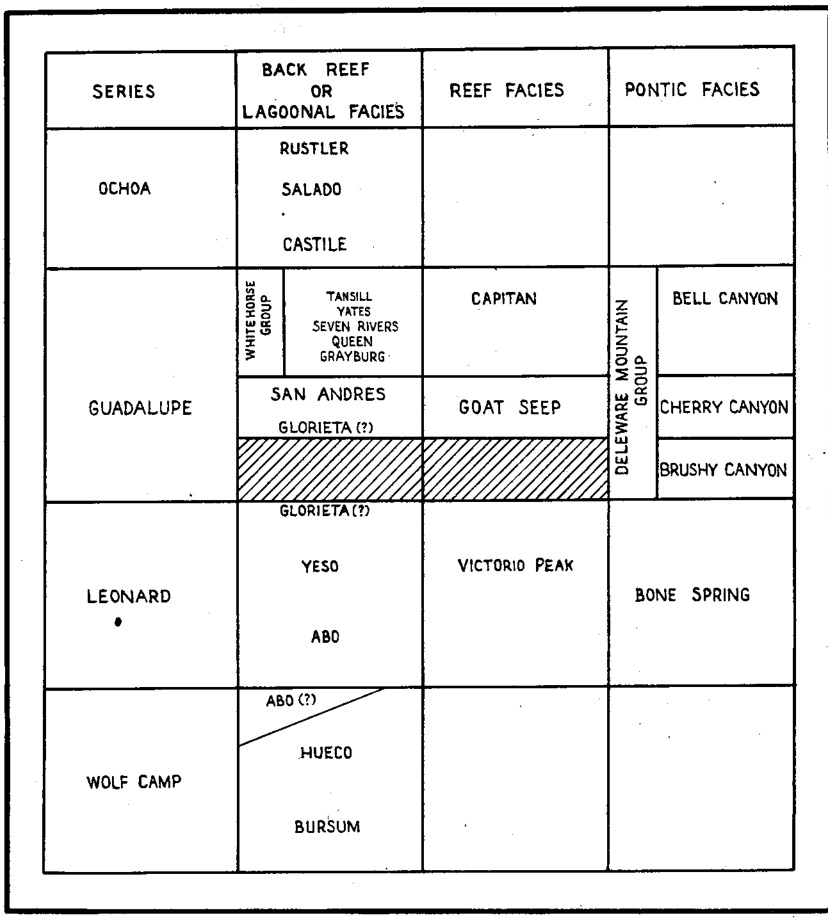

FIGURE 3. Correlation chart, Permian formations in New Mexico.

rests directly on pre-Cambrian. On the western and southern flanks and probably on the northern flank the truncated edges of beds of progressively younger ages appear beneath the Abo formation. The eastern flank appears to be faulted. The main period of uplift and erosion was at the close of the Pennsylvanian or early in the Permian. Wolfcamp beds were probably not deposited over the higher part of the area.

The general outline of the Eunice uplift coincides with the largest area of pre-San Andres oil production as shown on pl. 1. Outline cross sections are shown on pls. 8 and 9.

The Eunice uplift is one of the most prominent of a number of structural highs underlying the Central Basin Platform. It appears to lie at the intersection of two pre-Permian axes of folding, one trending nearly north-south in at least the southern part of Lea County and the other a northwest-southeast trend which can be traced into Lea County from Andrews County, Texas. Pennsylvanian beds are generally absent over the higher part of this fold, but older Paleozoic rocks are commonly present except over the high part of the Eunice uplift. The Monument pools are probably on a similar but less pronounced uplift separate from the Eunice uplift.

STRATIGRAPHY

GENERAL OUTLINE

All the Paleozoic systems except the Cambrian are represented in the sedimentary rocks of southeastern New Mexico, but a number of units of series rank are missing. Surface sections have been studied and described in the mountains of central New Mexico and western Texas, and the subsurface is known from the records of numerous wells. The following tabulation shows the principal rock units known in the area and the nomenclature used in this report.

TABLE 1. STRATIGRAPHIC UNITS IN SOUTHEASTERN NEW MEXICO

Age	Group and formation	Remarks
PERMIAN		
Ochoa		Not discussed in this report.
Guadalupe	Whitehorse group San Andres formation	
Guadalupe or Leonard	Glorieta formation	
Leonard	Yeso formation	
Leonard and Wolfcamp (?)	Abo formation	Leonard age in Lea County.
Wolfcamp	Hueco formation Bursum formation	

Age	Group and formation	Remarks
PENNSYLVANIAN		
Virgil	Fresnal group Keller group	No Pennsylvanian formations or groups are identified in subsurface.
Missouri		
Des Moines		
Atoka		
MISSISSIPPIAN		
Chester	Helms formation	(Restricted).
Meramec	Rancheria formation	"Mississippian Lime" of subsurface.
Osage	Lake Valley formation	Not recognized in subsurface.
Kinderhook	Caballero formation	May be present in Roosevelt and Chaves counties.
DEVONIAN		
Upper	Percha and Woodford formations Contadero formation Sly Gap formation	
Middle	Oñate and Canutillo formations	Not recognized in subsurface.
Lower	unnamed	Subsurface dolomite and limestone.
SILURIAN		
Upper	probably absent in southeastern New Mexico	
Middle	unnamed Fusselman	Limestone, dolomite, and shale.
Lower	probably absent in southeastern New Mexico	
ORDOVICIAN		
Upper	Montoya formation	
Middle	Simpson group	Subsurface only.
Lower	El Paso limestone and Ellenburger group Bliss sandstone	
CAMBRIAN	probably absent in southeastern New Mexico	

PERMIAN SYSTEM

CLASSIFICATION

In 1939 a group of geologists (Adams et al.) proposed a fourfold series subdivision of the Permian system. These subdivisions have been generally accepted but were not used by R. L. Clifton (1945) and John W. Skinner (1946) in their discussions of Permian stratigraphy and correlations. The present classification of the Permian formations of southeastern New Mexico is shown on an accompanying chart (fig. 3) .

In this classification three facies groups are distinguished based on the relationship to extensively developed barrier reefs which are prominent in the Guadalupe series but less evident in the other three series. One facies group is the reef itself with immediately associated rocks ; a second is landward from the reef ; and the third seaward from the reef.

Various names have been given to the areas shoreward from the reefs such as shelf, platform, back-reef, and lagoon. Objections can be raised to all these terms. The Castile formation belongs lithologically in the back-reef or lagoonal group, but it was deposited in a restricted basin and could hardly be called a shelf or platform facies. Even the term shoreward might be misleading because the actual shore lines were in places a hundred miles or more from the reefs. Many of the back-reef or lagoonal areas were actually shallow epicontinental seas differing from other shallow epicontinental seas only by being in a drier climate so that evaporation exceeded the supply of water from rainfall and runoff from surrounding land areas.

The rock facies developed seaward from the barrier reefs has likewise been called by different names : basin, basinal and pontic. The name pontic was proposed by the writer in 1938, because the rocks seaward from the Permian reefs of New Mexico and west Texas appeared to need a more distinctive name than the very general term basinal. The term is from the Greek word "pontos", one of the words for open sea or large sea and was applied particularly to the Black Sea, Pontos Euxeinos.

The Delaware Mountain group of rocks may be taken as typical of the pontic facies group:. Characteristic features are the general absence of dolomite and the dark to black color of the shales. Many of the limestones are also dark to black. The sandstones are less characteristic but are commonly fine-grained. These beds were deposited in a bay in which the waters were considerably deeper than in the adjacent reef area. The greatest depth of water in the bay was probably about the close of Capitan reef building time and was approximately 1800 feet.

The distinctive characteristics of the rocks of this facies are probably due, in part at least, to the depth of water in which they were deposited. The black limestone and shale of the Bone Spring formation have much the same features as those of the Delaware Mountain group and may be considered as equally typical of the facies group.

GUADALUPE-LEONARD CONTACT

The type section of the Guadalupe series is at the south end of the Guadalupe Mountains and is essentially the Delaware Mountain group. The lowest formation of the Delaware Mountain group is the Brushy Canyon, which according to P. B. King (1942, 1948) is confined to the Delaware Basin and disappears by overlap against the Bone Spring limestone to the north.[3] It was this pronounced unconformity that influenced the original pro-

[3]Subsurface data indicate that the Brushy Canyon is also present in the Midland Basin.

ponents of the Guadalupe series in placing the series boundary at the base of the Delaware Mountain group.

Frank E. Lewis (1941) presented a strong argument for placing the San Andres formation in the Guadalupe series, but other authors then and later included the San Andres in the Leonard series. More recent papers by R. L. Clifton (1945) and John W. Skinner (1946) present paleontological evidence confirming Lewis' earlier correlation of the San Andres with a part of the °type Guadalupe section in the Delaware Mountains.

The type section of the Leonard series is in the Glass Mountains where it was defined as co-extensive with the Leonard formation. The top of the formation as described by P. B. King (1930, 1942) is at the base of a limestone bed which was defined as the lowest unit of the overlying Word formation. As thus defined the Leonard series was supposed to be co-extensive with the zone of *Perrinites hilli* but later Cooper (Miller, 1945) and Clifton (1945) found that supposedly distinctive Leonard ammonoid genus in the lower limestone of the Word formation.

A prominent chert and quartz pebble conglomerate 300 feet below the lower limestone of the Word and overlying the Hess limestone facies of the Leonard is regarded by Lewis as the logical base of the Word formation and of the Guadalupe series. He correlates this conglomerate at least in part with the San Angelo conglomerate and states that the two conglomerates are so similar as to suggest a common source (1946, p. 20) .

The pronounced unconformity at the base of the Delaware Mountain group, the presence of the Brushy Canyon formation in the Delaware and Midland basins, and the probable absence of beds correlative with the Brushy Canyon on the shelf or platform areas indicate a pronounced break in sedimentation on the platform areas while the Brushy Canyon was being deposited in the basin areas. The probable unconformity at the base of the San Angelo conglomerate on the east side of the Permian Basin appears to be such a stratigraphic break, at least in surface sections.

No such marked stratigraphic break is found in New Mexico but the Glorieta sandstone appears to be correlative with the San Angelo conglomerate. The U. S. Geological Survey classifies the Glorieta sandstone as a member of the San Andres formation, but the New Mexico Bureau of Mines and Mineral Resources considers it a separate formation. Some geologists, including the writer, have found evidence that it grades laterally into the lower limestones and dolomites of the San Andres formation, but in other localities, particularly in the Gran Quivira quadrangle, some evidence has been found of lateral gradation into the underlying Yeso formation (Bates et al., 1947, p. 33) .

In general it appears that the base of the Glorieta sandstone, the base of the San Angelo conglomerate, and the base of the conglomerate above the Hess, located in widely separated areas, each represents the initiation of a new cycle of deposition and that all are of approximately the same age.[4] From the standpoint of stratigraphy alone this appears to be the logical base of the Guadalupe series. Paleontological data, however, do not appear to confirm this interpretation.

The upper part of the Victorio Peak member of the Bone Spring formation contains the fusulinid species *Parafusulina fountaini* and *Schwagerina setum.* According to P. B. King (1942, 1948) the Victorio Peak member is below the unconformity at the base of the Delaware Mountain group and therefore belongs in the Leonard series. The fusulinid fauna of the upper Victorio Peak is commonly considered as the uppermost fauna of the Leonard. However, it has been found in a few wells where by subsurface correlation it is above the base of the San Angelo and of the Glorieta. One such locality is in eastern Ector County, Texas, where *Parafusulina fountaini* is found in limestones associated with the "Holt pay" (Skinner, 1946, p. 1863). According to the writer's correlations, the "Holt pay" is in the lower part of the San Andres formation rather than below it.

In Spearow's McClelland well in sec. 22, T. 22 S., R. 23 E., Skinner (1946 cross sections) found the uppermost Leonard fauna including *Parafusulina fountaini* and *Schwagerina setum* in a limestone zone which is underlain at 2055 feet by a bed of sandstone which is logically correlated with either the Glorieta or the uppermost sand of the Yeso. The limestone is correlative with a limestone underlying the Cherry Canyon formation in Last Chance Canyon and containing a "Bone Spring" fauna (Skinner, 1946, p. 1865) . Last Chance Canyon does not cut deep enough to expose the underlying beds.

Adams (1949) reports the presence of *Schwagerina setum* in the Glass Mountains in beds above the conglomerate which Lewis places at the base of the Guadalupe series. Therefore paleontological as well as stratigraphic evidence indicates that this conglomerate is correlative with the San Angelo and with the Glorieta. The paleontological evidence also indicates that the stratigraphic position of this conglomerate, the San Angelo, and the Glorieta is below the upper part of the Victorio Peak member of the Bone Spring.

According to V. C. Peterson (1947, p. 11) , the upper sandstone of the Brushy Canyon formation grades northward into a reef limestone which overlies the Victorio Peak reef. This statement has not been confirmed by other observers,[5] and further detailed work in the area is desirable. If it can be shown that the upper part of the Victorio Peak containing the *Parafusulina fountaini* fauna is equivalent to some part of the Brushy Canyon

[4]Many geologists do not agree with the correlation of the base of the San Angelo with the base of the Glorieta. This difference in correlation will be discussed with the Yeso formation.

[5] Walter C. Warren and Roy M. Huffington, personal communications.

we can put the base of the Guadalupe series at. the base of this zone and also at the base of the San Angelo and Glorieta. Skinner's correlation (1946, fig. 8) , on the other hand, shows a marked stratigraphic break between the Glorieta and San Andres formations and between the San Angelo and the overlying Flower Pot formation. Determination of the boundary between the Guadalupe and Leonard series will depend on more detailed stratigraphic and paleontologic work in the type areas.

GUADALUPE OR LEONARD SERIES

Glorieta sandstone.—The Glorieta sandstone is herein considered the lowest formation of the Guadalupe or the uppermost formation of the Leonard series in central New Mexico. In surface sections it is "a white and yellow clean sandstone composed of angular to sub-round quartz grains of medium size" (Bates et al., 1947, p. 32) . It is 520 feet thick in northeastern Torrance County and is thinner both to the south and east. It is readily recognized in wells in Guadalupe and De Baca counties where it is separated from the underlying fine grained silty sandstones of the Yeso formation by a bed of dolomite. It is recognized in surface sections as far south as the northern Guadalupe Mountains and southern Sacramento Mountains where it is only a few feet thick.

The individual sandstone beds in the Glorieta are lithologically distinct from underlying beds and the formation as a whole is markedly different from the underlying Yeso, but there is no marked stratigraphic break and locally considerable difficulty is encountered in defining both the upper and lower limits of the formation.

Measured surface sections of the Glorieta in the Gran Quivira quadrangle, the Oscura Mountains, and the southern Sacramento Mountains are shown graphically on pl. 2. The locations of these sections are shown on pl. 1. The sandstone is 230 feet thick where measured in the Gran Quivira quadrangle (sec. 29, T. 1 N., R. 5 E., Bates et al., 1947, pl. 5) and in the Oscura Mountains is only 40 feet thick. A corresponding thickening of the underlying Joyita member of the Yeso formation from north to south as shown in the sections supports the argument for inter-gradation between the Glorieta and Joyita sands.

A section measured in the southern Sacramento Mountains (E, pl. 2) contains one 8-foot bed of white calcareous fine- to medium-grained sandstone which appears to be the Glorieta. Over 100 feet of limestone and dolomite underlying this sandstone is considered as upper Yeso but might be logically included in the Glorieta.

In Lea County the distinctive character of the Glorieta is not recognizable, and most subsurface geologists call the top of the first sandstone lens below the San Andres "top of Glorieta" and do not attempt to pick its base. "It is possible that the Glorieta wedges out completely toward the southeast and that the top of the so-called Glorieta sand of most of Lea County is the top of the Yeso" (R. E. King, 1945, p. 10) . A probable correlation of the Glorieta in one well in Lea County (Shell's Taylor-Glenn No. 1) is shown on p1. 3, but in the outline cross sections (pls. 5 to 9) the Glorieta is included with the upper Yeso.

LEONARD SERIES

Yeso formation.—The Yeso formation was deposited in a saline epicontinental sea. Complete surface sections are exposed only on the west side of the old Pedernal Mountains, and detailed sections measured in the Gran Quivira quadrangle, the Oscura Mountains, and northern and southern Sacramento Mountains are shown graphically on pl. 2.

In these four sections the formation consists of alternating beds of sandstone, shale, limestone, and gypsum. A prominent basal sandstone is found in the Gran Quivira quadrangle and the Oscura Mountains but not in the Sacramento Mountains. There is a general decrease in the relative abundance of elastic sediments and of gypsum from north to south with a corresponding increase in carbonates.

The first section is a composite section measured in the Gran Quivira quadrangle (Bates et al., 1947, pp. 29-30) . The.formation is 678 feet thick and is divided into four members. The uppermost Joyita member, 62 feet thick, is composed of siltstone and fine sandstone. The second member, the Cañas, 105 feet thick, is predominantly gypsum. The third member is the Torres, 405 feet thick, and is composed of alternating beds of sandstone, silt-stone, limestone, and gypsum.-The lowest member, the Meseta Blanca, 106 feet thick, is predominantly sandstone.

The second section was measured in the Oscura Mountains and is reproduced with the permission of the Standard Oil Company of Texas. The Yeso is 1205 feet thick as compared with 678 feet in the Gran Quivira quadrangle with the most marked thickening in the sandstone units, Joyita and Meseta Blanca members, at the top and bottom of the section. Thickening of the Joyita member is accompanied by a thinning of the overlying Glorieta and the two may be intergradational. The lower Meseta Blanca sandstone member is 380 feet thick, more than three times its thickness in the Gran Quivira area. This sandstone may be the basal sediments of the Yeso marine sea advancing from the south or southwest over a land area.

The third section shown on pl. 2 was measured by Richard C. Northup and Lloyd C. Pray in the northern Sacramento Mountains in secs. 22 and 27, T. 13 S., R. 11 E. The section is poorly exposed with neither the top nor bottom of the Yeso definitely identified. As measured, the formation is 1343 feet thick. The

Joyita and Cañas members can be recognized, but the basal sandstone is not present unless in the 150-foot covered interval at the base.

Another section was measured by Northup and Pray near the southern end of the Sacramento Mountains in secs. 30, 31 and 32, T. 19 S., R. 12 E. One 8-foot bed of sandstone is correlated with the Glorieta. The underlying 180 feet of limestone, dolomite, and silty sandstone with a prominent sandstone bed at the base is tentatively correlated with the Joyita member of the Yeso. Other members of the Yeso are even less distinctive. The Cañas member is apparently represented by limestone, and what appears to be the Torres equivalent contains only one thin bed of gypsum. However, at the base of the Yeso section over 100 feet of beds, predominantly gypsum, was measured and is overlain by a covered interval which may be gypsum in part. Farther north in the Sacramento Mountains the lower part of the Yeso contains numerous beds of gypsum.

In the area east of the Pedernal Mountains in Guadalupe and De Baca counties, the upper part of the Yeso is very similar to that in the surface sections to the west with the addition of beds of salt alternating with those of sandstone, shale, and dolomite. Correlation with the Oscura Mountains section is more satisfactory than with the Gran Quivira quadrangle section because of the more comparable thickness. A similar section extends eastward across Curry County and into Texas and southward across northern and southwestern Chaves County and eastern Lincoln County. Farther southeast the percentage of dolomite increases until in central and southeastern Lea County, southeastern Chaves County and parts of Eddy County the section is predominantly dolomite with persistent beds of fine-grained sandstone.

Beds equivalent to the Yeso in the Delaware Basin and in at least a part of the Carlsbad Shelf area (DeFord, 1942) are dark limestones interbedded with black shale, the Bone Spring formation. A barrier reef between the typically pontic Bone Spring beds and the Yeso dolomites to the north can be reasonably inferred, but the exact position of this reef is still largely a matter of conjecture.

Within the area where the Yeso is predominantly dolomite two persistent marker beds can be recognized. One is at the base of a sandy zone overlying the Blinebry pay of eastern Lea County, and the other is the top of the Drinkard sandy member named and described by R. E. King (1945, pp. 13-15) . These two marker horizons divide the Yeso into three units which are herein designated upper, middle, and lower Yeso. The upper and middle Yeso as here used are the same as R .E. King's upper Yeso (1945, p. 12) .

Detailed sections of the Yeso in four widely scattered wells are shown graphically on pl. 3 to illustrate the differences in the section in different areas.

The upper Yeso as here used is the part of the formation above the Blinebry pay of, southeastern Lea County. In Shell Oil Company's Taylor-Glenn test in sec. 3, T. 21 S., R. 37 E. it is 385 feet thick (pl. 3) . The top of the Yeso in this well is picked at 5295 feet, and the overlying 50 feet, predominantly sandstone, is classed as Glorieta. However, it is possible that the entire sand section is Yeso. The upper Yeso is predominantly dolomite with a considerable amount of interbedded sandstone and sandy dolomite in the lower part. The base of the sandy section is the base of the member. Many geologists correlate the upper Yeso and the Glorieta with the San Angelo formation and correlate the top of the Clear Fork with the top of the Blinebry pay. The writer, however, believes that the upper Yeso is correlative with upper Clear Fork and the Glorieta with the San Angelo.

The section in Shell's Taylor-Glenn well is typical of the northern part of the Central Basin Platform in Lea County. The formation thickens to the north and west. In southeastern Chaves County, De Kalb Agricultural Association's White No. 1 (G, pl. 3) in sec. 35, T. 10 S., R. 28 E. was chosen as illustrative. Here, however, the middle as well as the upper Yeso contains sand beds, and there is some uncertainty as to the position of the base of the upper member. A comparison of this section with that in Sanders Bros.' Hultman No. 1 (H, pl. 3) in sec. 32, T. 16 S., R. 26 E. in Eddy County shows the marked decrease in the amount of anhydrite from north to south.

Pure Oil Company's Federal Fee test (F, pl. 3) in sec. 31, T. 3 N., R. 28 E. was chosen to illustrate the section in De Baca and Guadalupe counties. Here no limestone or dolomite was found in the upper Yeso which consists of alternating beds of sandstone, red shale, anhydrite, and salt. The Joyita, Callas, and Torres members can be recognized and are correlated as shown on pl. 3. The base of the upper Yeso is correlated with the top of a dolomite zone at 2830 feet, and this dolomite zone is correlated with the lower limestone zone of the Torres member in outcrop sections to the west. Thus the upper Yeso of subsurface sections is interpreted as including the Joyita, Cañas, and most of the Torres members.

In southeastern Lea County the Paddock oil pay lies in the upper part of the upper Yeso as here interpreted.

The middle Yeso is almost entirely dolomite in the Eunice area of eastern Lea County. In the Shell Oil Company's Taylor-Glenn well it is 550 feet thick, extending from 5680 to 6230 feet. In Eddy County the member has much the same character but is thicker and includes several thin beds of sandstone. In Sanders' Hultman well it is 665 feet thick extending from 2810 to 3475 feet. Farther north in Chaves County (G, pl. 3) it is still thicker, but the recognition of both the top and bottom of the member is difficult because there is a marked increase in the amount of sand. In the rotary cuttings a considerable amount of shale, sandstone, and anhydrite is found in almost every sample indicating an alternation of numerous thin beds. The same characteristics are found in all wells in central and eastern Chaves County.

In De Baca and Guadalupe counties the middle Yeso (F, pl. 3) contains only a few thin beds of dolomite. Most of the section consists of alternating beds of red shale, sandstone, anhydrite, and salt. As correlated with the surface section in the Oscura Mountains it includes the lower limestone zone of the Torres member and probably a considerable amount of section that is missing in the surface sections.

In southeastern Lea County the Blinebry oil and gas pay lies at the top of the middle Yeso section.

The lower Yeso extends from the top of the Drinkard sandy member to the top of the underlying Abo formation. The Drinkard sandy member was named and described by R. E. King (1945, pp. 13-14) and its type section is the zone of interbedded dolomite and sandstone from 6100 to 6210 feet in the Texas Company's Blinebry No. 1 well in sec. 19, T. 22 S., R. 38 E. The Drinkard-Vivian pay zone lies approximately 300 feet below the top of the Drinkard member in the lower part of the lower Yeso (pl. 10) . The Drinkard-Andrews pay is in the upper part of the Abo formation.

The Drinkard sandy member is commonly correlated with the "Tubb sand" and "Fullerton sand", and both these names are applied by geologists to the zone in New Mexico as well as in Texas. However, the name Fullerton is preoccupied and the "Tubb sand" has not been described as such in geological literature. The sandy zone is very widespread in "shelf" areas of the Permian Basin, but has not as yet been definitely correlated with the surface section either on the east or west side of the basin.

Details of the Drinkard sandy member in the selected illustrative wells in Lea, Eddy, Chaves, and De Baca counties are shown on pl. 3, and suggested correlations are shown in outline cross sections, pls. 5 to 9 inclusive. In Chaves County and farther north the entire lower Yeso contains numerous beds of sand so that only the top of the Drinkard can be correlated satisfactorily. There is a suggested correlation' of the Drinkard sandy member with the basal sandstone of the Yeso in the Oscura Mountains section. If this is the correct correlation we might logically infer that the lower part of the Yeso of Lea County pinches out to the northwest. Another possible explanation is that it grades into continental deposits with Abo-type lithologv and its northern equivalent has been included in the Abo. A third possible explanation is that the entire lower Yeso grades into sandstone to the northwest and is the equivalent of the Meseta Blanca member.

In Eddy County and in southwestern Chaves County several beds of anhydrite are found in the lower Yeso as illustrated in the section of Sanders' Hultman well shown on pl. 3. The lower zone of anhydrite in this and other wells in the general area is probably correlative with the lower gypsum zone found by Northup and Pray in the southern Sacramento Mountains (pl. 2) .

Victorio Peak reef zone.—The Victorio Peak limestone was described by P. B. King as a member of the Bone Spring formation. As exposed in the Sierra Diablo and Guadalupe mountains in west Texas it "consists of gray, calcitic limestone in thick, fairly even beds, with a thickness of 500 to more than 1,000 feet" (King, 1942, p. 569). Observations by the writer in the Guadalupe Mountains lead to the belief that the Victorio Peak is in part a reef limestone forming a barrier between the upper part of the pontic Bone Spring limestone and at least a part of the Yeso formation, which represents the shelf or lagoonal facies. Whether the Victorio Peak reef facies is equivalent to all or only a part of the Yeso is not known.

Wells drilled in the Guadalupe foothills west of the Pecos River indicate that the Victorio Peak reef may extend across the Carlsbad Shelf along a trend intermediate between that of the Capitan reef to the south and the San Andres reef to the north. This is well illustrated by the first four wells on Skinner's cross section (1946, fig. 9, p. 1868) . The first well, Spearow's McClelland No. 1 in sec. 22, T. 22 S., R. 23 E., drilled through the back-reef or lagoonal equivalents of the lower part of the Capitan (Queen and Grayburg formations) , and then passed through the San Andres very near the reef front where it grades basinward into Cherry Canyon sands. Below the San Andres it found mostly limestones of the Yeso formation.

The second well of Skinner's section, Standard of Texas' Smith No. 1 in sec. 23, T. 22 S., R. 24 E., seven miles east of the McClelland well, found nearly a thousand feet of Cherry Canyon sands which have replaced the San Andres reef basinward. Below this is a dolomite section which is here interpreted as a near-reef facies of the Victorio Peak.

The third well, Standard of Texas' Wilson No. 1, did not go deep enough to show the character of the pre-Cherry Canyon formations. The fourth well, however, Ohio's Tracy Dome test, went through the entire Capitan reef section and also both Cherry Canyon and Brushy Canyon sand sections (middle and lower Delaware Mountain) before reaching the black limestones and shales of the Bone Spring. It is obvious that the Victorio Peak reef lies somewhere between the Tracy and Smith wells, and probably between the Smith and Wilson wells.

East of the Pecos River, only three wells in the Carlsbad Shelf area have been drilled through the Cherry Canyon section. One is Getty's Dooley No. 7 in sec. 24, T. 20 S., R. 29 E., which has the same section below the top of the Capitan as the Ohio's Tracy. The second well is Richfield's Lake McMillan Unit No. 1, in sec. 36, T. 20 S., R. 26 E. This well had a Cherry Canyon and higher section very similar to that in Standard of Texas' Smith well. The section below the Cherry Canyon is partly dolomite but predominantly limestone with some interbedded black shale. This may be interpreted as either a pontic or back-reef facies. The third test to penetrate the Cherry Canyon was Amerada's Record No. 2 in sec. 25, T. 19 S., R. 35 E. in Lea County. Although this well is over fifty miles east of Richfield's Lake McMillan well it shows very nearly the same sequence of formations and the same facies.

In the Amerada well, fusulinids identified as Leonard in age were found through an interval of 3130 feet from depths of 7240 to 10,370 feet. This section is tentatively correlated with the Yeso and Abo formations. On lithologic evidence alone the upper part, above 7620 feet, appears to be correlative with the "Holt zone" of Ector County, Texas, and therefore with the lower part of the San Andres. This interpretation is shown on pl. 6 but the evidence is inconclusive.

LEONARD AND WOLFCAMP (?) SERIES

Abo formation.—A section in southern Lea County 1000 feet or more thick and composed of limestone and dolomite with some interbedded red and green shale is believed by the writer to represent the Abo formation. This section in a few wells contains fusulinids of Leonard age. On the other hand in the southern Sacramento Mountains a limestone section, believed to be a part of the Abo formation, appears to be a northern extension of the type Hueco formation which is upper Wolfcamp in age. It is probable that one of these sections does not represent the Abo formation, but the available data on this question are inconclusive. The problem will be discussed further after a brief description of the formation as now identified in different areas.

Four detailed surface sections of the Abo formation west of the Pedernal Mountains are shown on pl. 2. The northern section is the type section of the formation as measured by Needham and Bates (1943, p. 1656) in Abo Canyon. However, the upper 104 feet of Needham and Bates' Abo section is now classed as the Meseta Blanca member of the Yeso formation (Bates et al., 1947) .

The type Abo consists of dark red shale, sandstone, and arkose, and is interpreted as continental in origin in contrast with the overlying Yeso formation and the underlying Bursum formation which are marine in origin. In the Gran Quivira quadrangle the Abo is 810 feet thick.

In the Oscura Mountains the Abo consists of arkosic sandstone and shale both with the intense dark red color which is characteristic of the formation in this part of the state. The detailed section (B, pl. 2) was measured by Walter C. Warren at the southern end of the mountains in T. 9 S., R. 6 E. The thickness of the formation here is 830 feet.

The section measured by, Northup and Pray in sec. 4, T. 16 S., R. 11 E. (D, pl. 2) shows the general characteristics of the

Abo formation in the central part of the Sacramento Mountains. It is a dark red shale with a coarse conglomerate at the base and a total thickness of only 400 feet. A section measured by W. Y. Penn (1932) farther north in Tularosa Canyon has about the same thickness, but the formation there is almost entirely coarse conglomerate.

Near the southern end of the Sacramento Mountains a lens of limestone appears in the Abo and thickens to the south. In the section measured by Northup and Pray in T. 19 S., Rs. 11 and 12 E. (E, pl. 2) the limestone section is 360 feet thick and is underlain by 100 feet of red shale and siltstone and overlain by 90 feet of interbedded red sandstone and shale, a total of 550 feet of Abo. The limestone is shaly and has some interbedded dark shale and sandstone. Thinning of the limestone section to the north is accompanied by a thickening of the underlying elastic section.[6]

No fusulinids have been found in the Abo limestone in the Sacramento Mountains but it has been traced a few miles to the south where Hueco-type fusulinids were collected.? It also appears to be the limestone from which Branson collected ammonoids in T. 22 S., R. 10 E. (Miller and Parizek, 1948) . Both the fusulinids arid ammonoids show a definite correlation with the Hueco limestone in its type locality in the Hueco Mountains.

In the surface sections from Abo Canyon south to the Sacramento Mountains, the Abo rests with angular unconformity on rocks ranging in age from lower Wolfcamp to Mississippian. Except in the southern Sacramento Mountains, the rocks are all coarse elastics of continental origin. These continental deposits either pinch out to the south or grade into marine limestones. The lime-depositing sea advanced from the south.

On the flanks of the Pedernal Hills in Torrance County, the Abo formation is absent except locally, and the Yeso formation rests on pre-Cambrian schists. Farther south, in the Gallinas Mountains, Abo beds 100 to 200 feet thick rest on pre-Cambrian rocks.

Farther south in eastern Lincoln County and southwestern Chaves County, beds correlated with the Abo are coarse arkose or "granite wash."

During Abo time a large amount of coarse elastic material was eroded from the Pedernal Mountains, which locally must have risen into mountains of considerable magnitude.

The top of the granite wash or Abo is probably not a time horizon as the tops of some of the pre-Cambrian hills stayed above sea level longer than others and continued to shed their detritus into the neighboring waters long after marine sediments buried the lower granite knobs.

In wells drilled in Guadalupe and De Baca counties the top of the Abo is difficult to identify because of the abundance of red

[6] Lloyd C. Pray, personal communication

[7] Walter C. Warren, personal communication.

shale and sandstone in the lower part of the Yeso formation. However, the dark red color of both the sandstones and shales is distinctive. The formation may be considered as continental in origin near the old Pedernal Mountains, but farther east in eastern De Baca County some thin beds of dolomite and anhydrite are present in the Abo section, indicating a transition from continental to marine conditions. In Guadalupe, De Baca, and northern Roosevelt counties, the Abo ranges in thickness from less than 600 to over 1,100 feet. The thinner sections are nearer the mountains and contain coarse sandstones and arkoses similar to those found in the surface sections on the west side of the mountains.

In Chaves County and southern Roosevelt County there is a sharp break between the dolomite and anhydrite of the lower Yeso and the dark red shale of the top of the Abo formation. This is the top of Abo of all subsurface studies in Chaves; Eddy, and Lea counties and can be followed as a reasonably accurate strati-graphic marker over wide areas. However, it may be 100 to 200 feet lower stratigraphically than the lithologic break farther north.

The Abo of central and eastern Chaves County, southern Roosevelt County, and northern Lea County consists of interbedded red, green, and gray shale, dolomite and anhydrite. The percentage of dolomite increases to the south, and in central Lea County there are only remnants of the characteristic red and green shale in the upper part of the formation. The top of the formation can be identified with reasonable accuracy over the entire Central Basin Platform. The range of the Abo formation in a number of wells is shown in the outline cross sections, pls. 5 to 9.

In Amerada's Phillips No. 5 well in sec. 1, T. 20 S., R. 36 E. in the Monument area, the top of Abo is placed tentatively at 6840 feet (pl. 6) . The lower part of the Abo in this well from 7140 to 7840 feet contains fusulinids of Leonard age. The Abo rests on beds of Wolfcamp age, probably the Hueco formation.

In the Eunice area of eastern Lea County, and over most of the Central Basin Platform the Abo section consists of dolomite interbedded with limestone and with thin beds of red and green shale. It rests unconformably on rocks ranging in age from pre-Cambrian to Pennsylvanian. Elsewhere over a large part of southeastern New Mexico east of the mountains, the Abo is underlain by beds of Wolf camp age as determined by fusulinids from numerous wells. The Drinkard-Andrews pay of the Drinkard pool, the Monument-Abo pool, and the Elliott pool produce oil from a porous dolomite in the upper part of the Abo formation.

The age of the Abo formation has been discussed at some length by P. B. King (1942) and R. E. King (1945) who concluded that the weight of evidence was indicative of Leonard age. P. B. King reported plant remains collected and studied by

C. B. Read as evidence of the Leonard age of at least a part of the formation (1942, p. 690) .

The continental redbeds of the typical Abo can be traced into their marine equivalents by lithologic correlation only and such a correlation is always subject to error. The assignment of a marine lower Leonard section in southern Lea County to the Abo is based on well to well correlations over a distance of more than 150 miles and further lithological correlations across a partly buried mountain range which separated two areas of deposition during Abo time. Despite these difficulties the general correlation appears to be well established but the upper and lower limits of the formation as placed in the outline sections (pls. 5-9) probably do not represent uniform time lines. The Abo of the Eunice area and the Central Basin Platform is shown by the fusulinids to be Leonard in age but farther northwest it may include beds of upper Wolfcamp age.

It has been shown that in all probability most of the Abo of the southern Sacramento Mountains is equivalent to a part of the Hueco formation of Wolfcamp age. Possibly the uppermost 90 feet represents the Leonard part of the formation.

The equivalent of the Abo formation under the Carlsbad Shelf area and in the Delaware Basin is probably the lower part of the Bone Spring formation. The thick section containing Leonard fusulinids in Amerada's Record No. 2 well (pl. 6) is placed in the Bone Spring and correlated with the Yeso and Abo formations of the shelf area. Below the fossiliferous Leonard section in this well is a predominantly sandy section from 10,370 to 10,710 feet which might be basal Abo.

WOLFCAMP SERIES

Hueco limestone.—The Hueco limestone in its type section in the Hueco Mountains in Hudspeth County, Texas, consists of the basal Powwow conglomerate overlain by a predominantly limestone section nearly 1600 feet thick, in which three divisions were recognized (King and Knight, 1945) . The Deer Mountain red shale member, 180 feet thick, is the lower member of the upper division. The Hueco limestone is assigned a Wolfcamp age but it is possible that some of the upper part may be of Leonard age. The Powwow conglomerate is mapped as the lowest member of the Hueco, but the limestones above the Powwow do not contain the lowermost Wolfcamp fusulinids so it appears that the Hueco represents only the upper or possibly the middle and upper part of the Wolfcamp series.

The Hueco limestone is represented in wells drilled on the Otero Mesa in Otero County where it is about the same thickness as at the outcrop. Farther north, however, in the Sacramento Mountains it becomes thinner and is represented by a limestone lens in the Abo. This lens thins and terminates in the mountains south of Alamogordo.

The Hueco is found in a number of wells in the southeastern counties, but in many wells the evidence available at present is not sufficient to differentiate it from the lower Wolfcamp Bursum formation. The subsurface distribution of the two formations will be discussed under another heading.

Bursum formation.—In discussing the Pennsylvanian-Permian contact, M. L. Thompson (1942, p. 20) mentioned the presence of fusulinid-bearing marine sediments of lower Wolfcamp age unconformably overlying Pennsylvanian rocks in a number of localities in south central New Mexico.

In 1946 this lower Wolfcamp limestone received no less than three names. Kelly and Wood (U. S. Geol. Survey, Prelim. map No. 47) described what is apparently the same section on the west side of Ladron Peak and called it the "Red Tanks member of Madera Limestone." They classed it as Pennsylvanian in age. Wilpolt et al. (U. S. Geol. Survey, Prelim. map No..61) introduced the name Bursum formation for beds exposed in Los Pitios Mountains and the vicinity of Abo Canyon. Stark and Dapples (1946, p. 1154) described the same section and named it the Aqua Torres formation.

The descriptions by Kelly and Wood and by Wilpolt et al. of the Red Tanks member and Bursum formation are inadequate by present standards of nomenclature, but in the case of the Bursum formation this was remedied in 1947 by Bates et al. (Bull. 26) who published two detailed sections, one in Abo Canyon and the other 3 1/2 miles to the southwest in sec. 14, T. 2 N., R. 4 E. The name Bursum formation is preferred by the Bureau of Mines and Mineral Resources, but it is unfortunate that the only adequate descriptions of the formation were from areas nearly forty miles north of the type locality which is at Bursum triangulation station in sec. 1, T. 6 S., R. 4 E. The section in T. 2 N., R. 4 E., and also a section measured by Walter C. Warren in the southern Oscura Mountains in T. 9 S., R. 6 E., are shown graphically on p1. 2.

The Bruton formation of Pennsylvanian Virgil age (Thompson, 1942, pp. 79-82) is very similar in lithology to the Bursum and it is probable that part or all of the Bruton has been included in descriptions of the Bursum (Thompson, 1942, p. 81) . The two formations are separated by an unconformity, but apparently they can be distinguished only by careful stratigraphical and paleontological study. The Bursum is overlain unconformably by the continental Abo formation.

A similar section, now included in the Bursum, was found by Thompson (1942, p. 82) in Fresnal Canyon in the northern Sacramento Mountains where it is 250 feet thick and overlies beds of upper Virgil age. It is overlain with angular unconformity by a coarse quartzite conglomerate at the base of the Abo formation. The formation thickens to about 350 feet a mile north of Fresnal

Canyon, but thins and disappears within a few miles to the south,[8] and is not found farther south in the Sacramento Mountains where it is cut out by the unconformity at the base of the Abo.

Most of the limestone beds of the Bursum formation contain an abundance of fusulinids of lower Wolfcamp age. The formation is older than the Hueco limestone which is middle and upper Wolfcamp in age.

Hueco and Bursum formations in subsurface.—Rocks containing Wolfcamp fusulinids are found in a large number of wells in southeastern New Mexico. They are missing in the Eunice area and generally over the higher parts of the Central Basin Platform. Over most of the area the rocks are limestone and dolomite with interbedded gray, black and red shale. There is a gradual increase in the amount of elastic, material to the north and west and near the old Pedernal Mountains red shale and sandstone are the predominant constituents.

The most complete Wolfcamp section so far encountered is in Phillips' Lea-Mex No. 4 test in sec. 17, T. 17 S., R. 33 E. (p1. 6) . Here the series is 2100 feet thick from 9700 to 11,800 feet in depth. Upper Wolfcamp Hueco fusulinids have been found in the upper part of the section and lower Wolfcamp pre-Hueco types in the lower part. Both the Hueco and Bursum formations are represented, but there does not appear to be any marked strati-graphic break between the two formations. The upper part is predominantly limestone with some interbedded. dolomite, chert, and gray shale, and the lower part is interbedded limestone and gray shale.

Farther east in Amerada's Hamilton No. 1 well (pl. 8) , the two formations can be distinguished with reasonable assurance. The Hueco is 695 feet thick from 9835 to 10,530 feet and is pre-dominantly dolomite and limestone with some chert and black shale. The underlying Bursum formation is 310 feet thick and is mostly limestone with interbedded gray and black shale and some chert. At 10,840 feet the Bursum lies unconformably on limestone of Mississippian age.

In northern Lea County in the Crossroads area the known Wolfcamp beds are predominantly limestone (pl: 7) . The lower part is placed in the Bursum formation but the upper part may be Hueco. In Barnsdall's State No. 1-A well in eastern Chaves County the Wolfcamp is 740 feet thick from 8400 to 9140 feet in depth. A detrital zone at about 8650 feet may mark the boundary
. between the Hueco and Bursum formations.

Wolfcamp beds found in wells in southeastern Lea County, Eddy County and in southern and southwestern Chaves County are apparently all Hueco. The fragmentary remains of fusulinids found in wells in De Baca and Guadalupe counties are not sufficiently diagnostic to differentiate the two formations.

[8] Lloyd C. Pray, personal communication.

It is probable that more detailed stratigraphic and paleontologic studies would serve to differentiate the Hueco and Bursum formations over the entire area. So far as known to the writer the Bursum carbonates are all limestone, and the Hueco in many wells contains both limestone and dolomite. There may be a marked stratigraphic break between the two as suggested by a detrital zone found in a few wells. The suggested range of the formations in a number of wells is shown in the outline cross sections, pls. 5 to 9.

The pay zone of the Bough pool in northern Lea County is in the lower part of the Bursum formation.

PENNSYLVANIAN SYSTEM

GENERAL FEATURES

Much of our knowledge of the Pennsylvanian of surface sections in south central New Mexico is through the detailed work of M. L. Thompson (1942, 1948) , who was formerly on the staff of the Bureau. By his studies of the fusulinids, he recognized four series which in descending order were Virgil, Missouri, Des Moines, and Derry (1942) . The first three are well established in the Mid-Continent region, and the Derry is the equivalent of the more widely known Atoka series. Thompson subdivided these series into groups and formations, but the series divisions only have been identified in the subsurface in southeastern New Mexico.

Recently Moore and Thompson (1949) have proposed a regrouping of the Pennsylvanian system and period into three series (epochs) with the former series reduced to the rank of stage (age) . The three series proposed may be called Lower, Middle, and Upper, but proposed geographic names are considered preferable. The New Mexico Bureau of Mines and Mineral Resources has not, as yet, accepted Moore and Thompson's reclassification of the Pennsylvanian nor the -an and -ian endings for series and stage names. The proposed classification is shown in table 2 in comparison with the classification followed at present

TABLE 2. CLASSIFICATIONS OF PENNSYLVANIAN SERIES

Moore and Thompson 1949	New Mexico Bureau of Mines and Mineral Resources	Names commonly used in Texas
Kawvian series (epoch)		
Virgillian stage (age)	Virgil series	Cisco series
Missourian stage	Missouri series	Canyon series
Oklan series		
Desmoinesian stage	Des Moines series	Strawn series
Atokan stage	Atoka series	Bend series
Ardian series		
Morrowan stage	Morrow series	absent in
Springeran stage	absent	central Texas

by the Bureau of Mines and Mineral Resources and with names commonly used in central Texas. Although Moore and Thompson's classification is here presented, it is in no way followed in the subsequent discussion.

Pennsylvanian older than Atoka may not be represented in New Mexico, but 110 feet of sandstone and shale with a few beds of limestone at the base of the section in the Sacramento Mountains might belong in the Morrow series.[9] Similarly some unf ossiliferous limestones and shales below known Atoka beds in Magnolia's Burro Hills test in southwestern Eddy County might be of Morrow age. Thompson identified several hundred feet of massive to massively bedded limestone at the base of the Pennsylvanian section in the Hueco Mountains as probably Morrow in age (1948) . In general, the Pennsylvanian rocks of New Mexico belong to the middle and upper parts of the system (Oklan and Kawvian series of Moore and Thompson).

R. V. Hollingsworth and associates in the Paleontological Laboratory in Midland, Texas, have studied the fusulinids from Pennsylvanian rocks penetrated by numerous wells in southeastern New Mexico. In most wells they have identified the different series that are represented, and in many wells have recognized units of lesser rank. In most cases, however, the exact limits of a series cannot be determined because of the absence or nonrecognition of persistent stratigraphic breaks and the scarcity of diagnostic fossils in parts of the section.

Pennsylvanian rocks are absent in the area of the Pedernal Mountains and its southern extensions, and coarse elastics found at intervals throughout the system both east and west of the Pedernal area show a prominent nearby mountain mass with recurrent uplifts during Pennsylvanian time.

Pennsylvanian rocks are absent in the Eunice area in eastern Lea County and over other parts of the Central Basin Platform. They are also absent over the western extension of the Matador uplift in southern Roosevelt County. In these areas, however, the absence of coarse elastics on the flanks of the uplifts suggest that the principal orogony was post-Pennsylvanian.

Detailed descriptions of two surface sections and two subsurface sections of Pennsylvanian rocks are shown graphically on pl. 4. One surf ace section is a composite of sections measured by Stark and Dapples (1946) in the Los Piños Mountains, Socorro County, and the other is a detailed section measured by M. L. 'Thompson in the northern Sacramento Mountains. Two wells . were selected to show the subsurface section, Magnolia's Burro Hills No. 1 well in southern Eddy County and Richfield et al.'s Mullis No. 1 well in southeastern Chaves County.

The greatest thickness of Pennsylvanian so far found in southeastern New Mexico is in Magnolia's Burro Hills well, where 3490 feet of rocks from 5750 to 9240 feet are assigned to that

[9] M. L. Thompson, personal communication.

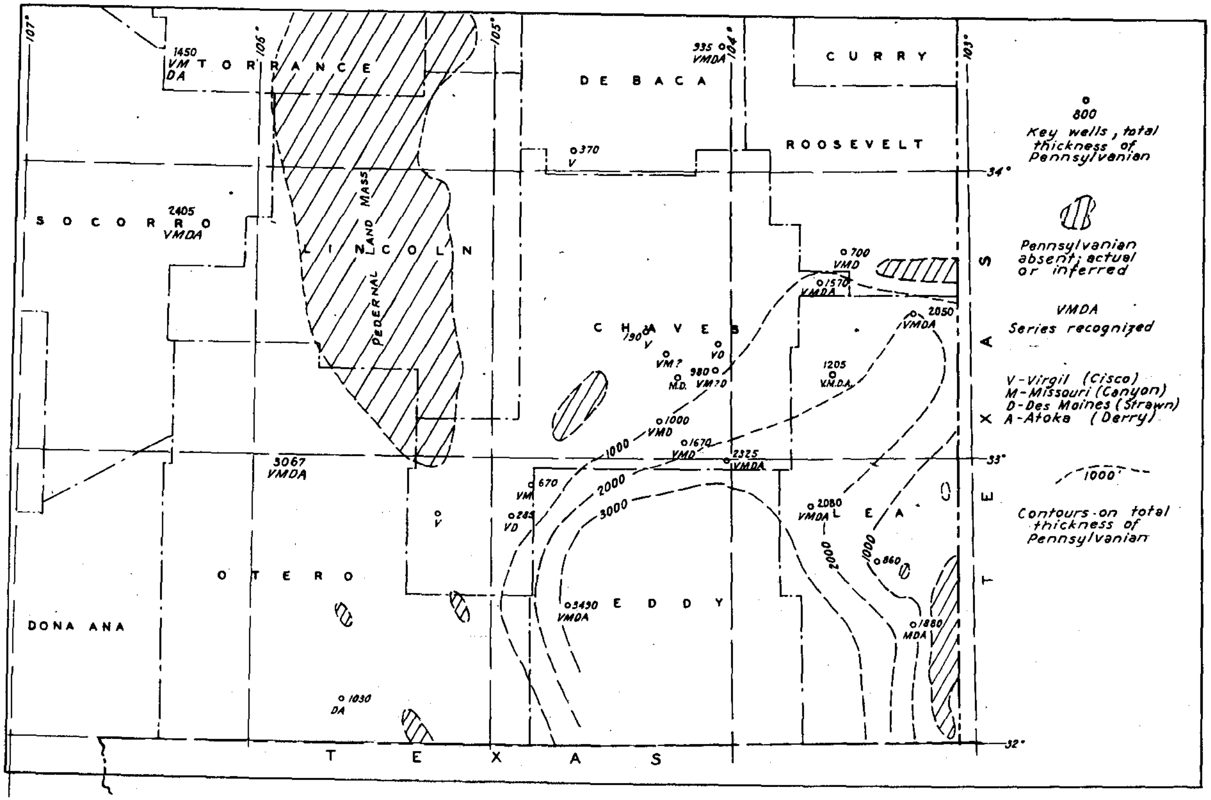

FIGURE 4. Pennsylvanian system in southeastern New Mexico.

system. Thompson measured 3065 feet of Pennsylvanian rocks in the northern Sacramento Mountains. By contrast the total of the composite section in the Los Piños Mountains is approidmately 1450 feet, although all four series of the Pennsylvanian above the Morrow are represented.

A regional map, fig. 4, shows variations in thickness of the Pennsylvanian section in wells in southeastern New Mexico and in some surface sections with suggested isopachs for the system in parts of the area.

VIRGIL SERIES

In the northern Sacramento Mountains, the Virgil series is represented by the Fresnal and Keller groups. The Fresnal group in its type locality in Fresnal Canyon (K, pl. 4) is 530 feet thick and consists of conglomerate, arkosic sandstone, gray and black shale with numerous beds of fossiliferous limestone. The upper part of the group is among the youngest portions of the Pennsylvanian known in North America (Thompson, 1942, p. 74) .

The underlying Keller group, 350 feet or more thick, is predominantly limestone with a few thin beds of conglomerate and gray shale in the upper part. In its type locality in the Oscura Mountains this group is 132 feet thick and is predominantly limestone with a few thin beds of sandstone in the lower part (Thompson, 1942, p. 71) .

The entire Virgil series as measured by Stark and Dapples (1946,.p. 1169) in the southern end of the Los Piños Mountains consists of 125 feet of limestone. This is apparently the lower part of the Keller group, the Fresnal group being absent. Probably only the uppermost 75 feet of the Madera arkosic limestone measured by Bates et al. in Abo Canyon belongs in the Virgil series.

East and southeast of the Pedernal Mountains the Virgil is one of the most widespread if not the most widespread division of the Pennsylvanian. Thompson (1942, pl. 1) reports Virgil rocks resting on pre-Cambrian in Transcontinental's McWhorter well in western De Baca County (pl. 5) , and the writer tentatively places 370 feet of limestone with interbedded red shale and sandstone from 4010 to 4380 in that well in the Virgil. In Texas Company's Wilson No. 1 (Dunken Dome) well (pl. 7) , in southwestern Chaves County, rocks of Virgil age probably extend from 4155 to 4690 feet in depth, but fusulinids were found only in the upper 100 feet. The rocks are mostly sandstone and black and red shale with only a few beds of limestone. They rest on a black shale which is now believed to be of Mississippian age. In De Kalb's Lewis well east of Roswell in Chaves County (pl. 5) only 190 feet of rocks of Virgil age are present from 5310 to 5500 feet and consist of red and gray shale with beds of sandstone and limestone resting on the pre-Cambrian.

Farther east the Virgil rocks are predominantly limestone with some interbedded shale and sandstone. In Magnolia's Burro

Hills test in southern Eddy County (L, pl. 4) , 800 feet of beds from 5750 to 6550 feet are classed as Virgil on the basis of fusuliriids. Probably both the Fresnal and Keller groups are represented, but no attempt is made to differentiate them. A similar section but with a smaller percentage of elastic material is found from 7610 to 8410 feet in depth in Richfield et al.'s well in southern Chaves County.

Rocks of Virgil age are notably absent in Texas & Pacific's State No. 39-A, Acct. 2, in sec. 9, T. 22 S., R. 36 E., in eastern Lea County where beds of Wolfcamp age rest on lowermost Missouri rocks. This well is on the western flank of the Eunice uplift, and the rocks of Virgil age were probably eroded after the pre-Permian uplift. The Virgil, like the remainder of the Pennsylvanian, is absent, probably because of pre-Permian erosion, over the greater part of the Eunice uplift and over large areas on the Central Basin Platform.

MISSOURI SERIES

In the northern Sacramento Mountains, 900 feet or more of beds represent the Missouri series (K, pl. 4) . The lower 90 feet is conglomerate overlain by sandstone. This lower elastic section is overlain by 110 feet of limestone with prominent cliff forming members at the top and near the base. Next above is 320 feet of sandstone and dark colored shale with a few thin beds of limestone. The upper 380 feet of the section is predominantly limestone with much dark shale especially in the middle part.

The Missouri section measured by Stark and Dapples in the southern part of the Los Piños Mountains (J, pl. 4) is 343 feet thick and consists of alternating beds of limestone, sandstone, and shale with 55 feet of limestone at the top. A 22-foot bed of arkose was found near the middle of the section. The Missouri series is represented by the lower part of the arkosic limestone member of the Madera formation as measured by Bates et al. in Abo Canyon.

The thickest reported section of Missouri rocks in southeastern New Mexico is in Magnolia's Burro Hills test (L, pl. 4) where 1200 feet of beds from 6550 to 7750 feet in depth are identified as belonging in this series on the basis of fusulinids. The section is predominantly limestone especially the lower 450 feet. The upper 750 feet contains numerous beds of dark gray to black shale and several beds of sandstone. One bed of sandstone, fifty feet or more thick, was found near the middle of the series. In Richfield et al.'s Mullis well (M, pl. 4) the Missouri section is much thinner and extends from 8410 to 9130 feet with a thickness of 720 feet. Here the section is almost entirely limestone with only thin beds of gray shale.

Northwestward from the Mullis well in Chaves County the Missouri section thins more or less abruptly, and is not readily differentiated from the underlying Des Moines limestones.

Limestone beds of Missouri age are present over at least parts of De Baca County. Thompson reports their presence in Matador's Woods test in extreme northwestern De Baca County, but Missouri fusulinids have not been recognized in wells farther east.

Intervals tentatively assigned to the Missouri series are shown on outline sections, pls. 5 to 9.

DES MOINES SERIES

A section 755 feet or more thick in the northern Sacramento Mountains is included by Thompson in the Des Moines series. The top is at the base of a conglomerate which marks the base of the Missouri series, and the base is in or at the top of a concealed section 145 feet thick. The lower 200 feet is predominantly limestone, and the upper 550 feet predominantly sandstone but with about 60 feet of limestone near the middle. Some of the sandstone beds are coarse grained to conglomeratic.

By contrast the Des Moines section measured by Stark and Dapples in Abo Pass railroad cut is 480 feet thick and is nearly all limestone with the exception of 40 feet of dark shale in the upper part. It includes all except the lower 130 feet of the marine limestone member of the Madera formation.

The sections of the Des Moines found in wells in southeastern New Mexico are predominantly limestone. In the Burro Hills test the interval from 7750 to 8500 feet is provisionally identified as Des Moines, but both the top and base are picked on indefinite lithologic data. The section is similar to the overlying Missouri except for the presence of considerable chert in some beds. In Richfield et al.'s Mullis well the section is thinner (9130 to 9600 feet) and contains smaller percentages of shale and chert.

Except for local areas east of the Pedernal Mountains where Virgil beds rest on pre-Cambrian, the Des Moines is probably more widespread than the Virgil. Fusulinids characteristic of the series have been found in numerous wells as far north as northern Guadalupe County. Correlations for a number of wells are shown on outline sections, pls. 5 to 9.

Like other divisions of the Pennsylvanian the Des Moines is absent over the Eunice uplift and many ,other parts of the Central Basin Platform. In the Skaggs area in T. 20 S., R. 37 E., Lea County, the Des Moines is the only division of the Pennsylvanian that is present. In Continental's Skaggs No. 5-B-23 shown in outline on pl. 6 the base of the Abo formation is tentatively placed at 7670 feet, and beds of Des Moines age extend to the top of Devonian dolomite at 8150 feet. The section is predominantly limestone with considerable amounts of chert near the middle, and with interbedded dolomite in the upper part. There is obviously an angular unconformity both above and below the Des Moines section in this area.

The pay section of the Cass pool is a porous dolomite in the upper part of the Des Moines section.

ATOKA SERIES

The Atoka or Derry series in the area west of the Pedernal Mountains and its southern extension is composed predominantly of elastic sediments. At Turrett Mesa in southern Los Pifios Mountains it is 498 feet thick (J, p1. 4) and is predominantly sandstone and conglomerate with a few beds of limestone and dark gray to black shale. Farther north in Tongue Ridge it is about 275 feet thick. This series includes the upper Sandia formation and about 130 feet of the marine limestone member of the Madera formation as measured by Bates and others in Abo Canyon. In this area the rocks of the Atoka series rest on the pre-Cambrian.

In the northern Sacramento Mountains Thompson measured a possible 437 feet of beds of Atoka age consisting predominantly of sandstone and shale with a few thin beds of limestone. However, the lower 112 feet of this section might be of Morrow age and the upper 145 feet is concealed so that no definite top of the series could be determined.

In Magnolia's Burro Hills test in southern Eddy County a possible 740 feet of beds from 8500 to 9240 feet may be Atoka in age, but here again 150 feet of limestone at the base of the section might belong in the Morrow. Fusulinids were found only in the upper part of the section. Possible base of the Atoka is placed at 9110 feet at the base of a prominent sandstone.

In Richfield et al.'s Mullis well in southern Chaves County (M, p1. 4) , 340 feet of beds from 9600 to 9940 feet are tentatively assigned to the Atoka series. The section consists of limestone with interbedded gray to black shale and a few thin beds of sandstone. Fusulinids were found near the middle of the section only, and the limits selected are very arbitrary.

No Atoka beds were found in wells farther northwest in Chaves County, but they are apparently continuous throughout a deep basin extending from southern Eddy County across eastern Chaves County and northern and western Lea County extending as far north as Barnsdall's State No. 1-A well in extreme eastern • Chaves County where the section from 10,380 to 10,710 feet is provisionally correlated as Atoka. This section consists of interbedded dark to black shale, sandstone, and limestone with a much higher percentage of elastics than in wells farther south.

MISSISSIPPIAN SYSTEM

GENERAL FEATURES

Laudon and Bowsher (1941, 1949) have studied the surface exposures of Mississippian rocks in southern New Mexico and their faunas in considerable detail. Data on subsurface features are obtained from detailed sample descriptions supplemented by analyses from the Paleontological Laboratory in Midland, Texas.

The type area of Mississippian rocks is in the Mississippi Valley where four series are generally recognized which, from top to bottom, are named Chester, Meramec, Osage, and Kinderhook. Laudon and Bowsher have found representatives of all four series in the Sacramento and San Andres mountains of southern New Mexico, but in the Hueco and Franklin Mountains of Texas, Chester and Meramec rocks only are present. Classification of the named units of the system in the Sacramento and Hueco Mountains are shown in table 3.

TABLE 3. CLASSIFICATION OF MISSISSIPPIAN ROCKS IN SACRAMENTO AND HUECO MOUNTAINS

(After Laudon and Bowsher, 1949)

Chester series	
Helms formation	Predominantly gray to brown sandy shales with thin beds of sandstone and limestone in Hueco Mountains.
Unconformity	
Meramec series	
Rancheria formation	Thin bedded gray silty limestones interstratified with gray shale in Hueco Mountains. Gray siltstone with secondary chert and interbedded shale in Sacramento Mountains.
Marked unconformity	
Osage series	
Lake Valley formation	
Doña Ana member	Crinoidal limestone with chert masses; limited to northern Sacramento Mountains.
Arcente member	Thin bedded calcareous siltstone and soft gray shale.
Tierra Blanca member	Thin bedded cherty crinoidal limestone forming conspicuous scarp.
Nunn member	Blue gray to green crinoidal marl and interbedded coquina.
Alamogordo member	Massive, black, cherty limestone.
Andrecito member	Soft gray calcareous siltstone.
Unconformity	
Kinderhook series	
Caballero formation	Basal black shale overlain by nodular limestone with interbedded calcareous shale; shale beds more prominent in upper part.
Unconformity	

Mississippian rocks are recognized over wide areas in the subsurface in southeastern New Mexico and western Texas. They are generally present in Eddy County, southeastern Chaves County and in Lea County except in the Eunice area and other structurally high parts of the Central Basin Platform. They are absent over the western extension of the Matador uplift in southern Roosevelt County but present in Magnolia's A. K. Smith test in the southwestern part of the county. They are generally absent in wells drilled in De Baca and Guadalupe counties.

In most of the subsurface sections the Mississippian is represented by a limestone section overlain by dark shale. The limestone section in most wells is correlated with the Rancheria formation of Meramec age and the shale section with the Helms formation as restricted by Laudon and Bowsher.

CHESTER SERIES

Helms formation.—The Helms formation of the Hueco Mountains was first described by Beede (1918) , who included in it rocks of Mississippian and Devonian age. Laudon and Bowsher have restricted the Helms to the upper shaly part which contained the original Chester fauna collected by Beede. The Helms as thus restricted "overlies the Rancheria unconformably. The lower beds consist of green, thin-bedded, 'chippy' shales with very thin, 'waferlike' brown sand lenses. The middle part consists of gray to brown, sandy shales with several brown slabby limestone beds. The limestone beds and associated marls carry excellent faunas. The upper beds consist mainly of brown, cherty, crinoidal limestones interbedded with gray marls. The fauna contains typical Chester forms" (Laudon and Bowsher, 1949, p. 34) .

A shale section overlying the "Mississippian limestone" in a number of wells in southeastern New Mexico is tentatively identified as the Helms formation. It is best developed in southern Lea County. In Amerada's Record No. 2 test it is 265 feet thick extending from 12,260 to 12,525 feet (pl. 6) . This section is dark gray to black shale with some thin beds of limestone. Farther west and north the formation is thinner and may be entirely absent in Chaves County, northern Lea County, and counties farther north. In some wells a dark shale with interbedded limestone is found between the top of the Rancheria limestone and overlying beds carrying Atoka fusulinids and there is a question whether these beds are Helms or Atoka. Such a section is found in Richfield et al.'s Mullis well in southern Chaves County from 9,940 to 10,050 feet (pls. 4 and 6) .

In Amerada's Hamilton No. 1 well in sec. 35, T. 16 S., R. 38 E. (pl. 8) , the total Mississippian section is 1540 feet thick from 10,840 to 12,380 feet in depth. It is predominantly limestone with a considerable amount of chert in two zones in the middle portion and with some interbedded gray shale. The upper part of the section has been identified as Chester in age and may be correlative with the Helms formation.

The subsurface shale section, here designated as Helms, is also called Barnett by many subsurface workers. Cloud and Barnes (1948, pp. 52-59) , however, have shown that the Barnett is not younger than Meramec in age and therefore not correlative with the Helms.

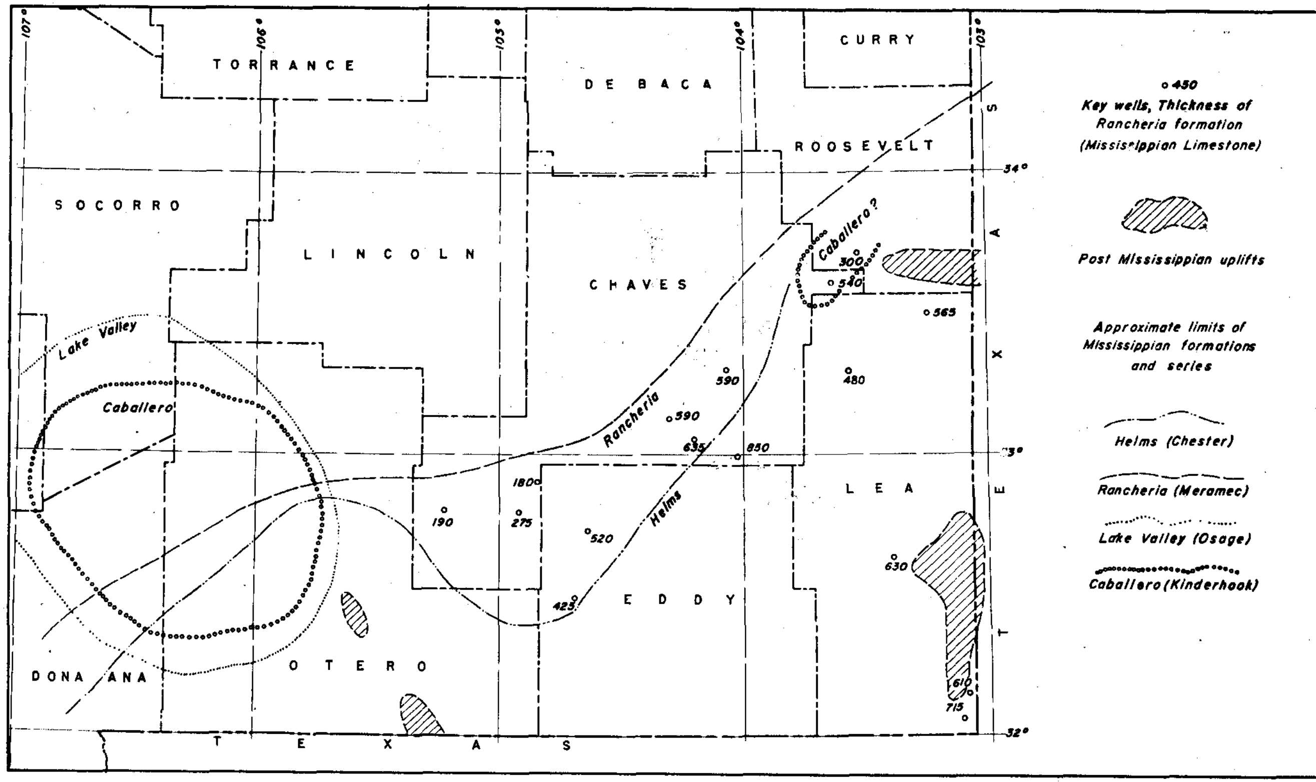

FIGURE 5. Mississippian system in southeastern New Mexico.

The approximate northern limit of the Helms formation is shown on fig. 5.

MERAMEC SERIES

Rancheria formation.—The Rancheria formation, named by Laudon and Bowsher for Rancheria Peak in the Huth) Mountains, has its maximum surface development in the southern Sacramento Mountains where it reaches a thickness of over 275 feet. It is described as a "monotonous evenly-bedded sequence of dove-gray to brownish-gray slightly calcareous siltstone carrying considerable amounts of brown, crinkly, secondary chert (?) rhythmically bedded with thin shale partings. The beds are rarely more than a foot thick" (Laudon and Bowsher, 1949, p. 31) .

The formation thins to the north probably by progressive overlap but extends as far north as Mule Canyon in T. 17 S., R. 10 E. In canyons farther south the formation thickens markedly to the east.[10]

In the Hueco Mountains the Rancheria formation "consists of monotonously thin-bedded, gray, silty limestones interstratified with thin gray shale. The beds average 7 inches in thickness and are rarely over 18 inches thick. The shale partings are generally under half an inch thick. The entire section is filled with elongate, slender, 'crinkly,' and nodular chert masses that ordinarily make up as much as 50 per cent of the rocks. Weathering of these cherts produces rich brown, angular rock chips causing the outcrop to resemble a woodyard, hence the name 'Woodyard cherts' (Beede, 1920). The Rancheria is slightly over 215 feet thick at Rancheria Peak. Fossils are rare but occur occasionally in the basal beds. A few occur sporadically throughout the section. *Leiorhynchus carbonif erum, Spirit er arkansanus* and *Dictyoclostus inflatus* var. *coloradoensis* are most common" (Laudon and Bowsher, 1949, p. 34) .

The Las Cruces formation of Meramec age unconformably underlying the Rancheria in the Franklin Mountains is not present in the Sacramento or Hueco mountains and is not recognized in wells farther east.

The limestone of the subsurface, herein called the Rancheria, varies in thickness up to 850 feet and is commonly siliceous and cherty. The color varies from light gray to light brown, and the texture from crypto-crystalline to paurograined. Some beds of limestone are shaly, and beds of gray shale and chert are found interbedded with the limestone.

The Paleontological Laboratory (Midland) has identified *Leiorhynchus carbonif erum,* a characteristic Meramec fossil, in a core from 13,090 to 13,100 feet from Amerada's Record No. 2 well in sec. 25, T. 19 S., R. 35 E. in Lea County and has also found *Leiorhynchus* in a core from 11,182 to 11,190 in Barnsdall's State No. 1-A in extreme eastern Chaves County. On the basis of these

[10] Lloyd C. Pray, personal communication.

identifications and the general character of the rocks, the Mississippian limestone section is correlated with the Rancheria formation. Lithologically it is more like the Rancheria in the Hueco Mountains than that in the Sacramento Mountains where it is predominantly siltstone.

The lower part of the thick limestone section in Amerada's Hamilton No. 1 well in eastern Lea County is correlated with the Rancheria formation and the upper part with the Helms.

OSAGE SERIES

Lake Valley formation.—The Lake Valley formation has its maximum development in the northern part of the Sacramento Mountains in the area immediately south of where the rocks plunge below the valley floor. The maximum thickness is about 275 feet. The formation has been studied in detail by Laudon and Bowsher (1941, 1949) who recognized and described six distinctive members.

The remarkable bioherms developed in the Lake Valley formation have their bases in the Alamogordo member and extend upward through the overlying Nunn and Tierra Blanca members and locally through the Arcente member. The crinoidal coquina beds of the Nunn and Tierra Blanca members grade laterally into the massive limestones of the bioherms.

All members of the Lake Valley formation thin to the south either by progressive overlap or because of unconformities at the base and top of the formation. The formation is not present in the Hueco Mountains and has not been recognized in any wells drilled east of the mountains. The approximate distribution of the Lake Valley formation as shown on fig. 5 is modified from Laudon and Bowsher (1949, fig. 6, p. 14) .

The Kelly formation of Osage age, overlying the Lake Valley in west central New Mexico, is not present in the Sacramento Mountains.

KINDERHOOK SERIES

Caballero formation.—The Kinderhook series is represented in the Sacramento Mountains by the Caballero formation which has a maximum thickness of less than 50 feet and is composed of shale and nodular limestone. The formation thins to the south and east and is absent in the Hueco Mountains and in subsurface sections farther east.

In eastern Chaves County and southwestern Roosevelt County a section of grayish-green shale and silt, sandy at the base, is found underlying the Rancheria limestone. In Barnsdall's State No. 1-A in Chaves County these beds extend from 11,290 to 11,475 feet in depth, and in Magnolia's A. K. Smith well, ten miles northeast in Roosevelt County, the interval is from 9320 to 9510. According to Hollingsworth [11] these beds are lithologically Kinder-

[11] R. V. Hollingsworth, personal communication.

hook-like. These beds are tentatively correlated with the Caballero, but this correlation is very questionable (fig. 5) .

DEVONIAN SYSTEM

GENERAL FEATURES

The most detailed studies of the Devonian rocks in the mountain areas of southern New Mexico have been made by Frank V. Stevenson whose work was summarized in a paper published in 1945. The exposures in New Mexico are limited to five mountain ranges, the Sacramento, San Andres, Caballos, Mud Springs, and Mimbres mountains. All the formations present are predominantly shale and siltstone with thin beds of limestone in some of the formations. The overall thickness is in excess of 350 feet in the Mimbres region, approximately 150 feet in the San Andres Mountains and 100 feet in the Sacramento Mountains.

Stevenson's classification of the Devonian beds is summarized in table 4.

TABLE 4. DEVONIAN ROCKS OF SOUTH CENTRAL NEW MEXICO

(After Frank V. Stevenson, 1945)

Upper Devonian	
Percha formation	
Box member	Gray calcareous shale with interbedded limestone. Mimbres Mountains only. Maximum thickness, 89 feet.
Ready Pay member	Black fissile shale. Maximum thickness in Mimbres Mountains, 383 feet.
Contadero formation	Carbonaceous shales and limestones overlying Sly Gap beds in central San Andres Mountains only. Unfossiliferous. Might correlate with upper Sly Gap or with Ready Pay. Maximum thickness 67 feet.
Sly Gap formation	Thin bedded, alternating layers of shale, siltstone, and limestone, very fossiliferous. Maximum thickness in San Andres Mountains, 117 feet. Average in Sacramento Mountains, 45 feet.
Middle Devonian	
Oñate formation	Variable and intergradational beds of shale, siltstone, fine-grained sandstone, and limestone. Limited to San Andres and Sacramento Mountains. Maximum thickness, 87 feet.

The Canutillo formation (Nelson, 1940,-p. 164) of the Franklin Mountains is in part, at least, Middle Devonian. The upper black shale member may be correlative with the Ready Pay member of the Percha.

The Woodford formation has been identified in a number of wells and is herein classed as Upper Devonian in age and correlated with the Ready Pay member of the Percha.

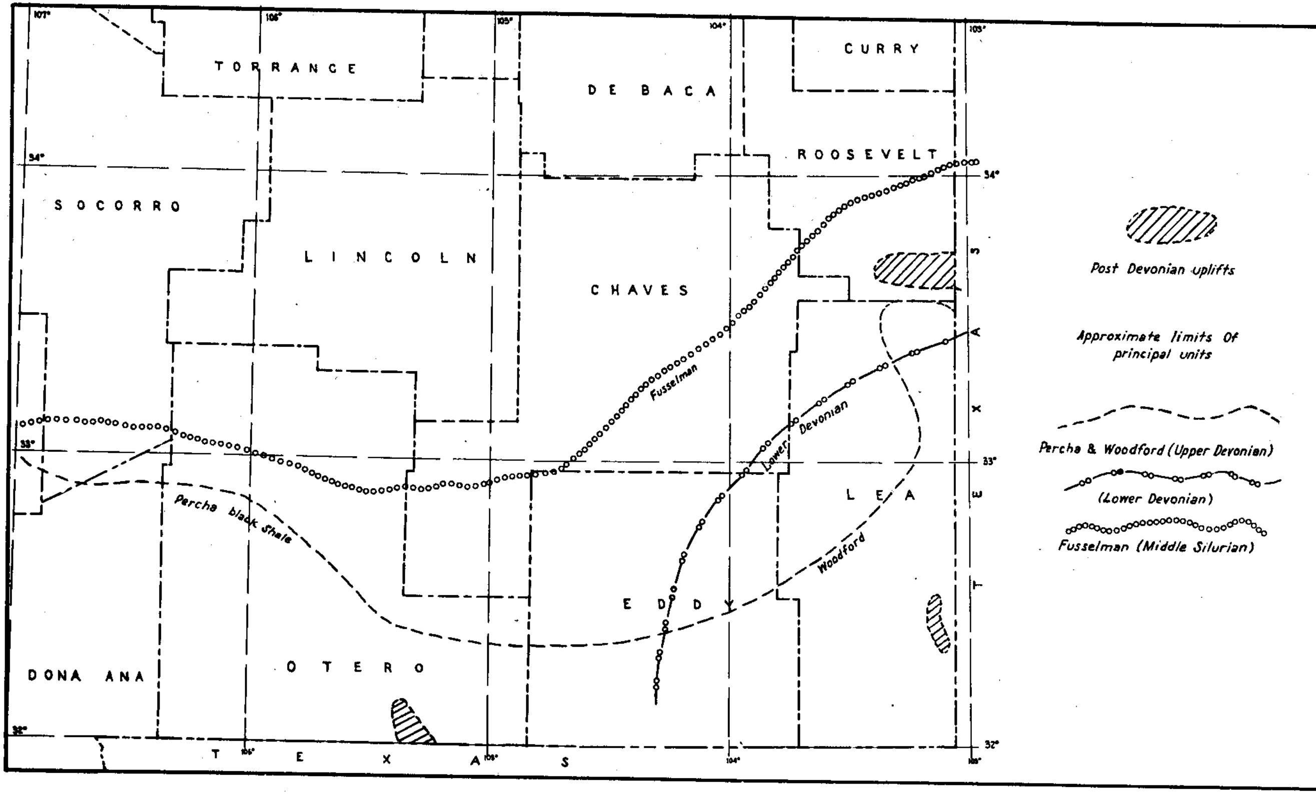

FIGURE 6. Devonian and Silurian systems in southeastern New Mexico.

A limestone and dolomite section found in numerous wells is believed to be Lower Devonian in age. It is not present in surface sections but might be correlative with the lower cherty member of the Canutillo formation.

UPPER DEVONIAN

Woodford formation.—A shale section commonly correlated with the Woodford chert of Oklahoma is found over a wide area in west Texas and southeastern New Mexico. It is described as "Brownish-black flaky shale with thin beds of finely crystalline, argillaceous dolomite and brownish-black chert. It contains conodonts and resinous spores" (Barton et al., 1946) .

On the Central Basin Platform the Woodford attains a maximum thickness of approximately 600 feet and is best developed in Winkler County, Texas, and Lea County, New Mexico. In El Paso Natural Gas Company's Ginsberg well in sec. 7, T. 25 S., R. 38 E., Lea County, the thickness is 500 feet from 8910 to 9410 feet in depth. The spores, *Tasmanites huronensis* are numerous especially in the upper part. A similar thickness of Woodford was found in the Dublin area in sec. 12, T. 26 S., R. 37 E. In Amerada's Record No. 2 in sec. 25, T. 19 S., R. 35 E. the Woodford is 155 feet thick from 13,220 to 13,375 feet (pl. 6).

In the Eunice area of southern Lea County the Woodford is absent but was probably deposited over the entire area and removed by pre-Permian or pre-Pennsylvanian erosion. North of the Eunice area two wells have found a Woodford section much thinner than that in the southern part of the county. In Phillips' Shipp No. 1 in sec. 20, T. 18 S., R. 37 E. the shale is 105 feet thick from 10,250 to 10,355 feet (fig. 5) , and in Amerada's Hamilton No. 1 in sec. 35, T. 16 S., R. 38 E. it is only 66 feet thick from 12,380 to 12,446 feet (fig. 8) . The Woodford was .not recognized in the discovery well in the Crossroads area, but a black spore bearing shale was found in Skelly's U. D. Sawyer No. 1 well at 12,574 feet. In all wells where present in Lea County and on the Central Basin Platform in Texas, the Woodford rests on dolomite or siliceous limestone which is believed to be Lower Devonian in age.

No Woodford shale has been found in wells in Chaves County (except possibly in the southwest part) , Eddy County, or in counties farther north, and the general thinning of the section from south to north indicates that it was not deposited north of Lea County and possibly not north of southernmost Eddy County. The probable limits of the Woodford is shown on fig. 6.

The Woodford is regarded by many geologists as lowermost Mississippian (lower Kinderhook) in age, but Ellison (1946) has presented strong evidence based on conodont and fossil wood studies that it is Upper Devonian.

Percha shale.—The Percha shale is exposed in surface sections in the Mimbres Mountains where, according to Stevenson

(1945) , it reaches a thickness of over 400 feet and is divided into two members. The upper member, which Stevenson named the Box member, is a gray to green calcareous shale with lenses and nodules of limestone. It is known only in the Mimbres region where it is highly fossiliferous. The lower, Ready Pay member is a black fissile non-fossiliferous shale which reaches a maximum thickness of 383 feet in the Mimbres Mountains. Similar black shales are widespread in southern New Mexico but are much thinner. In the Sacramento Mountains they are only a few feet thick and are overlain by the lower Mississippian Caballero formation and underlain by the Sly Gap formation of the Upper Devonian.

Stainbrook (1947) has studied the fauna of the upper Percha shale and concludes that it is lowermost Mississippian in age. "The Percha fauna is more closely related to that of the overlying Mississippian than to the underlying Devonian and the Mississippian system in New Mexico seems to begin with a body of black shale, the Silver member (Stevenson's Ready Pay member) , similar to the basal black shale of the Mississippian system in many other parts of North America" (1947, p. 302) .

The fauna studied by Stainbrook is from the Box member of the Percha, and no faunal evidence is available regarding the underlying black shale or Ready Pay member. This member is similar in character to the Woodford and apparently occupies the same stratigraphic position.

Some black shale found in wells in Otero County are probably the Ready Pay member of the Percha. They are also recognized as the upper member of the Canutillo formation.

Contadero and Sly Gap formations.—Stevenson named and described the Contadero and Sly Gap formations from surface sections in the San Andres Mountains. Both formations consist of shales with interbedded limestones. The Sly Gap is fossiliferous, and the fauna is Upper Devonian. In the southern part of the San Andres Mountains and in the Sacramento Mountains it underlies the Ready Pay member of the Percha. In the central part of the San Andres Mountains the unfossiliferous Contadero formation lies between the Sly Gap and the Ready Pay and may be a local correlative of one of these units. Neither the Sly Gap nor Contadero is recognized in wells east of the mountains.

MIDDLE DEVONIAN

Oñate formation.—The Oñate formation was described by Stevenson (1945) from surface sections in the San Andres Mountains. It is predominantly shale with interbedded siltstone, sandstone and limestone. A meagre fauna suggests an uppermost Middle Devonian age or possibly lowermost Upper Devonian: The formation is limited to the San Andres and Sacramento mountains and has not been recognized in the subsurface.

Canutillo formation.—The Canutillo formation of the Franklin Mountains as described by Nelson (1940, p. 164) has a basal section of light brown cherty limestone and an upper unit 40 feet thick of black fissile shale. Fossiliferous gray limestone with a Middle Devonian fauna and a thin bed of dense almost black sandstone lie between the upper and lower units. Laudon and Bowsher (1949, p. 36) by inference limit the Canutillo formation to the middle fossiliferous part of Nelson's Canutillo and correlate it with the Ofiate formation of the San Andres Mountains on the basis of lithology and fossil content. They suggest that the upper black shale may be correlative with the Percha.

A similar section was found in the Hueco Mountains except that the upper "Percha" shale is absent. The basal beds are about 100 feet thick and thin bedded and nodular chert commonly makes up as much as 90 percent of the unit. Overlying the chert beds are beds of soft, gray silty shale and silty limestone which appear to be correlative with the fossiliferous part of the Canutillo (Laudon and Bowsher, 1949, p. 34) . The Canutillo is in turn overlain unconformably by the Rancheria formation.

A little farther east in California Oil Company's Thiessen well in Sec. 19, Blk. E, University Survey, Hudspeth County, Texas, a black pyritic shale underlies the Rancheria limestone from 2100 to 2165 feet in depth and contains the plant spores,*Tasmanites huronensis* which occur abundantly in the Woodford. On the basis of lithology and the presence of the spores this shale should be correlated with the Woodford and Percha rather than the Canutillo. However, it rests directly on a very cherty limestone which seems to be the same as the Canutillo chert in the Hueco outcrops. The obvious inference is that the middle part of the Canutillo disappears a short distance east of the Hueco outcrops.

A similar black shale overlying chert is present from 2030 to 2075 feet in Fred Turner's Everett well in sec. 34, T. 22 S., R. 13 E., Otero County. Here, however, the black shale is overlain by a red shale which may represent either the Powwow conglomerate or the basal Abo.

Black shale, but without the underlying chert, was found in Turner's Evans well in sec. 22, T. 24 S., R. 12 E. from 1890 to 1970 feet and also in Union Oil Company's McMillan well in sec. 9, T. 25 S., R. 13 E., from 3485 to 3540 feet. In both these wells the black shale rests on dolomite which is correlated as Fusselman.

In the Texas Company's Wilson well (Dunken Dome) in southwestern Chaves County in sec. 29, T. 17 S., R. 18 E. (pl. 7) , a black shale from 4830 to 4870 feet in depth rests on a dolomite which is now identified as Fusselman on the basis of insoluble residues. This may be approaching the eastern limit of black shale deposition in the "Percha" basin. As previously noted, the characteristic black shale has not been found in wells farther east in Chaves or Eddy counties but reappears in southern Lea County as the Woodford shale.

The cherty lower Canutillo section might be Lower Devonian correlative with the Lower Devonian dolomites of southern Lea County. There is no fossil evidence as to its age.

LOWER DEVONIAN

A group of rocks, predominantly dolomites of Devonian and Silurian age, is present over a large part of southeastern New Mexico and west Texas. The Devonian part of this section is known from subsurface data only. In 1945 and 1946 a study group of the West Texas Geological Society (Barton et al., 1946) recommended that the name Hunton group be used for the Devonian and Silurian dolomites, limestones and associated rocks of the Central Basin Platform, but that name is not in common use.

Numerous fossils found in a well in central Andrews County, Texas, were studied by Stainbrook who reported that they most closely resembled the fauna of the Helderberg group of Lower Devonian age (Jones, 1944) . Stromatoporoids of early Devonian age are most common and have also been found in other wells.

The study group divided the Hunton section into several units of which the lower two are Silurian. The upper units believed to be Devonian in age are variable in thickness and difficult to identify in Lea County. Zones of chert or very cherty limestone and porous dolomite in the Devonian are oil and *gas* reservoirs in several fields On the Central Basin Platform in west Texas.

Limestones and dolomites of lower Devonian age are present over all of southern Lea County except where they have been removed by pre-Permian erosion. In general, the limestone is predominant in the southern part of the county and dolomite farther north. Some chert and cherty limestone beds are present, but the writer has not undertaken a correlation between different cherty units, nor has he segregated the Devonian from the underlying Silurian. Some suggested correlations are shown in outline cross sections, pls. 5 to 9.

The oil pay in the Knowles pool is believed to be in the Devonian. This pool was discovered in Amerada's Hamilton No. 1 Well in sec. 35, T. 16 S., R. 38 E. (pl. 8) and lies seven miles southwest of the Jones Ranch pool in northwestern Gaines County, Texas, where the production is also from the Devonian.

Reported Devonian rocks in northern Lea County are _questionable. Production from the Crossroads pool in T. 9 S., R. 36 E. was reported as Devonian (Henderson and Barr, 1949) , but in the writer's opinion it is more probably Silurian, possibly Fusselman. The pay in the Crossroads pool is probably the same as in the Bagley area 25 miles to the southwest in T. 12 S., R. 33 E.

The Lower Devonian dolomite section thins and disappears to the west. In Richfield et al.'s Mullis test in southeastern Chaves

County (pl. 7) 135 feet of chert from 10,890 to 11,025 feet is believed to be Devonian. This may be the equivalent of the much thicker dolomite section in southern Lea County. It may also be the same as the cherty section in the lower Canutillo in the Hueco Mountains. This chert section was not found in wells farther north or west in Chaves or Eddy counties. If it was continuous with the cherty section in the Hueco Mountains, it was probably removed by erosion over wide areas prior to the deposition of the Mississippian. Probable limits of the Lower Devonian rocks are shown on fig. 6.

SILURIAN SYSTEM

The Fusselman limestone reaches its maximum thickness of about 1000 feet in its type locality in the Franklin Mountains, where it is "mostly a massive magnesian limestone" (Darton, 1917, p. 43). In the San Andres Mountains the thickness ranges from 105 to 130 feet the maximum thickness being in Alamo Canyon. Here the formation consists of two members, an upper 50-foot member consisting of hard dark limestone carrying a distinctive fauna and a lower 85-foot member of compact, fine-grained gray limestone that weathers nearly white. Darton found no fossils in the lower member and included it in the Fusselman arbitrarily (Darton, 1917, p. 43 and 1928, p. 201). The Fusselman is determined as Niagaran (Middle Silurian) in age on the basis of its fossil content. The most common characteristic form is a *Pentamerus,* but many corals occur at some places.

A section of the Fusselman measured by a study group of the West Texas Geological Society in the Hueco Mountains is 630 feet thick and is predominantly dolomite in the lower part and limestone in the upper part. The dolomite beds are commonly thick and in many places reef-like. The texture ranges from finely crystalline to very coarsely crystalline. Colors are white, gray, and pink. Chert is present in many beds.

The upper part of the section is not fossiliferous in the Hueco Mountains, and there is some question as to whether it should be included in the Fusselman. Laudon and Bowsher (1949) report 30 feet of massive, coarsely crystalline, pink to gray limestone with large calcareous algae overlying the Fusselman in the Rancheria Peak area and lithologically quite unlike the underlying Fusselman. The reported similarity to the Chimney Hill formation of the Arbuckle Mountains is probably not significant because the latter is Lower Silurian in age.

The Silurian of the subsurface in southeastern New Mexico and west Texas is divided into two distinct units. The lower unit is the Fusselman, and is remarkably uniform over wide areas with much the same character as in the Hueco'Mountains. A section 650 feet thick from 9670 to 10,320 feet in Magnolia's. Burro Hills test in southern Eddy County is tentatively correlated with the Fusselman. It is a continuous dolomite section with a bed of chert at the top and a thin bed of chert in the lower part. It is overlain by the Rancheria limestone unconformably. The upper part may be younger than Fusselman and might even be Devonian. Contact with the underlying Montoya is picked at the top of a chert bed at 10,320 feet, but this contact is arbitrary inasmuch as the underlying section is very similar in character to that above.

Farther east the Fusselman is much thinner, 250 to 300 feet. Over most of southern Lea County its top is picked at the top of a persistent cherty zone. In Winkler County, Texas, the Fusselman is "predominantly medium to coarsely crystalline limestone" Barton et al., 1946) .

In the southern part of the Central Basin Platform in Texas the upper unit of the Silurian consists of approximately 220 feet of "green, gray, and red silty shale with shaly, finely crystalline limestone" (Barton et al., 1946) . A dense limestone is present at the base of this unit which is intermediate in lithology between the shale and the underlying Fusselman. This limestone facies becomes more prominent to the north and in southern Lea County the unit is mostly limestone with only traces of the characteristic gray and green shale. Still farther north the unit is predominantly dolomite.

In Ward County, Texas, graptolites from a core in the shale section have been identified as of Lockport, lower Niagaran age. Present evidence, therefore, indicates that the Fusselman and the overlying unnamed shale unit are both Middle Silurian.

In Amerada's State No. 1 BTA (pl. 7) , the discovery well of the Bagley area, the base of the Mississippian limestone section and top of a dolomite was reached at 10,785 feet. The top of the Montoya formation was picked 560 feet lower at 11,345 feet. This dolomite section is tentatively identified as Fusselman by the writer, but it may be that the upper part belongs in the upper unit of the Silurian or even in the Devonian. Similarly the pay in the Crossroads pool is tentatively called Fusselman. Top of the Fusselman (?) in the discovery well was reached at 12,115 feet.

Oil is produced from a porous dolomite identified as Silurian in the McCormack pool on the west flank of the Eunice uplift. The formation is probably Fusselman.

In surface sections in the San Andres Mountains the Fusselman thins and disappears a short distance north of the latitude of Alamogordo and is not found in any mountain areas farther north. In Chaves County it extends as far north as Richfield's White No. 3-1 in sec. 6, T. 12 S., R. 29 E. (p1. 5) where it consists of 420 feet of very cherty dolomite from 8340 to 8760 feet. Here it is overlain unconformably by Mississippian (Rancheria) limestone and shale and lies unconformably on the Ellenburger. In wells farther north in Chaves County it was probably present but removed by pre-Pennsylvanian erosion. It is absent in Guadalupe and De Baca counties where, in all tests so far drilled, Pennsylvanian or Permian rocks rest directly on the pre-Cambrian. The probable northern limits of the Fusselman formation are shown on fig. 6.

ORDOVICIAN SYSTEM

UPPER ORDOVICIAN

Montoya formation —Surface exposures of the Montoya limestone have received little detailed study since the classic work of N. H. Darton (1917, 1928) , and the following notes are taken from his publications. The formation underlies most of southern New Mexico except where removed by erosion. It ranges from 200 to 300 feet in thickness and in most areas consists of two members, a lower dark-colored massive limestone, locally sandy, and an upper member of slabby beds with many thin layers of chert. The formation is a prominent feature in most of the mountain ranges. It extends as far north as the southern end of the Oscura Mountains but thins and disappears within a short distance to the north.

In the Sacramento Mountains the lower member crops out as a high cliff and is from 75 to 120 feet thick. In Alamo Canyon its base is a gray sandstone. The upper member is 60 feet thick and consists largely of alternating thin beds of chert and limestone.

The Montoya formation contains numerous fossils which serve to determine its age as Richmond, Upper Ordovician. In all outcrop sections in New Mexico and in the Franklin and Hueco mountains of west Texas, the Montoya overlies the Lower Ordovician El Paso limestone unconformably with the Middle Ordovician missing. Farther north in the San Andres Mountains the Fusselman thins and disappears and the Montoya is overlain by the Middle Devonian Oñate formation and in the northern end of the range by the Upper Devonian Sly Gap formation. In' the southern end of the Oscura Mountains the Montoya is overlain. by Pennsylvanian rocks.

The Montoya of southern Lea County is similar to that of the surface sections in the mountains to the west. It reaches a maximum thickness of 400 feet in the Dublin area in T. 26 S., R. 37 E. and decreases in thickness to the north. The thinnest section so far found in southern Lea County is in Continental Oil Company's Warren No. 1-B-29, in sec. 29, T. 20 S., R. 38 E. where it is 215 feet thick from 8450 to 8665 feet. In southeastern Chaves County the formation is much thinner. In Richfield's Trigg well in sec. 35, T. 14 S., R. 27 E. it is 130 feet thick from 9440 to 9570 feet. Farther north and west the formation is absent and the Fusselman or younger beds rest directly on the Ellenburger.

In the Bagley area of northern Lea County (Amerada's State No. 1-BTA) the Montoya is 240 feet thick from 11,345 to 11,605

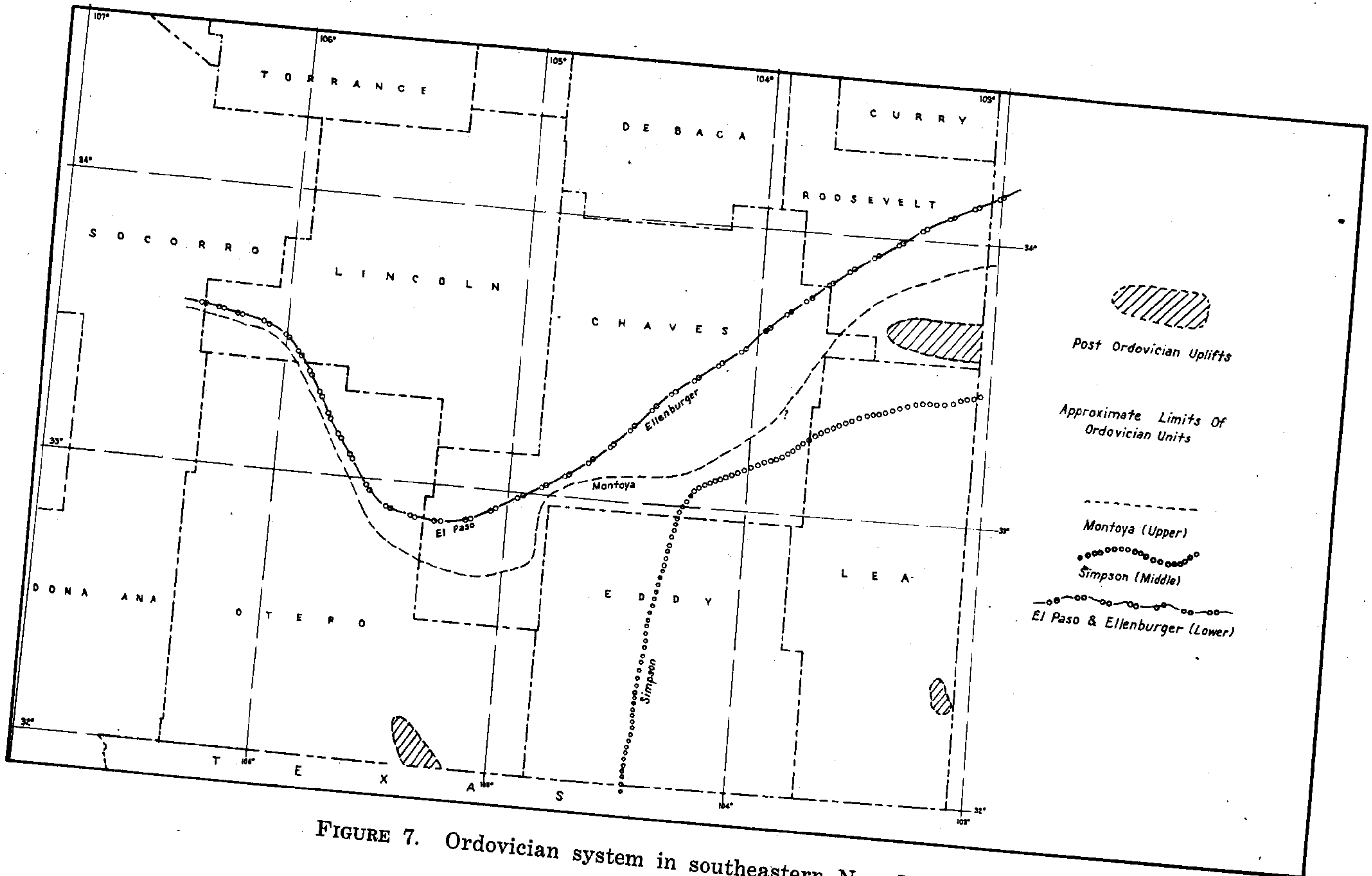

FIGURE 7. Ordovician system in southeastern New Mexico.

feet in depth. It is present at least as far north as Magnolia's A. K. Smith well in southwestern Roosevelt County.

The probable northern limit of the Montoya is indicated on fig. 7, and its vertical limits in a number of wells are shown on outline cross sections, pis. 5 to 9. For some of the wells the limits of the formation have been determined by insoluble residue studies, but in most cases such determinations are not available.

The Montoya formation produces oil in the Cary pool in sec. 22, T. 22 S., R. 37 E., Lea County.

MIDDLE ORDOVICIAN

Simpson group.—The Simpson group of Middle Ordovician age has been described in detail from surface sections in southern Oklahoma (Decker et al., 1931) where it is divided into five formations. These units have been recognized generally in the subsurface of west Texas and southeastern New Mexico, but there has been a reluctance in applying the Oklahoma names because of the distance from the type localities. Local names have been proposed for producing sandstone members in west Texas, and these units can be generally recognized in Lea County, New Mexico. The subdivisions of the Simpson group are shown in table 5.

TABLE 5. SIMPSON GROUP, CENTRAL BASIN PLATFORM, WEST TEXAS AND SOUTHEAST NEW MEXICO

(After Barton et al., 1946)

Bromide formation	**Light-gray, lithographic and finely crystalline limestone.**
Tulip Creek formation	**Interbedded green shale and limestone with reddish-brown shale streaks and embedded rounded quartz grains.**
McKee sandstone member at base	**Medium-grained white and green sandstone with phosphatic grains and many rounded quartz grains.**
McLish formation	**Interbedded limestone and green shale with thin beds of siltstone. Frosted quartz grains are less abundant than above or below.**
Waddell sandstone member at base	**Hard white sandstone with thin beds of green shale.**
Oil Creek formation	**Interbedded green shale and limestone with embedded frosted quartz grains.**
Connell sandstone member at base	**Fine-grained, ferruginous sandstone.**
Joins formation	**Brown and gray finely crystalline and granular limestone grading laterally into dolomite. Embedded frosted quartz grains; slightly glauconitic at base.**

The writer has not undertaken to differentiate the individual units of the Simpson group in Lea County, but most of them can be recognized particularly by the use of electrical or radioactivity logs. The group as a whole reaches its maximum thickness in New

Mexico in the Dublin area where in Humble's Federal-Leonard No. 1 in sec. 12, T. 26 S., R. 37 E. (pl. 8) it is 1060 feet thick from 10,760 to 11,820 feet. The group thins to the north and northwest partly by transgressive overlap of younger units of the group and partly by thinning and disappearance of upper units.

In ,Amerada's State No. 1-BTA well in the Bagley area of northern Lea County, 65 feet of Simpson beds have been recognized from 11,605 to 11,670. In Richfield's Trigg well in sec. 35, T. 14 S., R. 27 E. in southern Chaves County the Simpson is represented by 50 feet of sandstone and red and green shale from 9570 to 9620 feet. These wells were probably near the northwestern limit of deposition of the Simpson since it is missing in wells farther north in Chaves County and also in wells in Eddy County. No rocks of Middle Ordovician age have been found in any of the mountains of southern New Mexico.

As noted above, three sandstone members in the Simpson group.have been found productive of oil in west Texas. Only one of these, the McKee sandstone, has so far proved productive in New Mexico, but this sand is producing oil in five fields in south central Lea County. A brief summary of the producing fields will be presented later.

LOWER ORDOVICIAN

Ellenburger group and El Paso limestone.—The dolomites and limestones of the Lower Ordovician of Oklahoma, Texas, and New Mexico have been studied in much detail, principally because of their economic importance as oil and gas reservoirs. Surface studies have been most detailed in the type area of the Ellenburger group in the Llano uplift in Central Texas and in the Arbuckle Mountains of Oklahoma where the group is known as the Arbuckle. Reference is made to recent detailed studies by Cloud and Barnes (1948) for a description *of the Ellenburger group of central Texas and also detailed measured sections of the El Paso group in the Franklin and Beach mountains of west Texas.

The subsurface section in west Texas and southeastern New Mexico is commonly called the Ellenburger formation. It has been subdivided into more or less distinctive units principally by insoluble residue studies. Earlier published insoluble residue determinations have not been confirmed by more detailed work so no reliable subdivision of the Ellenburger subsurface of west Texas and New Mexico is available for the present report.

The Ellenburger group of the Llano uplift is restricted to rocks of Lower Ordovician age. Some Cambrian dolomites and limestones formerly included in the Ellenburger are now members of the Wilberns formation. The Ellenburger is divided into three formations, named from top down, Honeycut, Gorman and Tan-yard, but these represent only about the lower half of the Lower Ordovician of the Ozark uplift of Missouri and Arkansas and of the Arbuckle Mountains (Cloud and Barnes, 1948).

Detailed sections of the El Paso limestone in the Beach and Franklin mountains of west Texas have been studied and correlated with Lower Ordovician rocks in the Llano, Arbuckle, and Ozark areas on the basis of their fossils (Cloud and Barnes, 1948, p. 66 et seq., also p. 352 et seq.) . The Bliss (?) sandstone of Beach Mountain, or at least the upper part of it, is correlative with the Tanyard formation, lower Ellenburger. The El Paso limestone of Beach Mountain as measured is 1125 feet thick, but only the lower 400 feet of this section is correlated with the middle and upper formations of the Ellenburger. The upper 715 feet is correlated with the upper part of the Arbuckle group and with post-Jefferson City formations of the Ozark uplift, and correlative beds are missing in the Llano uplift.

The same faunal divisions of the El Paso except Tanyard were found in the Franklin Mountains. The fossils in the Bliss sandstone are not diagnostic, and it may be correlative with the sandstone in the Beach Mountains or it may be Cambrian in age. The El Paso formation is 1590 feet thick and consists of limestone, dolomite, a little shale, and less sand. The lower 855 feet of the formation is correlated with the Honeycut and Gorman formations of the Ellenburger and the upper 735 feet with the upper part of the Arbuckle and Ozark sections.

Preliminary insoluble residue studies[12] suggest that the lower part of the El Paso limestone section may be older than any of the Ellenburger as known in the subsurface of southeastern New Mexico and west Texas. This leads to speculation as to the possibility that the subsurface Ellenburger includes only the upper part of the Ellenburger of Llano uplift and that most of it is equivalent to the upper part of the Arbuckle group, and to post-Jefferson City rocks of the Ozark uplift. It must be kept in mind, however, that this is merely a suggestion, and much detailed work will be necessary before it can be 'checked.

The name El Paso is commonly used for the Lower Ordovician dolomites and limestones found in wells in Otero County and in Hudspeth County, Texas, but farther east the corresponding section is more commonly called Ellenburger. The maximum thickness of 845 feet in Otero County is in Turner's Everett well from 3025 to 3870 feet.

The subsurface Ellenburger has its maximum development in southern Crane County, Texas, where it is over 1300 feet thick (Barton et al., 1946) . Some sand is found in the lower 90 feet and a sandy bed is found near the middle, but most of the section is dolomite, gray, buff, and light brown and ranging from finely to coarsely crystalline.

The Ellenburger is 445 feet thick from 9110 to 9555 feet in Olsen's Langlie well in sec. 11, T. 25 S., R. 37 E., southern Lea County (p1. 8) . It is thinner to the north and on the west flank

[12] E. W. Vanderpool, personal communication.

of the Eunice uplift it is locally absent with Simpson beds resting on pre-Cambrian. It is also absent in the Skaggs area in T. 20 S., R. 37 E. with Simpson resting on pre-Cambrian. In other wells north of the Eunice area the thickness is less than 100 feet. In Amerada's State No. 1-BTA, it is only about 40 feet thick (p1. 7).

The Ellenburger is well developed in southeastern Chaves County where, in Richfield's Trigg well, it is 350 feet thick from 9620 to 9970 feet in depth (pl. 6) . It is thinner to the northwest and in the vicinity of Roswell is cut out by pre-Virgil possibly pre-Pennsylvanian truncation. Probable northern limits of the Ellenburger and El Paso are shown on fig. 7.

CAMBRIAN SYSTEM

No rocks of definitely known Cambrian age are found in southeastern New Mexico.

McCloud and Barnes (1948) have shown that the Bliss (?) sandstone of Beach Mountain near Van Horn, Texas, is lower Ellenburger in age. The type Bliss sandstone of the Franklin Mountains and the Bliss sandstone of the Sacramento Mountains are also probably lower Ordovician in age. Thin beds of sandstone in the lower part and a prominent bed at the base of the El Paso limestone are found in most wells in Otero County and in southwestern Chaves County. These, like the Bliss sandstone of outcrop sections, are presumably Ordovician.

A sandstone found in some wells in Lea County has been called Wilberns by some geologists thereby correlating it with the upper Cambrian of the Llano uplift in central Texas. It is more likely to be a basal sandstone of the Ellenburger.

GEOLOGICAL HISTORY

CAMBRIAN

Southeastern New Mexico was probably a land area throughout Cambrian time. Cambrian limestones, dolomites, and sandstones are well developed in the Llano uplift and in the Marathon uplift in Texas, but we do not know how far these rocks extended to the northwest. Critical fossils are lacking in the surface and subsurface sections which might be Cambrian in west Texas and New Mexico.

ORDOVICIAN

Lower Ordovician limestones and dolomites were deposited in an epicontinental sea over a large part if not all of west Texas and southeastern New Mexico. The lower Tanyard formation of the Ellenburger group of the Llano uplift is represented by a sandstone in Beach Mountain, near Van Horn, Texas, and probably in southern Otero County, New Mexico. The Ellenburger of Lea County may be the upper part of the type Ellenburger plus younger beds. A basal sandstone found in many wells was probably deposited in a transgressive sea and represents the initial stage of Ordovician deposition.

Present limits of the Ellenburger-El Paso carbonates (fig. 7) show no evidence of near shore conditions, so the limits of the depositional basin to the north and northwest are unknown. Thinning of the Ellenburger around the Eunice uplift probably represents both post-Ellenburger erosion and non-deposition of the lower part.

Middle Ordovician limestones and elastics overlie the Lower Ordovician carbonates unconformably indicating a stage of withdrawal of the sea and erosion. The unconformity, however, is angular in local areas only. Around the Eunice uplift the Simpson beds transgress the entire Ellenburger section in a few places.

The Middle Ordovician Simpson group is widespread over western Texas and southeastern New Mexico and consists of alternating elastics and carbonates. The source of the elastics is unknown. Basal sands of the Oil Creek, McLish, and Tulip Creek formations suggest the initiation of new cycles of sedimentation in each case. Present northern and western limits of the Simpson in Eddy, southeastern Chaves, and northern Lea counties (fig. 7) may be near the original limits of deposition.

The unconformity, if any, between the Simpson and overlying Montoya is not angular, but everywhere to the north and west the Montoya overlaps the Simpson and rests unconformably on the Ellenburger; nowhere so far as is known in New Mexico or west Texas does it rest on older rocks. The Montoya basin of deposition was probably considerably more extensive than the present areal extent of the formation.

SILURIAN

Lower Silurian rocks are missing in New Mexico, so there must have been a long stage of sea withdrawal and erosion. Another carbonate-depositing sea advanced over the area in Middle Silurian time with the deposition of the Fusselman limestones and dolomites over a large area (fig. 6) . Present limits of the Fusselman in Lea County will remain indeterminate until we have a definite age determination of the dolomites in northern Lea County and southern Roosevelt County. In surface sections in south central New Mexico the formation does not extend as far north as does the underlying Montoya or the overlying Devonian. Limestones and dolomites overlying the typical Fusselman in Lea County and grading southward into shale in Texas belong with the Fusselman in the Middle Silurian. There is no evidence of an unconformity between them and the Fusselman.

So far as known Upper Silurian rocks are missing in New Mexico so we must assume a stage of sea withdrawal between the Silurian and overlying Devonian dolomites.

DEVONIAN

If our correlations are correct a carbonate-depositing sea invaded southeastern New Mexico from the south or southeast during Lower Devonian time and covered southern Lea County at least. Whether it extended as far north as the Crossroads area of northern Lea County is, as yet, undetermined. A chert and cherty limestone zone in the lower Canutillo formation of the Franklin and Hueco mountains and also present in a number of wells in Otero County might be correlative with the thicker dolomite section in Lea County, but the evidence for such a correlation is meagre. The probable extent of the carbonate-depositing sea is shown in fig. 6.

Middle Devonian rocks are not known in the subsurface and another big break in the sedimentary record is evident. A thin section of shale and limestone of upper Middle Devonian age has been found at the surface in southern New Mexico and western Texas (Canutillo and Oñate formations) , but this Middle Devonian sea apparently extended only a short distance east of the Hueco and Sacramento mountains.

The widespread Woodford formation is herein classified as Upper Devonian and correlated with the Ready Pay member of the Percha shale, and possibly with the upper black shale member of the Canutillo. These formations represent a widespread stage of black shale deposition probably in fairly deep quiet waters, which probably covered only the southern part of southeastern New Mexico (fig. 6) . The Contadero formation and the highly fossiliferous Sly Gap formation underlying the Percha in the San Andres and Sacramento mountains might be sediments deposited in a locally shallower sea or might be deposits of an entirely different and earlier marine invasion.

MISSISSIPPIAN

The lower Mississippian Kinderhook series is represented by the thin (up to 60 feet) Caballero formation, which is exposed in the Sacramento and San Andres mountains. Laudon and Bowsher (1949, fig. 5) show the distribution of the formation with an indefinite eastern boundary. The formation, however, is not recognized in the subsurface to the east of the Sacramento Mountains, and its limited areal extent is shown in fig. 5. Kinder-hook beds, consisting predominantly of shale, may be present in southern Roosevelt County and easternmost Chaves County. These beds may or may not be correlative with the Caballero. Their, areal extent is unknown as they have been recognized in only two wells, Magnolia's A. K. Smith No. 1 and Barnsdall's State No. 1-A.

The bioherms of the Lake Valley formation form a conspicuous feature of the Osage series in the Sacramento Mountains, but apparently this formation like the Caballero does not extend far east of its present outcrops (fig. 5) . Present information indicates that a large part of southeastern New Mexico was a land area during Kinderhook and Osage times.

In Meramec time a limestone depositing sea covered a large area in southeastern New Mexico and west Texas. This "Mississippian limestone" is correlated with the Rancheria formation (Laudon and Bowsher, 1949) , and the overlying dark gray to black shale is correlated with the Helms formation (restricted) of Chester age. The probable northern limits of the two formations are shown on fig. 5.

PENNSYLVANIAN

Although there were long breaks in the sedimentary record in the earlier Paleozoic and numerous advances and retreats of the sea, there is no evidence of mountain making movements in southeastern New Mexico until some time in the Pennsylvanian. The lower Pennsylvanian Springer series is not represented. . The upper Morrow sea advanced over the Hueco mountain area and possibly as far north as the Sacramento Mountains and southern Eddy County. Coarse elastic rocks in the lower Atoka of central New Mexico indicate a nearby mountainous area, the Pedernal Mountains. There may have been similar but less pronounced uplifts along the Matador uplift and in the Central Basin Platform area but they are less apparent.

Atoka (Derry) seas spread over a large part of central and southern New Mexico as shown by Thompson (1948, fig. 6, p. 70) and also covered most of Eddy and Lea counties. At least a part of the area north of the Matador uplift was invaded by the Atoka sea. The Des Moines sea was much more extensive and covered most, if not all southeastern New Mexico with the exception of the uplift of the Pedernal Mountains. A coarse conglomerate and thick sand body in the upper part of the series in the Sacramento Mountains is evidence of renewed uplift of the Pedernal Mountains.

The Missouri seas may have been somewhat more restricted than those of the Des Moines epoch, but the marked thinning of the series in the vicinity of the Matador uplift and farther north may be in part the result of pre-Virgil erosion rather than non-deposition. Further evidence of pre-Virgil uplift and erosion is found on the Matador uplift and in the vicinity of Roswell where rocks of that series rest directly on the pre-Cambrian.

The Virgil epoch marked another widespread advance of the sea which during that time probably advanced farther up on the flanks of the Pedernal Mountains than at any earlier stage. The Virgil sea persisted in some areas, particularly in the Sacramento Mountains, until the close of the epoch as shown by fusulinids, which are recognized as among the youngest Pennsylvanian types known in North America.

All the Pennsylvanian seas deposited limestones except where the limestone deposition was interrupted by encroachment of elastic sediments. There were probably large areas of shallow epicontinental seas with numerous transgressive and regressive stages.

Available evidence regarding the present distribution of the Pennsylvanian series is shown by letter symbols on fig. 4. Pennsylvanian rocks are missing in several areas as shown on the map, but all of these areas except the Pedernal Mountains were probably areas of marine deposition during parts of the Pennsylvanian.

PERMIAN

Mountain-making movement with faulting and locally intense folding marked the early stages of the Permian in southeastern New Mexico and adjoining parts of Texas. As a result the lowermost Permian beds commonly rest with angular unconformity on truncated edges of older rocks ranging in age from pre-Cambrian to late Pennsylvanian. Extensive solution and erosion removed large quantities of rocks from the crests of the Eunice uplift and other highs on the Central Basin Platform, but this material was largely older Paleozoic carbonate rocks, and only a limited amount of sandstone and shale is found in the basal Permian rocks surrounding and overlying these and similar pre-Permian folds. In the Pedernal Mountains, however, the erosion was mostly of pre-Cambrian rocks and the resultant sediments were predominantly arkose, conglomerate, sandstone, and red hale.

The earliest Permian seas of lower Wolfcamp age covered parts of central New Mexico where they are represented by thin beds of limestone interbedded with coarse conglomerates and sandstones, the Bursum formation. This early Wolfcamp sea also covered parts of Eddy and Lea counties and extended as far north as southern Roosevelt County. In this area its deposits were predominantly limestone. The Upper Wolfcamp Hueco sea was much more widespread east of the mountains and extended as far north as De Baca County. West of the mountains the Hueco limestones appear to grade into a elastic section which is correlated with the Abo. No Wolfcamp beds are present over the Eunice uplift, which was probably a land area during all of Wolfcamp time.

The Abo formation in its type area at Abo Pass and also in the Oscura Mountains and the northern part of the Sacramento Mountains consists of continental red beds and conglomerates, the only beds of continental origin in the Paleozoic sequence of southeastern New Mexico. At least a part of these continental Abo rocks appear to grade laterally southward into the marine upper Wolfcamp Hueco formation.

The dolomites and interbedded shales of an early Leonard sea in Lea County grade laterally northwestward into red beds similar to the typical Abo and make up the Abo formation of the area east of the mountains. This is the earliest Permian sea which covered the entire Eunice uplift and the Central Basin Platform. It extended over only a part of the Pedernal Mountain area.

Upper Leonard, Yeso seas extended over all of southeastern New Mexico with the possible exception of some of the higher peaks of the Pedernal Mountains. There are marked facies changes in the formation from southeast to northwest. The gradation is from a pontic facies to the south in the Delaware Basin area through a reef facies into bedded dolomites of a back-reef or lagoonal facies. These in turn grade into interbedded evaporites, sands, and shales and eventually into continental deposits north of the area discussed in this report. The encroachment of sandstone (Joyita member) caused a partial regression of the Yeso seas and probably marked the closing stage of the Leonard series.

Another marine transgression marked by the Glorieta sandstone probably initiated the Guadalupe epoch during which the barrier reefs of the Permian seas attained their most spectacular development. The history of the Guadalupe and Ochoa series of the Permian are not a part of the present report.

OIL AND GAS POOLS

GENERAL

Pre-San Andres production of oil and gas is confined to Lea County, and all discoveries prior to 1948 were on the Central Basin Platform in southeastern Lea County. The stratigraphic setting of the different pays is shown on pl. 10. This section illustrates in a general way the lithology of pre-San Andres formations in Lea County by means of actual sections from selected wells.

The first discovery of oil or gas in pre-San Andres rocks is credited to the year 1944 although gas was actually found in the Justis pool late in 1943. A total of 22 pre-San Andres pools were discovered prior to January 1, 1949, equally divided between the Permian and pre-Permian. Six new pools were discovered in 1949 prior to August first.

Statistical and engineering data on the oil pools of New Mexico are compiled by the Lea County Operators Committee and the New Mexico Bureau of Mines and Mineral Resources. These data are published annually by the Bureau and the New Mexico Oil Conservation Commission as circulars and bulletins of the Bureau. Tables 6 and 7 show a few pertinent data regarding the pre-San Andres pools. These data are taken from Circulars 19-A and 20 to which reference is made for more complete details.

TABLE 6. PERMIAN POOLS, YESO AND ABO FORMATIONS, LEA COUNTY, NEW MEXICO

Producing formation	Pool	Discovery Date	Average Depth	Pipe line runs, barrels				Producing wells 1-1-49
				To 1-1-47	1947	1948	To 1-1-49	
Upper Yeso	Harrison	11-24-45	5015-5070	5202	2827	1963	9992	1
	Justis	4-18-44	4705-5070					gas
	Monument-Paddock	1- 6-48	5189			63045	63045	3
	Paddock	3-29-45	5010-5300	719883	1295676	1587234	3602793	96
Middle Yeso	Blinebry	12-10-45	5455-5725	16608	24383	33719	74710	8
	Monument-Blinebry	4-26-48	5660-5720			24001	24001	2
Lower Yeso	North Drinkard	3- 1 48	6625-6715					gas
	South Drinkard	5-14-48	6420-6490			3473	3473	2
	Weir	5-20-46	6760-6837	17128	13162	9745	40035	1
Lower Yeso and Abo	Drinkard	10-26-44	6150-7160	799444	3340159	6254338	10393941	310
Abo	Monument-Abo	9- 6-48	7180			1911	1911	1
			Totals	1558265	4676207	7979429	14213901	424

TABLE 7. PRE-PERMIAN POOLS, LEA COUNTY, NEW MEXICO

Producing formation	Pool	Discovery Date	Average Depth	Pipe line runs, barrels				Producing wells 1-1-49
				To 1-1-47	1947	1948	To 1-1-49	
Des Moines	Cass	12-20-44	7665- 7730	124096	96107	132529	352732	4
Fusselman (?)	Crossroads	5- 6-48	12106-12258			45916	45916	1
	McCormack	11-24-47	7200		2580	46008	48588	2
Montoya	Cary	6-16-48	7190			16901	16901	1
McKee	Hare	7-20-47	7920- 8160		29883	160580	190463	4
	South Hare	9- 7-47	7400		11075	55214	66289	3
	Monument-McKee	11- 3-48	9890- 9907					1
	Teague	3-23-48	9300- 9450			76356	76356	3
	Warren-McKee	12-15-48	8965- 9055			3076	3076	1
Ellenburger	Brunson	9-14-45	7480- 8190	355978	1366610	2658973	4381561	66
	Dublin	10- 9-44	11850-11950	38847	613	abandoned	39460	0
			Totals	518921	1506868	3195553	5221342	86

PERMIAN POOLS OF THE LEONARD AND WOLFCAMP SERIES

Four pay zones have been found in rocks of Leonard age, of which three are in the Yeso formation and one in the Abo. The uppermost pay is at the top of the Yeso formation and is commonly designated the Paddock pay. The principal pool is the Paddock in Ts. 21 and 22 S., R. 37 E. Other pools producing from this zone are the Monument-Paddock, Harrison, and Justis (gas). The second pay lies approximately 350 feet below the Paddock pay in the upper part of the middle Yeso. It is known as the Blinebry pay and is productive in the Blinebry and Monument-Blinebry pools.

The lower pay of the Yeso formation is so far the most prolific of any in the Leonard series and is known as the Drinkard pay or more properly the Drinkard-Vivian pay. It is the main pay of the Drinkard pool and is also productive in the North Drinkard, South Drinkard, Weir, and House pools. The upper part of the Abo formation is productive in the Drinkard pool (Drinkard-Andrews pay) and also in the Monument-Abo and Elliott pools.

All the pays in the Leonard series listed above are zones of porous dolomite and accumulation is controlled in part by structure and in part by variations in porosity within the zones. All of the fields are within the map areas of pls. 21 and 23 in Bulletin 18 of the New Mexico Bureau of Mines and Mineral Resources. These maps show structure contours on the top of the Yates formation. The structure of underlying formations down to the base of the Permian is very similar to that of the Yates.

Oil is found in the lower part of the Wolfcamp series in the Bough pool in northern Lea County. The discovery well is Magnolia Petroleum Company's Betenbaugh No. 1 in sec. 12, T. 9 S., R. 35 E. which was completed May 10, 1949, with an initial production of 510 barrels of oil per day. The pay is a porohs limestone from 9617 to 9635 feet. Fusulinids from a core from this well from 9630 to 9641 show the lower Wolfcamp age of the pay.

A similar zone in what appears to be the same stratigraphic position showed oil in commercial quantities in a drill stem test in Amerada Oil Company's State No. 1-BTA test in sec. 2, T. 12 S., R. 33 E. which is 22 miles southwest of the Betenbaugh well. The drill stem test was from 8992 to 9172 feet.

PENNSYLVANIAN POOL

The only pool producing from rocks of Pennsylvanian age in southeastern New Mexico is the Cass pool in sec. 23, T. 20 S., R. 37 E. The pay is a porous dolomite in the lower Des Moines (Strawn) series. In this area the lower Des Moines is approximately 450 feet thick and is the only part of the Pennsylvanian present. A more complete section of the Pennsylvanian is found in northern Lea County in the Crossroads area where all four of the middle and upper Pennsylvanian series are present (pl.. 10).

The Landon-Strawn pool in southwestern Cochran County, Texas, produces oil from a dolomite of Des Moines, probably lower Des Moines age. Its location is nine miles east of the northeast corner of T. 11 S., R. 38 E.

MISSISSIPPIAN POOL

Oil was found in the "Mississippi Lime", Rancheria formation, in the Crossroads pool in Mid-Continent Petroleum Company's U. D. Sawyer No. 1-B in sec. 34, T. 9 S., R. 36 E. The well was completed on March 22, 1949, at a total depth of 12,750 feet in the "Mississippian Limestone". Top of "Mississippian" and top of pay were found at 11,805 giving an abnormal thickness for the formation of over 945 feet. This and steep dips found in a core suggest close proximity to a fault.

DEVONIAN POOL

Oil is found in a lower Devonian dolomite in the Knowles pool southeast of Lovington. The discovery well is Amerada's Hamilton No. 1 in sec. 35, T. 16 S., R. 38 E. which was completed May 4, 1949, at a total depth of 12,646 feet. The top of the Devonian dolomite was reached at 12,446 feet. This discovery is about seven miles southwest of the Jones Ranch pool of northwestern Gaines County, Texas, where production is found also in Devonian dolomite. Another Devonian pool within a mile of the New Mexico state line is the Dollarhide-Devonian pool in southwestern Andrews County, Texas. The pay in the Crossroads pool of northern Lea County may be Devonian in age, but the writer believes that it is more probably Silurian.

SILURIAN POOLS

The McCormack pool produces from the Fusselman formation on the west flank of the Eunice uplift. The oil is in a porous dolomite which makes a narrow hogback ridge dipping to the west and unconformably overlain by the Abo formation thus forming a stratigraphic trap. The structural relationship to other pools in the area is shown on the outline cross section p1. 9.

The pay in the Crossroads pool of northern Lea County is tentatively correlated as Silurian in age probably belonging in the Fusselman formation. The pool was discovered by Mid-Continent Oil Company's U. D. Sawyer No. 1-A in sec. 27, T. 9 S., R. 36 E., completed in May 1948 at a total depth of 12,258 feet. The top of the Fusselman (?) was reached at 12,106 feet.

The discovery well in the Bagley area in northern Lea County is Amerada's State No. 1-BTA in sec. 2, T. 12 S., R. 33 E. The well was completed July 16, 1949, with an initial production of 1744 barrels per day. The oil is in a porous dolomite which is tentatively placed in the Fusselman (pl. 7) . The top of the dolomite was reached at 10,785 feet.

The Dollarhide-Fusselman pool in southwestern Andrews County, Texas, is less than a mile from New Mexico state line.

ORDOVICIAN POOLS

The Cary pool in sec. 22, T. 22 S., R. 37 E. produces from a porous dolomite in the Montoya formation of upper Ordovician . age. It is significant as the only pool producing from that formation in the west Texas-southeast New Mexico area. It lies on the southwest flank of the Eunice uplift where the Montoya formation makes a hogback overlain unconformably by the Abo formation.

The McKee sandstone member of the Tulip Creek formation of the Simpson group, Middle Ordovician, is the pay zone of the Hare and South Hare pools on the west flank of the Eunice uplift. It is also the pay in the Teague pool, nine miles south of Eunice ; the Warren-McKee pool, eight miles north of Eunice ; and the Monument-McKee pool.

The Ellenburger formation furnishes one pool, the prolific Brunson pool on the west flank of the Eunice uplift. The Dublin pool near the southeast corner of Lea County was abandoned in 1945.

The Fowler pool, ten miles south of the Brunson pool, was discovered in Stanolind's South Mattix Unit No. 1 well in sec. 15, T. 24 S., R. 37 E. The well was completed May 20, 1949, at a total depth of 9705 feet with an initial production of 383 barrels per day. The top of Ellenburger and top of pay was reported at 9505 feet.

The Nelson pool in western Andrews County, Texas, is on the eastern flank of the Eunice uplift and the Dollarhide-Ellenburger pool in southwestern Andrews County is within a mile of the state line.

The Ordovician pools on the flanks of the Eunice uplift furnish excellent examples of stratigraphic traps with the pay zones unconformably overlain by younger beds. A detailed study of the oil pools of the Eunice uplift would make a very desirable contribution to the geology of New Mexico.

FUTURE POSSIBILITIES FOR PRE-SAN ANDRES PRODUCTION

In Bulletin 23 the prospects for additional production in southeastern New Mexico were pointed out as they appear to the author, R. E. King. At that time four zones in the Leonard series and two in pre-Permian formations were producing oil or gas. Since that time five new producing zones have been found in the pre-Permian and one in the Permian, while several new pools have been added to those producing from the Permian.

The producing zones in the Yeso and Abo formations of the Leonard series are in a backreef or platform dolomite facies and all the pools so far discovered are on the Central Basin Platform. This facies zone forms• a broad arch around the north flank of the Delaware Basin grading northward into an anhy dritic facies and southward through a reef zone into a pontic black shale facies in the Delaware basin. Additional oil pools are probable both in the reef zone and in the back-reef dolomite zone.

The finding of oil in lower Wolfcamp, Bursum limestone in two wells over twenty miles apart in northern Lea County gives promise of important future discoveries from that formation. The formation is widespread over southeastern New Mexico and appears to be uniform in composition over wide areas.

A thick Pennsylvanian section predominantly limestone underlies a large part of southeastern New Mexico (fig. 4), and these rocks are potentially oil bearing over a large area. At present the most promising area appears to be the deep basin extending from southern Eddy County northeastward to northern Lea County. Possibly the flanks of this basin toward the uplifts of the Central Basin Platform on the east and the Matador uplift and Pedernal Mountains on the north and northwest will furnish stratigraphic and structural traps.

Pennsylvanian rocks penetrated by wells in De Baca and Guadalupe counties and northernmost Roosevelt County contain a predominance of coarse elastics and black and red shales commonly assumed to be unfavorable for petroleum accumulation, but this assumption may be in error. Between these wells and wells drilled in southern Chaves and Roosevelt counties is a wide belt of country which is entirely unexplored. It is a zone 45 to 60 miles wide and extends across northern Chaves County and central and northern Roosevelt County into southern Curry County. This may be the site of a deep basin of Pennsylvanian and older rocks.

The discovery of oil in the "Mississippian Limestone", Rancheria formation, in the Crossroads area of northern Lea County, reveals possibilities for future pools from that formation over a large part of southeastern New Mexico.

The lower Devonian limestone is probably more limited in areal extent in New Mexico than other producing units (fig. 6) . Only one pool in New Mexico can definitely be assigned to this unit, but pools in Andrews County, Texas, within a few miles of the state line indicate the probability of additional important pools in New Mexico, particularly in southern Lea County on and around the flanks of the pre-Permian uplifts.

Although the interpretation suggested in this re port includes all the dolomite in the lower part of the section in northern Lea County in the Silurian and Ordovician, it may be that the upper part, including the pay section in the Crossroads and Bagley pools, is Devonian in which case the area of probable new pools from the Devonian is greatly extended to the north an d northwest. The Fusselman is probably as widespread as any of the lower Paleozoic dolomite formations and is very promising for probable future pools as far north as northern Lea County and possibly still farther north. If, as herein suggested, the Crossroads and Bagley pools produce from the Fusselman, New Mexico's pools in that formation are as much as 70 miles apart. Important pools farther east in Andrews County, Texas, are further proof of the importance of the formation as a source of oil.

The Montoya is a widespread dolomite formation which has been penetrated in many wells but produces oil in only one pool. Its importance as a probable reservoir must not be overlooked.

The Simpson group including the McKee sandstone is restricted to the southeastern counties of New Mexico (fig. 7) and thins to the north and west. However, if this thinning is an approach to an old shore line, the sandstone beds may become thicker and coarser grained toward the shore line and afford excellent oil and gas reservoirs anywhere within the area underlain by the Simpson group.

The Ellenburger is probably the most widespread and prolific of the pre-Pennsylvanian formations in west Texas and New Mexico. Present information indicates that it is comparatively thin in central and northern Lea County, but the thin sections that have been encountered in wells might be due in part to pre-Simpson erosion over uplifts developed about the close of Lower Ordovician time. Ellenburger dolomites underlie a large part of southern New Mexico (fig. 7) and are potentially oil bearing anywhere within this area.

All data presented in this report point to one conclusion. Under the greater part of southeastern New Mexico there is a thick section of potential oil and gas bearing rocks so that wherever the structural conditions are right, either anticlines or strati-graphic traps, we may confidently expect to find petroleum reservoirs in one or more formations. Naturally there is a wide range in attractive possibilities from one part of the area to another. Certain mountainous areas can be completely excluded particularly where pre-Cambrian rocks or large masses of igneous intrusions appear at the surface. Much of the Pedernal Mountains area and certain very limited areas which have been explored to the pre-Cambrian with negative results may also be excluded.

Stratigraphically the most attractive general area includes all of Lea and Eddy counties and also southeastern Chaves County. A possible structural basin north of the Matador uplift may prove equally attractive.

Other areas that must not be overlooked are the Guadalupe Mountains, the Sierra Diablo Plateau, the southern Sacramento Mountains, the Tularosa Basin, Chupadera Mesa, and the Estancia Valley. All or parts of these areas are underlain by thick sections of marine pre-Permian rocks and must therefore be considered as potentially petroliferous.

SELECTED BIBLIOGRAPHY

ADAMS, JOHN E., and others, 1939, Standard Permian section of North America: Bull. Amer. Assoc. Petrol. Geol., vol. 23, no. 11, pp. 1673-1681.

ADAMS, JOHN E., 1949, Permian rocks of the trans-Pecos region: West Texas Geol. Soc. Guidebook, Field trip No. 4.

BARNES, V. E., CLOUD, P. E., JR., and WARREN, L. E., 1947, Devonian rocks of central Texas: Bull. Geol. Soc. Amer., vol. 58, no. 2, pp. 125-140.

BARTON, JACKSON M., and others, 1946, Columnar section of pre-Permian rocks of Central Basin Platform, west Texas and southeastern New Mexico : Compiled by Pre-Permian Study Group, West Texas Geol. Soc.

BATES, ROBERT L., and others, 1942, The oil and gas resources of New Mexico, 2nd ed.: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 18.

BATES, ROBERT L., and others, 1947, Geology of the Gran Quivira quadrangle, New Mexico: N. Mex. Bur. Mines and Min. Res. Bull. 26.

BEEDE, J. W., 1918, Notes on the geology and oil possibilities of the northern Diablo Plateau in Texas: Texas Univ. Bull. 1852.

CLIFTON, R. L., 1945, Permian Word formation; its faunal and stratigraphic correlatives, Texas: Bull. Amer. Assoc. Petrol. Geol., vol. 29, no. 12, pp. 1766-1776.

CLOUD, P. E., JR., and others, 1946, Stratigraphy of the Ellenburger group in central Texas—A progress report: Texas Univ. Pub. 4301, pp. 133-161.

CLOUD, P. E., JR., and BARNES, V. E., 1948, The Ellenburger group of central Texas: Texas Univ. Pub. 4621.

COOPER, G. ARTHUR, and others, 1942,, Correlation of the Devonian sedimentary formations of North America : Bull. Geol. Soc. Amer., vol. .53, no. 12, pp. 1729-1794.

DARTON, N. H., 1917, A comparison of Paleozoic sections in southern New Mexico : U. S. Geol. Survey Prof. Paper 108-c.

DARTON, N. H., 1928, "Red Beds" and associated formations in New Mexico; with an outline of the geology of the state : U. S. Geol. Survey Bull. 794.

DECKER, CHARLES E., and others, 1931, The stratigraphy and physical characteristics of the Simpson group : Oklahoma Geol. Survey, Bull. 55.

DEFORD, RONALD K., 1942, Major structural features, southeast area: *The oil and gas resources of New Mexico,* 2nd ed., pp. 160-163, N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 18.

ELLISON, SAMUEL P. JR., 1946, Conodonts as Paleozoic guide fossils: Bull. Amer. Assoc. Petrol. Geol., vol. 30, no. 1, pp. 93-110.

FRITZ, MADELEINE A., 1944, Upper Devonian bryozoa from New Mexico : Jour. Paleontology, vol. 18, no. 1, pp. 31-41.

HENDERSON, CHARLES F., and BARR, CHARLES R., 1949, Developments in 1948 in west Texas and southeast New Mexico: Bull. Amer. Assoc. Petrol. Geol., vol. 33, no. 6, pp. 908-930.

JONES, T. S., 1944, Dolomite porosity in Devonian of west Texas Permian Basin: Bull. Amer. Assoc. Petrol. Geol., vol. 28, no. 7, pp. 1043-1044.

KELLEY, V. C., and Wow), G. H. 1946, Lucero uplift, Valencia, Socorro, and Bernalillo counties, New Mexico: U. S. Geol. Survey, Oil and Gas Investigations, Preliminary Map 47.

KING, PHILIP B., 1931, Geology of the Glass Mountains ; Pt. 1, Descriptive geology: Texas Univ. Bull. 3038.

KING, PHILIP B., 1934, Notes on upper Mississippian rocks in trans-Pecos Texas: Bull. Amer. Assoc. Petrol. Geol., vol. 18, no. 11, pp. 1537-1543.

KING, PHILIP B. 1942, Permian of west Texas and southeaste rn New Mexico; Pt. 2, B., Texas-New Mexico symposium: Bull. Amer. Assoc. Petrol. Geol., vol. 26, no. 4, pp. 535-763.

KING, PHILIP B., and KNIGHT, J. B., 1945, Geology of the Hueco Mountains, El Paso and Hudspeth counties, Texas; Description and correlation of upper Paleozoic rocks of Hueco Mountains : U. S. Geol. Survey, Oil and Gas Investigations, Preliminary Map 36, sheet 2.

KING, PHILIP B., 1948, Geology of the southern Guadalupe Mountains: U. S. Geol. Survey Prof. Paper 215.

KING, ROBERT E., 1945, Stratigraphy and oil-producing zones of the pre-San Andres formations of southeastern New Mexico-A preliminary report: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 23.

LAUDON, L. R. and BOWSHER, A. L., 1941, Mississippian formations of Sacramento R., New Mexico: Bull. Amer. Assoc. Petrol. Geol., vol. 25, no. 12, pp. 2107-2160.

LAUDON, L. R., and BOWSHER, A. L., 1949, Mississippian formations of southwestern New Mexico: Bull. Geol. Soc. Amer., vol. 60, no. 1, pp. 1-88.

LEWIS, FRANK E., 1941, Position of San Andres group, west Texas and New Mexico: Bull. Amer. Assoc. Petrol. Geol., vol. 25, no. 1, pp: 73-103.

LEWIS, FRANK E., and BARTON, JACKSON M., 1946, Glass Mountains-Marathon Basin : Guidebook, West Texas Geological Society Fall Field Trip.

LLOYD, E. Russell., 1938, Theory of reef barriers (abstract) : Bull. Amer. Assoc. Petrol. Geol., vol. 22, no. 12, p. 1709.

MILLER, A. K., 1945, Some exceptional Permian ammonoids from west Texas: Jour. Paleontology, vol. 19, no. 1, pp. 14-21.

MILLER, A. K., and YOUNGQUIST, WALTER, 1947, The Discovery and significance or a cephalopod fauna in the Mississippian Caballero formation of New Mexico: Jour. Paleontology, vol. 21, no. 2, pp. 113-117.

MILLER, A. K., and PARIZEK, ELDON J., 1948, A lower Permian ammonoid fauna from New Mexico: Jour. Paleontology, vol. 22, no. 3, pp. 350-358.

MOORE, RAYMOND C., and THOMPSON, M. L., 1949, Main divisions of Pennsylvanian period and system: Bull. Amer. Assoc. Petrol. Geol., vol. 33, no. 3, pp. 275-302.

NEEDHAM, C. E., and BATES, ROBERT L., 1943, Permian type sections in central New Mexico: Bull. Geol. Soc. Amer., vol. 54, no. 21, pp. 1653-1668.

NELSON, L. A., 1940, Paleozoic stratigraphy of the Franklin Mountains of west Texas: Bull. Amer. Assoc. Petrol. Geol., vol. 24, no. 1, pp. 157-172.

PENN, WILLIAM Y., 1932, Upper Pennsylvanian fossils of the Sacramento Mountains, New Mexico: Unpublished thesis, Leland Stanford Junior University.

PETERSON, V. C., and SKINNER, JOHN W., 1947, Guadalupe Mountains of New Mexico-Texas : West Texas Geol. Soc. Guidebook, Spring field trip.

READ, C. B., and others, 1944, Geologic map and stratigraphic sections of Permian and Pennsylvanian rocks of parts of San Miguel, Santa Fe, Sandoval, Bernalillo, Torrance, and Valencia counties, north central New Mexico: U. S. Geol. Survey, Oil and Gas Investigations, Preliminary Map 21.

READ, C. B., and WOOD, G. H., Distribution and correlation of Pennsylvanian rocks in late Paleozoic sedimentary basins of northern New Mexico: Jour. Geology, vol. 55, no. 3, pp. 220-235.

SKINNER, JOHN M., 1946, Correlation of Permian of west Texas and southeast New Mexico : Bull. Amer. Assoc. Petrol. Geol., vol. 30, no. 11, pp. 1857-1874.

STAINBROOK, MERRILL A., 1935, A Devonian fauna from the Sacramento

Mountains near Alamogordo, New Mexico: Jour. Paleontology, vol. 9, no. 8, pp. 709-714.

STAINBROOK, MERRILL A., 1947, Brachiopods of the Percha shale: Jour. Paleontology, vol. 21, no. 4, pp. 297-328.

STAINBROOK, MERRILL A., 1948, Age and correlation of the Devonian Sly Gap beds near Alamogordo, New Mexico: Am. Jour. Sci., vol. 246, no. 12, pp. 765-790.

STARK, J. T., and DAPPLES, E. C., 1946, Geology of the Los Piños Mountains, New Mexico: Bull. Geol. Soc. Amer., vol. 57, no. 12, Pt. 1, pp. 1121-1172.

STEVENSON, FRANK V., 1945, Devonian of New Mexico: Jour. Geology, vol. 53, no. 4, pp. 217-245.

STOYANOW, ALEXANDER, 1948. Some problems of Mississippian stratigraphy in southwestern United States: Jour. Geology, vol. 56, no. 4, pp. 313-326.

THOMPSON, M. L., 1942, Pennsylvanian system in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 17.

THOMPSON, M. L., 1948, Studies of American fusulinids: Kansas Univ. Paleontological Contr., Protozoa, Article 1, pp. 1-184.

WELLER, J. MARVIN, and others, 1948, Correlation of the Mississippian formations of North America : Bull. Geol. Soc. Amer., vol. 59, no. 2, pp. 91-196.

WILPOLT, R. H., and others, 1946, Geologic map and stratigraphic sections of Paleozoic rocks of Joyita Hills, Los Piños Mountains, and northern Chupadera Mesa, Valencia, Torrance, and Socorro counties, New Mexico: U. S. Geol. Survey,-Oil and Gas Investigations, Preliminary Map. 61.

WOOD, G. H., and NORTHROP, S. A., 1946, Geology of Nacimiento Mountains, San Pedro Mountain, and adjacent plateaus in parts of Sandoval and Rio Arriba counties, New Mexico: U. S. Geol. Survey, Oil and Gas Investigations, Preliminary Map. 57.

INDEX

Figures in *italic* indicate main references.

PUBLICATIONS

PUBLICATIONS OF THE MINERAL RESOURCES SURVEY

No.	*Title and Author*	*Date*	*Price*
1	The Mineral Resources of New Mexico; Fayette A. Jones	1915	Out of print
2	Manganese in New Mexico; E. H. Wells	1918	Out of print
3	Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico; E. H. Wells	1919	Out of print

PUBLICATIONS OF THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

BULLETINS

No.	*Title and Author*	*Date*	*Price*
4	Fluorspar in New Mexico; W. D. Johnston, Jr. (Superseded by Bulletin 21)	1928	Out of print
5	Geologic Literature of New Mexico; T. P. Wootton (Superseded by Bulletin 22)	1930	Out of print
6	Mining and Mineral Laws of New Mexico; Charles H. Fowler (Superseded by Bulletin 16)	1930	Out of print
7	The Metal Resources of New Mexico and their Economic Features; S. G. Lasky and T. P. Wootton	1933	Out of print
8	The Ore Deposits of Socorro County, New Mexico; S. G. Lasky	1932	.60
9	The Oil and Gas Resources of New Mexico; Dean E. Winchester (First edition; superseded by Bulletin 18)	1933	Out of print
10	The Geology and Ore Deposits of Sierra County, New Mexico; G. Townsend Harley	1934	.60
11	The Geology of the Organ Mountains, with an Account of Dona Ana County, New Mexico; Kingsley Charles Dunham	1935	Out of print
12	The Non-Metallic Mineral Resources of New Mexico and their Economic Features (Exclusive of Fuels) ; S. B. Talmage and T. P. Wootton	1936	.50
13	Geology and Economic Features of the Pegmatites of Taos and Rio Arriba Counties, New Mexico; Evan Just	1937	.50
14	Some New Mexico Fusulinidae; C. E. Needham	1937	.50
15	The Geology and Ore Deposits of Northeastern New Mexico (Exclusive of Colfax County) ; G. Townsend Harley	1940	.60
16	Mining, Oil, and Mineral Laws of New Mexico; C. H. Fowler and S. B. Talmage (Supersedes Bulletin 6)	1941	.75
17	Pennsylvanian System in New Mexico; M. L. Thompson	1942	.50
18	The Oil and Gas Resources of New Mexico; compiled by Robert L. Bates (Second edition; supersedes Bulletin 9)	1942	2.50

No.	*Title and Author*	*Date*	*Price*
19	Manganiferous Iron-ore Deposits near Silver City, New Mexico; Lawson P. Entwistle	1944	.50
20	Stratigraphy of the Colorado Group, Upper Cretaceous, in Northern New Mexico; Charles H. Rankin	1944	Out of print
21	Fluorspar Resources of New Mexico; H. E. Rothrock, C. H. Johnson, and A. D. Hahn (Supersedes Bulletin 4)	1946	2.50
22	Geologic Literature of New Mexico Through 1944; Robert L. Bates and Marian R. Burks (Supersedes Bulletin 5)	1945	Out of print
23	Stratigraphy and Oil-producing Zones of the Pre-San Andres Formations of Southeastern New Mexico—A Preliminary Report; Robert E. King	1945	.50
24	Building Blocks from Natural Lightweight Materials of New Mexico; Donn M. Clippinger	1946	.50
25	Mica Deposits of the Petaca District, Rio Arriba County, New Mexico, with Brief Descriptions of the Ojo Caliente District, Rio Arriba County, and the Elk Mountain District, San Miguel County; Richard H. Jahns	1946	2.00
26	Geology of the Gran Quivira Quadrangle, New Mexico; Robert L. Bates, Ralph H. Wilpolt, Archie J. MacAlpin, and Georges Vorbe	1947	.60
27	Contributions of New Mexico's Mineral Industry to World War II; compiled by T. D. Benjovsky	1947	.50
28	Pumice Aggregate in New Mexico—Its Uses and Potentialities; Donn M. Clippinger and Walter E. Gay	1947	Out of print
29	Pre-San Andres Stratigraphy and Oil-producing zones in Southeastern New Mexico—A Progress Report; E. Russell Lloyd	1949	2.00

GROUND-WATER REPORT

*1	Geology and Ground-Water Resources of the Eastern Part of Colfax County, New Mexico; Roy L. Griggs	1948	3.00

OIL AND GAS REPORTS

4-A	New Mexico Oil and Gas Statistical Data for 1948; compiled by E. E. Kinney, Lea County Operators Committee, and New Mexico Oil Conservation Commission	1949	2.25
4-B	New Mexico Oil and Gas Engineering Data for 1948; compiled by E. E. Kinney, Lea County Operators Committee, and New Mexico Oil Conservation Commission	1949	2.25
4-C	San Juan Basin, New Mexico, Oil and Gas Data Summary Cumulative to January 1, 1949; compiled by E. E. Kinney	1949	.50

• Prepared in cooperation with the U. S. Geological Survey and the State Engineer of New Mexico.

No.	*Title and Author*	*Date*	*Price*
	CIRCULARS		
1	An Outline of the Mineral Resources of New Mexico; E. H. Wells	1930	Out of print
2	Geology and Ore Deposits of the Ground Hog Mine, Central District, Grant County, New Mexico; S. G. Lasky	1930	Out of print
3	First, Second, and Third Annual Reports of the Director, and Preliminary Report for the Fourth Year; E. H. Wells	1931	Out of print
4	The Hobbs Field and Other Oil and Gas Areas, Lea County, New Mexico; Dean E. Winchester	1931	Out of print
5	Gold Mining and Gold Deposits in New Mexico; E. H. Wells and T. P. Wootton, 1932; revised by T. P. Wootton	1940	No charge
6	Carbon Dioxide in New Mexico; E. H. Wells and A. Andreas (Superseded by Circular 9)	1938	Out of print
7	Outlook for Further Ore Discoveries in the Little Hatchet Mountains, New Mexico; S. G. Lasky	1940	Out of print
8	Selected Bibliography on Coal in New Mexico; Robert L. Bates	1943	No charge
9	Carbon Dioxide in New Mexico; Sterling B. Talmage and A. Andreas (Reprinted from Bulletin 18)	1942	No charge
10	Natural Light-weight Building-block Materials of New Mexico; T. D. Benjovsky and D. M. Clippinger	1945	Out of print
11	Reconnaissance Survey of the Headstone Mining District, Rio Arriba County, New Mexico; T. D. Benjovsky	1945	No charge
12	Future Oil Possibilities of New Mexico; Robert L. Bates	1946	Out of print
13	Compilation of State Tax Law Relating to Mineral Properties in New Mexico; E. P. Ripley	1946	No charge
14	Oil and Gas Production Data, Eddy County, New Mexico, 1943-1945; compiled by N. Raymond Lamb and W. B. Macey	1947	Out of print
15	Tables of Fluorescent and Radioactive Minerals; compiled by Robert L. Hershey	1947	No charge
16	New Mexico Oil and Gas Production Data for 1946 (Exclusive of Lea County) ; compiled by N. Raymond Lamb and W. B. Macey	1947	Out of print
17	Caprock Pool Statistical Report, Chaves and Lea Counties, New Mexico; compiled by N. Raymond Lamb and William B. Macey	1947	Out of print
18	Geology and Ore Deposits of Red River and Twining Districts, Taos County, New Mexico —A Preliminary Report; Charles F. Park, Jr. and Philip F. McKinlay	1948	No charge
19-A	New Mexico Oil and Gas Statistical Data for 1947; compiled by N. Raymond Lamb and Lea County Operators Committee	1948	No charge
19-B	New Mexico Oil and Gas Engineering Data for		

No.	Title and Author	Date	Price
	1947; compiled by N. Raymond Lamb and Lea County Operators Committee	1948	No charge
20	New Mexico Oil and Gas Summary Data for 1948; compiled by Lea County Operators Committee	1949	No charge
21	Barite of New Mexico; compiled by Donn M. Clippinger	1949	No charge

ANNUAL REPORTS

No.	Title and Author	Date	Price
1	For the Fiscal Year July 1, 1945-June 30, 1946; E. C. Anderson	1946	Out of print
2	For the Fiscal Year July 1, 1946-June 30, 1947 (includes Annual Report of State Inspector of Mines) ; E. C. Anderson	1947	Out of print
3	For the Fiscal Year July 1, 1947-June 30, 1948 (includes Annual Report of State Inspector of Mines); E. C. Anderson	1948	Out of print
4	For the Fiscal Year July 1, 1948-June 30, 1949 (includes Annual Report of State Inspector of Mines); E. C. Anderson	1949	No charge

OIL AND GAS MAP

No.	Title and Author	Date	Price
	Oil and Gas Map of New Mexico; revised and enlarged to Jan. 1, 1949, by Richard C. Northup and Donald D. Forrey. Scale about 101/2 miles to 1 inch	1949	1.50 (paper) 2.00 (cloth)

WELL LOGS

Over 6,000 typed drillers' logs of wells drilled in New Mexico ---------- Prices on request

PUBLICATIONS OF THE U. S. GEOLOGICAL SURVEY, FOR SALE BY THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

BULLETINS

No.	Title and Author	Date	Price
752	Coal Resources of the Raton Coal Field, Colfax County, New Mexico; W. T. Lee	1924	.50
859	Geology of the Santa Rita Mining Area, New Mexico; A. C. Spencer and Sidney Paige	1935	.40
860-A	The Coal Field from Gallup Eastward toward Mount Taylor; Julian D. Sears	1934	.35
860-B	The Mount Taylor Coal Field; Charles B. Hunt	1936	1.00
860-C	The La Ventana-Chacra Mesa Coal Field; Carle H. Dane	1936	.40
*870	Geology and Ore Deposits of the Bayard Area, Central Mining District, New Mexico; Samuel G. Lasky	1936	.80
*885	Geology and Ore Deposits of the Lordsburg Mining District, Hidalgo County, New Mexico; Samuel G. Lasky	1938	1.25
922-C	Manganese Deposits in the Little Florida Mountains, Luna County, New Mexico—A Preliminary Report; S. G. Lasky	1940	.25

*Prepared in cooperation with the New Mexico Bureau of Mines and Mineral Resources.

No.	Title and Author	Date	Price
922-M	Tin Deposits of the Black Range, Catron and Sierra Counties. New Mexico; Carl Fries, Jr.	1940	.50
945-C	Beryllium and Tungsten Deposits of the Iron Mountain District, Sierra and Socorro Counties, New Mexico; R. H. Jahns	1944	1.25

PROFESSIONAL PAPERS

*200	Geology and Ore Deposits of the Magdalena Mining District, New Mexico; G. F. Loughlin and A. H. Koschmann	1942	2.00
*208	Geology and Ore Deposits of the Little Hatchet Mountains, Hidalgo and Grant Counties, New Mexico; Samuel G. Lasky	1947	2.50

WATER-SUPPLY PAPER

842	Flood in the Canadian and Pecos River Basins of New Mexico—With Summary of Flood Discharges in New Mexico; Tate Dalrymple and others	1937	.20

BOOKLET

	Prospecting for Uranium; published in cooperation with the United States Atomic Energy Commission	1949	.30

MAPS AND CHARTS

	Topographic map of New Mexico. Scale about 8 miles to 1 inch; contour interval 100 meters	1925	.75
	Geologic Map of New Mexico; N. H. Darton. Scale about 8 miles to 1 inch; contour interval 100 meters	1928	1.50
	Maps Showing Thickness and General Character of the Cretaceous Deposits in the Western Interior of the United States; J. B. Reeside, Jr. about 8 miles to 1 inch; contour interval 100 Scale 225 miles to 1 inch. Preliminary Map 10, Oil and Gas Investigations	1944	.25
	Stratigraphic Distribution of the Pennsylvanian Fusulinidae in a Part of the Sierra Nacimiento of Sandoval and Rio Arriba Counties, New Mexico; Lloyd G. Henbest and others. Preliminary Chart 2, Oil and Gas Investigations	1944	.25
	Correlation of Basal Permian and Older Rocks in Southwestern Colorado, Northwestern New Mexico, Northeastern Arizona, and Southeastern Utah; N. W. Bass. Preliminary Chart 7, Oil and Gas Investigations	1944	.40
	Map of Eddy and Lea Counties, Showing Oil and Gas Fields by Colors. Scale about 5% miles to 1 inch	1945	No charge
	Geology and Asphalt Deposits of North-central Guadalupe County, New Mexico; Joseph M. Gorman and Raymond C. Robeck. Scale 1 mile to 1 inch. Preliminary Map 44, Oil and Gas Investigations	1946	.60
	Lucero Uplift, Valencia, Socorro, and Bernalillo		

No.	*Title and Author*	*Date*	*Price*
	Counties, New Mexico; V. C. Kelley and G. H. Wood. Scale 3 miles to 1 inch. Preliminary Map 47, Oil and Gas Investigations ----------------	1946	.60
	Stratigraphic Relations of Eocene, Paleocene, and Latest Cretaceous Formations of Eastern Side of San Juan Basin, New Mexico; C. H. Dane. Preliminary Chart 24, Oil and Gas Investigations --	1946	.35
	Geologic Maps of a Part of the Las Vegas Basin and of the Foothills of the Sangre de Cristo Mountains, San Miguel and Mora Counties, New Mexico; S. A. Northrop, H. H. Sullwold, Jr., A. J. MacAlpin, and C. P. Rogers, Jr. Scales, 2/3 mile to 1 inch and 4 miles to 1 inch. Preliminary Map 54, Oil and Gas Investigations --	1946	.60
	Geology of Nacimiento Mountains, San Pedro Mountain, and Adjacent Plateaus in Parts of Sandoval and Rio Arriba Counties, New Mexico; S. A. Northrop and G. H. Wood. Scale 1% miles to 1 inch. Preliminary Map 57, Oil and Gas Investigations ----------------------------------	1946	.60
	*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; R. H. Wilpolt, A. J. MacAlpin, R. L. Bates, and Georges Vorbe. Scale 1 mile to 1 inch. Preliminary Map **61,** Oil and Gas Investigations --	1946	.65
	*Geology of Northwestern Quay County, New Mexico; Ernest Dobrovolny, C. H. Summerson, and Robert L. Bates. Preliminary Map 62, Oil and Gas Investigations ----------------------------------	1946	.75
	Geology and Mineral Deposits of the Gallinas District, Lincoln County, New Mexico; V. C. Kelley, H. E. Rothrock, and R. G. Smalley. Scale 2 miles to 1 inch. Preliminary Map 3-211, Strategic Minerals Investigations ------------------	1946	.30
	Geologic map of part of eastern San Juan Basin, Rio Arriba County, New Mexico; C. **H.** Dane. Preliminary Map 78, Oil and Gas Investigations	1947	1.00
	Geology of Southern Part of Archuleta County, Colorado; G. H. Wood, V. C. Kelley, and A. J. MacAlpin. Scale 1 mile to 1 inch. Preliminary Map 81, Oil and Gas Investigations ---------------	1948	1.00
	Stratigraphy and Geologic Structure in the Piedra River Canyon, Archuleta County, Colorado; C. B. Read, G. H. Wood, A. A. Wanek, and Pedro Verastequi Mackee. Scale 1 mile to 2 inches. Preliminary Map **96,** Oil and Gas Investigations	1949	.80
	Topographic maps of approximately 100 quadrangles in New Mexico and adjacent parts of Arizona, Colorado, and Texas. Scales range from 1,000 feet to **1** inch, to 4 miles to 1 inch		.20 each

*Prepared in cooperation with the New Mexico Bureau of Mines and Mineral Resources.

No.	*Title and Author*	*Date*	*Price*

PUBLICATION OF THE U. S. GENERAL LAND OFFICE, FOR SALE BY THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

	State of New Mexico. Geographic map, scale 12 miles to 1 inch	1936	.35

PUBLICATION OF THE UNIVERSITY OF NEW MEXICO, FOR SALE BY THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

MAP

	Mining Districts of New Mexico; Stuart A. Northrop. Scale 20 miles to 1 inch	1942	.75