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A. X. ILLINSKI, PRESIDENT

OIL AND GAS POSSIBILITIES OF THE PUERTECITO DISTRICT, SOCORRO AND VALENCIA COUNTIES, NEW MEXICO

BY
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CONTENTS.

ILLUSTRATIONS.

BOARD OF REGENTS.

OFFICERS OF THE BOARD.

PUBLICATIONS OF THE MINERAL RESOURCES SURVEY OF NEW MEXICO.

Bulletin No. 1. The Mineral Resources of New Mexico, Fayette A. Jones, 1915.

Bulletin No. 2. Manganese in New Mexico, E. H. Wells, 1918.

Bulletin No. 3. Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico, E. H. Wells, 1919.

LETTER OF TRANSMITTAL.

SOCORRO, N. M., JAN. 15, 1920.

HON. O. A. LARRAZOLO,
Governor of New Mexico, Santa Fe,
New Mexico.

DEAR SIR :

On behalf, and by authority of the Board of Regents of the New Mexico State School of Mines, I have the honor to submit for publication as Bulletin No. 3, of the Mineral Resources Survey of the New Mexico State School of Mines, a report on Oil and Gas Possibilities in the Puertecito District, Socorro and Valencia Counties by E. Wells.

Yours respectfully,
A. X. ILLINSKI, President,
State School of Mines.

OIL AND GAS POSSIBILITIES OF THE PUERTECITO DISTRICT, SOCORRO AND VALENCIA COUNTIES, NEW MEXICO.

BY E. H. WELLS.

INTRODUCTION.

This report represents an endeavor to supply locators, operators, and others who may be interested, with information regarding the geology and oil possibilities of an area near Puertecito, New Mexico, in which a number of well-defined anticlines occur. Many placer oil locations were made in this district during the spring and summer of 1919.

The original intention of the Board of Regents of the New Mexico State School of Mines, under whose direction the present investigations were conducted, was to have the report cover all of the known possible oil structures of Socorro County, and the writer spent several weeks during the first part of the field season in making preliminary examinations of several structures in the eastern part of the county. This work was discontinued on receiving notice that Mr. N. H. Darton of the United States Geological Survey had made a detailed examination of the structures of eastern Socorro County and that his report on them would probably be available in a few months ; it being thought inadvisable for the New Mexico State School of Mines to prepare a report covering the same territory, which would be issued at a later date. The field work during the remainder of the season was confined to the Puertecito district. In addition to the work done in the mapped area, a reconnoissance examination of some of the surrounding country was made. An exceptionally severe rainy season which made the roads almost impassable much of the time, seriously interfered with some of the contemplated investigations.

Geological mapping was done largely with transit and stadia; distances were obtained from stadia readings, and elevations were computed with the aid of vertical angles. Some of the surveys were tied only to outlying section corners, which may not be exactly in their proper locations in all cases. The elevation datum is based on aneroid barometer readings carried to the district from an established bench mark at Socorro, New Mexico, and it may be in error as much *as* 100 feet.

The writer takes this opportunity to express his thanks to Mr. W. H. Herrick, Civil Engineer and County Surveyor for Socorro County, for information utilized in writing the report and in the preparation of the map ; and to Messrs. N. A. Field, H. C. Medley, and R. R. Jackson for courtesies extended during the progress of the field work. The United States Geological Survey identified a number of fossils submitted to them and furnished other valuable data. Suggestions and information supplied by Mr. N. H. Darton of the Survey have been of great value.

G E O G R A P H Y .

LOCATION AND ACCESSIBILITY.

The area designated in this report as the Puertecito district is in Socorro and Valencia Counties, New Mexico. It includes all of T. 4 N., R. 6 W.; and parts of T. 3 N., R. 5 W.; T. 3 N., R. 6 W.; T. 3 N., R. 7 W.; T. 4 N., R. 5 W.; and T. 4 N., R. 7 W. Puertecito is a small settlement on the Alamosa Creek and is situated about 3 miles southwest of the southeast corner of the district. East of Puertecito this creek is known as the Rio Salado. It discharges into the Rio Grande near San Acacia.

Puertocito is 35 miles north-northwest from Magdalena, which is the terminus of a branch line of the Atchison, Topeka & Santa Fe Railway connecting it with Socorro. The wagon and auto road from Magdalena to Puertecito is an ungraded road over rather rough country. Stretches of heavy sand ^re numerous, and the grades are steep in places. The Field and Payne anticlines are 6 to 10 miles northwest of Puertecito. Suwanee,

on the main line of the Atchison, Topeka & Santa Fe Railway, is connected with Puertecito by *a road* about 50 miles long, which is not as well travelled as the Magdalena road, but which has less objectionable grades. Transportation of drilling rigs and supplies to the district will be I relatively large item in the cost of drilling wells.

TOPOGRAPHY.

The central and eastern parts of the Puertecito district are included in the Puertecito Basin, a broad depression of roughly circular outline that is bounded on the north and west by *a* basalt-capped mesa, on the south by a line of cuesta escarpments separating it from the main Alamosa Creek valley, and on the east by a northward-trending range of hills with steep east slope, which is an effectual harrier to travel between it and the valley to the east. The basalt-capped mesa occupies a large area to the north of the district, but the part which forms the western boundary of the basin is a narrow arm less than 2 miles in maximum width. This arm is separated into two parts by an erosional gap. The part of the district lying to the west of the mesa arm is included in the broad north-south Red Lake valley, one of the main tributary valleys of the Alamosa Creek. The surface water of the entire area discharges into the Alamosa Creek through arroyos, which are dry except during and shortly after heavy rains characteristic of the region in the summer months and during the melting of the light winter snows.

The basalt flows capping the mesa undoubtedly were originally of much greater areal extent than they are at present.. Remnants of them are found 5 miles or more beyond the south boundary of the district and several miles beyond the east boundary. The area they occupied at the time of their extrusion is thought to have been *a* broad, flat erosional valley ; and whereas they now occupy the areas of greatest elevation, they were at one time the lowest areas relative to the surrounding country.

The present topography is largely the result of the relatively greater resistance to erosion of the basalt of the flows and some of the sedimentary strata, notably the Dakota sandstone, as compared with the soft clay shales which make up nearly all of the remainder of the formations appearing at the surface. Except along the edges of the basalt sheet, the rate of erosion must have been slow until the streams succeeded in cutting their channels through it into the less-resistant underlying rocks. The decrease in area of the mesa and its development to its present outlines have been accomplished in the main by a process of undermining whereby the easily eroded underlying rocks have been rapidly carried away, causing great blocks of the basalt to break away from the main sheet from time to time. The escarpments of the mesa are in places so deeply covered with basalt detached from the capping that the formations which would normally outcrop are entirely obscured. Where the Dakota sandstone appears at the surface, it is being undermined in much the same way. It is of much topographic importance as the capping of a chain of cuestas in the southern part.

The lowest part of the area has an elevation of about 6000 feet arid the greatest elevation is nearly 7275 feet. The lava-capped mesa rises 500 to 900 feet above the basin bottom in the eastern part of the district, but its height above the Red Lake valley is 250 to 700 feet. The cuestas capped with the Dakota sandstone have escarpments as much as 250 feet high.

WATER AND FUEL.

Inasmuch- as there is no surface-water supply in the district, springs and wells must be depended on to supply the water requisite for drilling and camp use. A number of springs yield small to medium amounts of water the mineral content of which is very moderate on the whole. The yeso or gypsum springs are an exception to this rule. The map shows the approximate location of all the springs and wells known to the writer.

Throughout the basin the depth of the water table from the surface varies from a few feet to about 150 feet. In some parts the well water is invariably too highly charged with mineral matter to permit its domestic use, though it is given to stock without bad effects. In other places the well water is quite. potable.

Deposits of coal occur in the Datil Mountains coal district a few miles to the south. The only place where coal is being mined is at the Mayo mine near Riley and about 8 miles east of Puertecito. This fuel can be obtained at a reasonable price and the cost of haulage to drill sites should not be high. Scrub cedars are sparsely scattered over a considerable portion of the district, but they would probably not serve as a satisfactory fuel.

S T R A T I G R A P H Y .

INTRODUCTORY STATEMENT.

Only a brief and general treatment of the sedimentary rocks in the vicinity of Puertecito can be given in this bulletin. Available data on the formations is exceedingly meager, and very little time could be devoted to this phase of the geology in the course of the present investigations. A United States Geological Survey report on the Datil Mountains coal field by Mr. D. E. Winchester, also a report by the same author on the geology of the Alamosa Creek valley of Socorro County with special reference to oil and gas possibilities will be ready for distribution in the near future, and will no doubt contain much valuable information regarding the stratigraphy of the Puertecito district, especially with reference to the Cretaceous rocks.

The only sedimentary systems which appear at the surface within the boundaries of the map are the Cretaceous and Triassic, the Cretaceous rocks occupying the southern and western part. To the north the line of contact between the two is obscured by basalt flows. The older sedimentary formations, which include rocks of Permian and Pennsylvanian age, are partially exposed east of the district at distances varying from 4 to 10 miles. This area is one of the most difficultly accessible in Socorro County, which fact together with unfortunate accidents in attempting to reach it made the obtaining of detailed sections impossible. The thicknesses given are estimated but should be accurate within the limits stated. In the field the outcrops are by no means continuous, the more easily eroded members constituting valleys in which erosional debris has accumulated in sufficient amounts to conceal the underlying solid rocks.

On the whole the rocks of the Puertecito district bear a striking similarity to those of eastern Socorro County, but they probably undergo a somewhat abrupt transition not far to the north and west. The stratigraphic column given by Darton[1] for part of northwestern New Mexico differs markedly from the one given in this report for the Puertecito district.

The recent investigations of a number of geologists indicate that the age previously established for some of the sedimentary rocks of Socorro County and other parts of New Mexico should be revised. Heretofore the Pennsylvanian series has been considered to include two main groups, the Magdalena and Manzano. The old classification is:

San Andreas limestone. Yeso formation.
Abo sandstone.
Pennsylvanian series { Manzano group { Unconformity.
Madera limestone. Magdalena group { Sandia formation.

The Magdalena group contains an abundant and well-preserved fauna, and its age has been established beyond question. The Manzano group, on the other hand, is much poorer in well-preserved fossils, and its classification as Pennsylvanian has been in a sense tentative. Sufficient data have now been accumulated to justify considering this group of Permian age instead of Pennsylvanian. The writer is indebted for this information to Mr. N. H. Darton of the United States Geological Survey, whose forthcoming report on structures in New. Mexico so designates the age of the Manzano group. Mr. Darton's plan of combining the San Andreas and Yeso formations under the name of the Chupadera formation is followed in this report. Prof. W. F. Cummins has also kindly informed the writer that he has determined the age of the San Andreas and Yeso formations of eastern Socorro County to be Permian.

[1]Darton, N. H., A reconnoissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, pp. 11-13, 1910.

Approximate section of rocks in the Puertecito District, New Mexico.

System.	Series.	Group.	Formation.	Description.	Thickness in feet.
Cretaceous.	Upper Cretaceous.		Mesaverde formation.	Drab and carbonaceous shales, yellow and brown sandstones, and coal seams.	
			Mancos shale.	Soft drab shales, carbonaceous shales, and massive yellow sandstones.	
			Dakota sandstone.	Yellow cross-bedded sandstone, usually forming escarpment.	5–60
Triassic.			Puertecito formation.	Purplish-red shales, purplish-red and purplish gray sandstones, and thin conglomerate beds.	1150–1250
Carboniferous.	Permian.	Manzano.	Chupadera formation.	Varigated gypsum beds, shales and limestones.	1000–1200
			Abo sandstone.	Red sandstones, and small amounts of sandy shales and impure limestones.	250–350
	Pennsylvanian.	Magdalena.	Madera limestone.	Bluish-gray thick-bedded limestones; some shales and sandstones.	500–600
			Sandia formation.	Bluish-drab to black shales, bluish-gray to black limestones, sandstones and quartzites. Organic matter in some of the shales and limestones.	500–600
Pre-Cambrian.				Granites, gneisses, schists, and quartzites.	

PRE-CAMBRIAN ROCKS.

The nearest exposure of pre-Cambrian rocks is in the Sierra Ladrones about 20 miles east of the Puertecito district. They consist in this part of the state of coarse-grained granites, gneisses, amphibolite schists, mica schists, and quartzites. The oldest rocks are the quartzites and mica schists, which are mostly metamorphosed sediments. Much of the granite and amphibolite schist was intruded into the ancient sediments. Metamorphism has been so profound that the original nature of many of the rocks is largely obscured.

The pre-Cambrian history of New Mexico is known only in a general way, but its main events can be inferred approximately. The schists and quartzites among the rocks indicate a very ancient sea in which abundant sedimentation took place. Later the sediments were elevated and probably thrown into lofty mountain ranges, these changes being accompanied *by* great igneous activity. In places the volume of intrusive rocks greatly exceeded that of the original sediments. The period of mountain building and igneous intrusion appears to have ceased much earlier than the opening of the Paleozoic era. Degradational processes continued actively, however, until the end of the Mississippian, when northern New Mexico was base leveled to a remarkable extent. In early Pennsylvanian times the sea advanced from the south over the base-leveled surface, and Pennsylvanian sediments were deposited on the eroded surface of the pre-Cambrian rocks. The unconformity at the base of the Pennsylvanian is exceedingly pronounced and represents an interval of time that may be as long or longer than all subsequent time to the present.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

MAGDALENA GROUP.

SANDIA FORMATION AND MADERA. LIMESTONE.

In the Puertecito district rocks of Pennsylvanian age rest directly on the old pre-Cambrian rocks. They are partly exposed along a northward-trending escarpment 10 miles east of the district and should continue to the west beneath the younger sedi-

mentary rocks throughout the mapped area. The exposures of Pennsylvanian rocks on the flanks of the Sierra Ladrones were not examined, but some Mississippian fossils are reported by the United States Geological Survey in the beds just above the pre-Cambrian rocks. Other Pennsylvanian exposures occur in the Magdalena Mountains and at Socorro Mountain. In the former locality rocks regarded as-Mississippian have a thickness of 125 feet, but it is doubtful if any Mississippian strata extend as far north as Puertecito.

The Pennsylvanian rocks of central New Mexico are included in the Magdalena group and are divided into two formations. The lower is called the Sandia formation, while the upper is known as the Madera limestone. To locate exactly the plane of division between the two is a difficult matter. No important unconformities have been noted within the Pennsylvanian strata, but slight disconformities occur in places. At Socorro Mountain some of the sandstone members contain limestone pebbles as much as 2 inches in diameter evidently derived from the underlying limestone beds. The limestone pebbles and coarse-grained sandstones strongly indicate that minor oscillations of either the land or the level of the Pennsylvanian sea resulted in temporary land areas during the period. A notable amount of shales, especially in the Sandia formation, is suggestive of near-shore conditions in this locality during a considerable part of Pennsylvanian time.

The Sandia formation consists of interbedded shales, lime.. stones, sandstones, and quartzites having a thickness of 500 to 600 feet. The shales are bluish-drab to black in color and are in part calcareous. In places they contain much organic matter and have thin seams which resemble coal. They have been prospected for coal at Socorro Mountain and other points in fruitless attempts to uncover workable deposits. The bluish-gray to black limestones are in beds 10 to 40 feet thick. Some members are quite pure ; others are earthy and more or less carbonaceous. Thin chert seams and nodular masses are sparsely scattered through them. The sandstones are coarse grained and are made up of clear and white grains of quartz. Very little fine material occurs in them, and thin seams are dominantly conglomeratic.

They are erratic in thickness and distribution. Quartzites are more prominent near the base of the formation. They have been derived mainly from sandstones and conglomerates, but the silicification of some of the shales has been sufficiently complete to give them a distinctly quartzitic aspect.

The Madera limestone overlies the Sandia formation. It is predominantly limestone but is supplied with some shales. and sandstones. The limestones are massive and thick bedded. Their color is chiefly bluish gray. Like the limestones of the Sandia formation they are highly fossiliferous at numerous horizons. The shales are in thin beds and somewhat calcareous. Both the limestones and the shales are only slightly carbonaceous. The Madera has a number of sandstones of the same character as those found in the lower formation. The sandstone members of the Magdalena group usually range from 5 .to 30 feet in thickness, but about 50 miles east of Puertocito a cross-bedded sandstone near the middle of the group has a thickness of 75 feet. The formation is probably between 500 and 600 feet thick.

The following section of Pennsylvanian and Mississippian rocks at Kelly in the Magdalena Mountains follows closely one given by Gordon[1]:

Section at Kelly, Magdalena District, Socorro County, New Mexico.

	Feet.
Madera limestone:	
Blue compact limestone, for the most part thick bedded; some shale	400
Sandia formation:	
shales, limestones, and conglomeratic sandstones or quartzites	410
Compact earthy limestone	75
White conglomeratic quartzite	40
Shales and quartzites with conglomerate at the base	125
Kelly limestone (Mississippian):	
Subcrystalline limestone with compact 5-foot layer (Silver Pipe) near the middle	125

The correlation of the Pennsylvanian rocks of Socorro County with the Pennsylvanian rocks of the Texas oil fields is a matter of considerable interest to those who are investigating the oil possibilities of central New Mexico. In reply to a letter requesting information on this point Dr. G. H. Girty, the specialist of the United States Geological Survey on the invertebrate paleontology of the Carboniferous, submitted the following statement :

[1]Lindgren, Waldemar, Graton, L. C., and Gordon. C. H. The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 244, 1910.

The horizon of the greatest oil strikes in the fields most prominently before the public is the group of rocks known to the oil men as the "Bend formation," and presumably that is the one Mr. Wells would be most interested to have correlated. I can say this much, that some of the faunas of the Magdalena group suggest a correlation with the "Bend formation" of Texas and with the supposedly equivalent Morrow formation of Arkansas and Oklahoma, but the faunal resemblance is not strong enough to guarantee any definite correlation. This also I can say with reasonable assurance, that nothing at all comparable with the Cisco fauna is at present known in the Magdalena group which may provisionally be considered older than the Cisco.

Several factors introduce elements of doubt into the predicated correlation: (1) Much of my Magdalena material has not been assigned to definite horizons within the group; (2) the Magdalena may be older than the Cisco, as suggested above, but the Texas faunas above the "Bend" and below the Cisco are very little known, so they may show resemblance to the Magdalena fauna equally as strong as those of the "Bend" and Morrow, or even stronger; (3) In view of the geo graphic distance that intervenes between these occurrences and the known changes which all these faunas undergo when traced westward, the "Bend" fauna, if it did occur in New Mexico, might be expected to' differ from the "Bend" fauna of Texas, so that the differences from the typical "Bend" which are shown by the Magdalena fauna might be ascribed to differences in geography and environment, whereas on the other hand the resemblance to the typical "Bend" might be ascribed to relationship with faunas just a little younger that the "Bend" which themselves resemble the "Bend" fauna I think that the evidence encourages further investigation but is not in itself conclusive.

Dr. Geo. Otis Smith, director of the Survey, supplied additional information as follows:

A few plant fragments sent by Sidney Powers to David White, Chief Geologist of the Survey, appear, according to the interpretation of Mr. White, to indicate that the Tesmus formation from which the speci mens were obtained near Marathon, Texas, is probably the equiva lent of the Sandia formation in the Socorro and Albuquerque regions of New Mexico. Mr. White is rather inclined to believe that the Sandia represents Strawn time more probably than Bend. Paleobotanlcally, the Strawn is uppermost Pottsville while the Bend may belong to the upper part of the middle Pottsville, if the correlation by the invertebrate paleontologists of the Bend with the Morrow formation is well founded.

PERMIAN SERIES.

MANZANO GROUP.

The Permian series, formerly regarded *as* absent in, Socorro County, can now be affirmed to be represented by rocks having an aggregate thickness of 1200 to 2200 feet. It includes the formations previously included in the Manzano group and designated as the Abo sandstone, Yeso formation, and San Andreas limestone. The group name, Manzano, is retained, and the lower formation is still called the Abo sandstone. The plane of separation between the Yeso and San Andreas is in many places difficult to locate, and the plan of combining them under the name of the Chupadera formation is especially appropriate in the Puertecito district.

A pronounced unconformity separates the Manzano group from the underlying Pennsylvanian rocks. This unconformity is noted wherever the contact between the two is exposed. The base of the Manzano is in most places conglomeratic and contains limestone pebbles formed during the erosion of the upper surface of the Pennsylvanian. The stratification planes of the rocks above and below the surface of the unconformity are essentially parallel, though the contact represents a surface that was rendered slightly undulating by erosive action. Probably no great amount of material was removed while the Pennsylvanian rocks stood above the level of the sea, nor were there any but minor diastrophic disturbances.

In the vicinity of the Mesa del Yeso 12 miles northeast of Socorro and about 45 miles east-southeast from the Puertecito district the Manzano group is completely exposed. The section given below is partly by Lee[1] but contains some modifications and additions as determined by the writer while doing field work in the same locality :

Section near Mesa del Yeso, Socorro County, New Mexico.

	Feet.
Manzano group:	
Chupadera formation (San Andreas and Yeso).	
Alternating limestone and gypsum beds of prevailing bluish-gray to dark drab color and varying from 20 to 75 feet in thickness	550

[1]Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande Valley, New Mexico: U. S. Geol. Survey Bull. 389, pp. 21-23, 1909.

Grayish drab, yellow, and yellowish-brown sandstone	215
Interstratifted red and pink sandstones and grayish-drab gypSum beds	170
Gray limestone	5
Red and yellow sandy shale	16
Red sandstones and gypsiferous shales with a subordinate amount of earthy limestone	250
Limestone, fossiliferous	50
Abo sandstone.	
Red and maroon sandstones with a subordinate amount of shale and earthy limestone	550
Limestone	6
Blue shale	10
Not exposed	30
Pink to brown sandstone and shale	20
Conglomerate, limestone pebbles in a matrix of sand	25
	1895
(Erosional unconformity)	
Limestone (Magdalena group).	

ABO SANDSTONE.

The Abo sandstone overlies the Madera limestone. The predominant rocks are sandstones, as the name suggests, and shales are of minor importance. The conglomerate at the base has already been noted. The sandstone is on the whole coarse grained and well cemented. The shales are more or less sandy ; in places they are quite soft. A few thin strata of impure limestones complete the stratigraphic range of the formation. Prevailing colors are deep red and maroon, though some of the shales are of a grayish-drab color. The purplish tints characteristic of the Puertecito red beds are lacking. Fossils are sparingly present, and considerable difficulty has been experienced in finding forms which would definitely determine the age of the forme-tion. About 6 or 8 miles east of the Puertecto district, the Abo sandstone forms a low ridge between the high escarpment of the Chupadera formation to the west and the Pennsylvanian limestone hills of intermediate height to the east. The base of the formation is obscured by products of weathering. The thickness in the Puertecito district is estimated at 250 to 350 feet.

CHUPADERA FORMATION.

The Chupadera formation is the name proposed by Darton for the sedimentary beds previously designated as the Yeso and San Andreas formations. It rests upon the Abo sandstone with which it is as a rule conformable. The Chupadera is character ized by a remarkable amount of gypsum, which constitutes more than half of the formation in places. Interbedded with the gypsum are shales, limestones, and sandstones, the shales being more or less gypsiferous. Sandstones are very sparingly present. Shaly strata are most abundant in the lower part and decrease in amount towards the top of the formation. The upper part consists entirely of limestones and gypsum beds, with the gypsum standing first quantitatively. Near the base the colors are dark gray, yellowish brown, pink, and red. In the upper part these colors give place to cream, buff, and light bluish gray. The lower beds have a distinctly variegated appearance.

The individual beds of the Chupadera formation vary greatly at different points. The gypsum is especially prone to occur as lenses which may locally attain a thickness of 100 feet or more. A number of the limestone strata are highly fossiliferous, though the fossils are on the whole poorly preserved. The massive pink and light yellow sandstone 150 to 200 feet thick, which is the usual top member of the old Yeso formation of eastern Socorro County, is absent near Puertecito ; otherwise the Chupadera in the two localities is much alike. The thickness is between 1000 and 1200 feet.

TRIASSIC SYSTEM.

PUERTECITO FORMATION.

The Puertecito formation is the name used in this report to designate the sedimentary beds which are between the Permian and Cretaceous rocks. This formation is made up largely of shales and sandstones, with the shales having the greater aggregate thickness. A few thin strata of conglomerate are interbedded with the shales and sandstones. Maroon, purplish red, and purplish gray are the characteristic colors ; and white, grayish drab, and purplish blue are subordinate.

The lower three-fourths of the Puertecito formation, though consisting largely of purplish-red shales, contains numerous purplish-red and purplish-gray sandstone layers 10 to 25 feet thick. The sandstones are relatively most abundant near the base of the formation. Members of minor importance include purplish-blue shales and light-colored sandstones. The upper

one-fourth is made up almost entirely of maroon shales, and to a minor extent of purplish-red sandstones and grayish-drab shales. Most of the conglomerate is located in the middle part of the formation, where it constitutes beds 6 inches to 2 feet thick composed of rounded pebbles one-fourth to 1 inch in diameter. The shales are in small part calcareous. They are notably soft and very easily eroded. The sandstones, on the other hand are resistant to weathering and erosion, and outcrop prominently. The thickness is from 1150 to 1250 feet.

The Puertecito formation appears at the surface throughout the eastern and central part of the district and extends to the east well up on the west flank of the range of hills which make the eastern boundary of the Puertecito Basin. It is in the eastward-facing escarpment of these hills that most of the Chupadera formation is exposed. A detached area of the rocks of the forma. tion occurs in secs. 8 and 17, T. 3 N., R. 6. W. Another small detached exposure lies a short distance beyond the north boundary of the mapped area in sec. 34, T. 5 N., R. 7 W., and a strip $1^1/_2$ to 3 miles wide extends northward from the main area a number of miles beyond the district along the east side of the main lava-capped mesa.

The only fossils discovered in the Puertecito formation consisted of fragments of petrified wood. They indicated that some of the trees were several feet in diameter but did not serve to determine the age of the containing strata. Lithologically the rocks bear a close resemblance to those of established Triassic age in near-by localities and are considered by Mr. N. II. Darton' to be largely Triassic. Possibly the upper part of the formation includes strata deposited during Jurassic and Lower Cretaceous times.

The marked contrast between the Puertecito rocks and the underlying rocks is indicative of an important time interval between the periods of deposition ; a conclusion which is also supported by 'the unconformity at the base. The strata of the two formations near the contact are essentially parallel, and evidently the interruption of sedimentation did not witness any notable crustal disturbances.

'Personal communication.

CRETACEOUS SYSTEM.

UPPER CRETACEOUS SERIES.

Cretaceous rocks near Puertecito have a notable thickness, possibly as much as 4000 feet. They have been divided into a number of conformable formations which are, beginning at the bottom, the Dakota sandstone, Mancos shale, and Mesaverde formation. Possibly the Lewis shale and Laramie formation of Darton's classification' in northwestern New Mexico are also present. Within the mapped area the Dakota sandstone and Mancos shale are probably the only representatives, but a small thickness of the lower Mesaverde may occur.

The upper beds of the Puertecito formation may be of later age than Triassic, but the unconformity at the base of the Cretaceous represents a considerable interval of time. No notable warping affected the underlying sediments prior to the deposition of the Dakota sandstone. The basal conglomerate characteristic of some of the lower unconformities is largely absent.

Except where they are covered by basalt flows, Cretaceous rocks are the only surface •rocks in much of the southern and western part of the district. They have been completely removed by erosion in the vicinity of the anticlines in the central and eastern part, and have too small a thickness along the axis of the main upfold in the western part to be of any importance in connection with oil and *gas* accumulation. The thickness becomes increasingly great towards the west and south.

DAKOTA SANDSTONE.

The Dakota sandstone consists of vitreous, partly cross-bedded sandstone of a light yellow to buff color. The sandstone is in places separated into two or 'more members .by thin shale beds. It varies from medium to coarse grained, and here and there it is pink or brownish-black on exposed surfaces. Its ability to withstand the action of the elements is remarkably good ; consequently the contact line between it and the underlying soft red shales is usually near the top of a line of cuestas. The classification of this formation *as* Dakota is based on its lithelogic character and its position in the stratigraphic series. A few fragments of fossil wood were found but they could not be identified as belonging to the Dakota flora. In thickness the Dakota sandstone ranges from 5 to 60 feet.

Marton, N. H., Op. Cit., pp. 12, 13

MANCOS SHALE.

Overlying the Dakota sandstone is a thick series of shales and sandstones called the Mancos shale. Soft drab shales are the main rocks, though dark carbonaceous shales, and massive yellow sandstones are present in considerable quantities. Some of the carbonaceous shales are not far removed from true coal seams. Unlike all of the sedimentary rocks below it with the execption of the Pennsylvanian formations, the Mancos shale is highly fossiliferous at a number of horizons. Fossils collected about 250 feet above the Dakota sandstone were classified by the United States Geological Survey *as* belonging to the Benton fauna, which *is* characteristic of the rocks between the Dakota and Niobrara where both of these formations are recognizable, and in northwestern New Mexico a similar fauna is found in the lower part of the Mancos shale. The following forms were identified :

Cardium pauperculum (Meek?).
Callista? sp.
Tellina sp.
Gyrodes sp.
Pugnellus fusiformis (Meek).
Volutoderma sp.
Mactra sp.
Fasciolaria? sp.
Ptychodus sp.
Prionotropis.
Hemiaster sp.
Gryphaea newberri Stanton.

MESAVERDE FORMATION.

The Mesaverde formation bears a close resemblence to the Man-cos shale, which it overlies conformably. It is made up of drab shales, carbonaceous shales, and yellow and brown sandstones Seams of coal of workable grade and thickness give the formation considerable economic importance. No time was given to a study of the Mesaverde rocks, and their thickness was not determined.

IGNEOUS ROCKS.

Igneous rocks, both extrusive and intrusive, occur in various places in the Puertecito district. In the main they are basalts, andesites, and their porphyritic equivalents. The basalt varies in color from reddish or brownish black to pure black. Some of it is very scoriaceous. It is mainly fine grained, but olivine phenocrysts are abundant in some localities. Magnetite is invariably present ; often in sufficient amounts to deflect the needle of a transit 10° or more. The andesite is predominantly porphyritic and of a gray color. It bears many phenocrysts which appear to be largely plagioclase feldspar, and the most common ferro-magnesian mineral is hornblende. No microscopic examinations of the rocks of the district were made. Probably other varieties closely related to those mentioned are represented.

Basalt is the chief extrusive rock. It constitutes the capping of the lava mesa in the northern and western part of the district, the mesa continuing to the north for some distance. The vent or vents through which the flows were extruded were not located, but possibly the cone known as the Cerro de Oro in sec. 22, T. 5 N., R. 6 W., and the smaller cone near the edge of the mesa in the western part of sec. 1, T. 3 N., R. 7 W., may mark minor centers of eruption. Most of the basalt shows prominent flow structure and may have flowed quite a distance before coming to rest. The thickness along the mesa escarpment is 25 to 150 feet. Probably the original thickness was somewhat greater than these figures.

The eruption of the basalt occurred in Tertiary time. A sufficiently long period of time since the Cretaceous had elapsed for the Cretaceous and older sedimentary rocks to be folded into nearly their present attitude, and for erosion to have cut down to the Permian rocks in places and to have reduced important areas to nearly the same level throughout. The maximum depth of erosion must have exceeded 4000 feet. A shorter but nevertheless considerable period of time has transpired since the outpouring of the basalt. During this period the main folds have been accentuated. The area of the flows has been decreased perhaps by one-half, and erosion has also produced good-sized basins having an average elevation of 500 feet less than that of the mesa.

In the areas where the basalt flows do not obscure the sedimentary rocks, intrusive rocks are common in places. They con• sist of basalt, andesite, and andesite porphyry, and occur as dykes, sills, and irregular bodies. Three-fourths or more of the intrusive rocks observed are in the form of sills. Most of the dykes are less than 15 feet in thickness, and their length may be as much as half a mile. The sills are 5 to 50 feet thick and of variable horizontal dimenisons. Because of the small size of the individual intrusions it was found impracticable to attempt to show them on the map. To the southeast the Cretaceous rocks contain many intrusions, but within the district igneous activity has been much greater in the rocks of the Puertecito formation than in the Cretaceous. The time of the intrusions is thought to agree in part with that of the basalt flows, and it is likely that all of the igneous action was confined to the Tertiary.

The areas showing the greatest amount of intrusions are in the eastern part of the district. Dykes are relatively most abundant in the southeastern part. The prevailing strike is north, and they stand nearly vertical. Most of them lie to the east of the fault traversing sec. 1, 12, and 13 of T. 3 N., R. 6 W., and sec. -36, T. 4 N., R. 6 W., but a persistent dyke was also noted in the NW. $^{1}/_{4}$ of sec. 14, T. 3 N., R. 6 W.

Sills are very common in parts of sec. 4 and 5, T. 3 N., R. 5 W., and in parts of secs. 19, 20, 28, 29, 32, and 33, T. 4 N., R. 5 W. Dykes occur also but are subordinate. This is the area of greatest igneous activity within the district. Large amounts of igneous rock have been injected into the sedimentary rocks, and the structure has been considerably complicated. Some of the sills are 30 to 50 feet thick and can be traced for several thousand feet. In part the intrusions are irregular in shape and can hardly be classed as either dykes or sills.

In the NE. $^{1}/_{4}$ of sec. 26, T. 4 N., R. 6 W., a number of sills crop at the surface. They strike nearly due north and dip to the east at angles of 7° to 10°. The dip angle exceeds that of the sedimentary rocks in the surrounding areas, and possibly they are not strictly parallel with the bedding planes. The sills have a thickness of 5 to 15 feet and a maximum length of perhaps

1200 feet. Another area where sills are locally prominent is in the N. Y2 of sec. 24, T. 4 N., R. 6 W.

Near the foot of the mesa escarpment in the north-central part of sec. 19, T. 4 N., R. 6 W., two prominent knobs of basalt rise to *an* elevation of 100 feet or more above the surrounding sedimentary rocks. They are parts of a dyke-like vertical intrusion having a north and south extension of 700 feet and a maximum width of 75 feet. The basalt carries some inclusions acquired during its passage through the underlying sedimentary rocks.

Several basalt sills of small thickness were located in the W. 1/2 of sec. 24, T. 4 N., R. 7 W. They are in the Puertecito formation a short distance east of the contact between it and the Cretaceous rocks.

STRUCTURAL GEOLOGY APPLIED TO OIL AND GAS.

The only rocks that are ordinarily of importance as receptacles of oil and gas are the sedimentary rocks, or those which have been built up layer upon layer by water action. At the time of their deposition these layers or strata were nearly horizontal, but the earth's crust has undergone a slow deformation varying in intensity in different localities whereby the originally horizontal strata have been thrown into folds of various kinds and have in places been broken and faulted. By structure in oil geology is meant the attitude of the strata which has been effected by folding and faulting movements.

The terms most commonly used to indicate the geological structure of sedimentary beds are anticlines, domes, terraces, monoclines, homoclines, and synclines. The first three are the most favorable for the existence of oil reservoirs, and frequently the term structure is used in a restricted sense to apply only to them. These various structures may be defined *as* follows :

An *anticline* is an upfold of relatively much greater length than width. The strata dip downward on both sides of a line along the top of the fold known *as* the axis. If the axis dips downward in both directions from a point an anticlinal dome is the result. An anticline whose axis dips in the same direction throughout its length is called a plunging anticline.

A *dome* is on upfold in which the strata dip away in all directions from a central point or apex. In the ideal dome the dips are about equal in all directions, but in nature the dips in two opposite directions are usually more pronounced than they are at right angles to these directions. In the latter event the structure may be called an anticlinal dome.

In a *terrace* the strata are practically horizontal or have a very slight dip angle. Most terrace's occur *as* minor structures on homoclines and on the flanks or along the axis of anticlines.

A *homocline* is a tilted block of sedimentary beds. The dip of the strata is in the same general direction throughout and does not differ greatly in value in different places.

The term *monocline* is frequently used instead of homocline in referring to a tilted block of strata. The better usage is to confine it to folds in which the strata undergo a transition in attitude from horizontal to inclined and back to horizontal.

A *syncline* is the opposite of an anticline, in other words a downfold instead of an upfold. Structurally it is a trough, while an anticline is a ridge. A syncline also has an axis which is a line from which the strata rise on both sides.

STRUCTURE-CONTOUR LINES.

The most satisfactory way of delineating surface forms, such as hills, ridges, and valleys, on a map is by means of contour lines, and the map then becomes a topographic map. A contour line is defined as a line locating all points of a certain definite elevation within the boundaries of the map, or as the line of intersection of a horizontal plane with the surface of the ground. In other words, one would be moving horizontally when travelling along a contour line.

Another illustration that may assist in giving an understanding of the meaning of contour lines follows: Suppose that an area is being gradually submerged by water. Provided the water is an uninterrupted body every part of its surface will be at the same elevation and the shore line will be a contour line as well. A map showing successive shore lines made by the rising water until the highest point is submerged would be a contour map, and if the distance between successive elevations of the surface of the water were 50 feet the contour interval would be 50 feet. The elevation of contour lines is mostly expressed in feet above sea level.

The rising water in the above illustration would convert the valleys into bays and gulfs and the hills into islands; thus a valley would be represented on contour lines by V-shaped sags and a hill by sinuous non-intersecting closed lines all enclosing a common point. In places of steep slope the contour lines would be closer together than in nearly flat areas, and if the contour interval and the scale of the map were known the slope at any point could be determined.

Structure-contour lines are also lines of equal elevations, but instead of expressing topography they indicate the attitude of one of the stratification planes of the sedimentary rocks. The removal of all of the rocks above a stratification plane would convert it into a ground surface, and a structure-contour map of it would become a surface-contour map. If a series of conformable sedimentary beds could be tilted and folded without any additional deposition taking place and without weathering and erosion, the topography would define the structure. Anticlines would be indicated by ridges and elongated hills, synclines by valleys, and domes by round or elliptical hills. All land sun faces, however, have undergone varying amounts of erosion whereby the rocks have been removed to widely different depths. In many places the present surface forms are the opposite of the structural forms, and a valley may follow along the crest line of an anticline or the lowest part of a basin may contain the apex of a dome.

On the map of the Puertecito district which accompanies this report (opposite page 48) structure contours have been worked out for an area of about 30 square miles in the central and southern part, this area containing the most promising structures. Beneath the basalt-capped mesa the structure is too indefinite and in the eastern part it has been too greatly complicated by igneous dykes and sills to justify an attempt to represent it by structure-contour lines. The Dakota sandstone is readily identified wherever it crops out and has been utilized extensively in working out the structure. A number of sandstones and conglomeratic beds of Triassic age outcropping in the vicinity of the axes of the anticlinal domes have also been of much service. Local dips are in many places of little or no value due to the distortion accompanying the weathering of the soft shales. This is especially true in the western part of the area where Cretaceous rocks are exposed. The elevations indicated by the structure contours refer to the approximate height above sea level of the base of the Puertecito formation.

STRUCTURE OF THE DISTRICT.

The dominant structure of the Puertecito district and surrounding country is homoclinal, with prevailing dips to the south, southwest, and west. It can also be described as homoclinal if the term is used to indicate a tilted block of sedimentary rocks. This homocline constitutes the west and southwest flanks of a major uplift which has its culmination perhaps 10 miles east of the district. Erosion has been especially vigorous along the axis of the uplift and has lowered the surface considerably below that of the district proper. The true structure at the culmination of the uplift and for many miles to the east is hidden by detrital material partly supplied by the hills to the west and representing part of the sedimentary deposits of the valley of the Rio Puerco, one of the important tributaries of the Rio Grande. The Sierra Ladrones may be on the same main axis of folding that occurs in the latitude of the district.

There are good grounds for believing that pre-Cambrian rocks occur immediately below the recent sand and gravel deposits covering the axis of the main uplift of this part of New Mexico. When proceeding in a general southwesterly direction from the area of maximum elevation and in the direction of the dip of the beds, belts of all of the sedimentary rocks described on pages 9-21 are crossed in chronological order. At some distance south of the district, the Cretaceous rocks in places dip beneath Tertiary sandstones and conglomerates, and these in turn are overlain by a great series of Tertiary lava flows. Important unconformities occur above the Cretaceous rocks.

The homocline in the eastern part of the district has dips to the west of 2° to 8°, which continue for at least 8 miles beyond the limits of the district. In the southern part the strata dip to the south and southwest at angles of $2^1/_2$° to 7°, these dips prevailing for perhaps 12 miles beyond the south boundary. In the western part of the district and in an adjacent strip several miles wide, the chief direction of dip is southwest at angles of 2° to 6°, though west dips of $1^1/_2$° to 4° are common in the northwestern part. Beneath the basalt capping of the mesa the structure is obscured.

The Puertecito homocline is traversed by a number of anticlines whose axes trend in a general northerly direction. Some of the anticlines are plunging upfolds with axes dipping to the south throughout their entire length, but others have axial dips to the north for short distances and are anticlinal domes. At all of the anticlinal domes the southward dip of the axis is much more prominent than the northward dip.

FAULTING.

The folding movements which affected the rocks of the Puertecito district and surrounding country were accompanied by a very minor amount of faulting. Undoubted displacements of a fairly deep seated nature were located only in one locality in the southeastern part of the district. The so-called "red-bed faults" are worthy of discussion, and a notable fault occurs west of the mapped area in the vicinity of Broom Mountain.

The most noticeable irregularity in the boundary line between the Cretaceous and Puertecito formations is in the southeastern part of the district where an elongated area of Cretaceous rocks extends northward about $3^1/_2$ miles from near the south boundary of the mapped area and lies one-half to 2 miles west of the line between ranges 3 and 4. This area is a down-faulted block, but, rather curiously, it is now topographically higher than the areas of the Puertecito formation on both sides of it. Faulting is very evident in the southern part, but at most points the contact is obscured by recent accumulations of sand and gravel. The maximum displacement on the west side is at least 400 feet, and that on the east side may be slightly greater. Undoubtedly the displacement gradually decreases in amount towards the ends of the faults. The down-faulted block is also folded and constitutes a syncline whose axis is about parallel to the bounding faults on each side. The Dakota sandstone makes escarpments c varying prominence at the boundaries of the area of Cretaceous rocks,

but along the axis of the syncline it is overlain by several hundred feet of the Mancos shale formation.

Very probably the syncline referred to in the preceding para graph does not entirely represent deep-seated folding. The sag of the axis can be explained in part as being due to deformation of the underlying plastic shales of the upper Puertecito forma. tion. Numerous faults of small displacement traverse the Cretaceous rocks, but they seem. to be surficial also and attributable in part to the deformation of the shales below.

The Yeso spring in sec. 35, T. 4 N., R. 6 W., is evidently fed by water circulating along the west fault. The water issuing from the spring contains a high percentage of calcium sulphate, and an area of nearly 50 acres surrounding it is covered with recently deposited gypsum. At two other places, one in the SE. $^1/_4$ of sec. 23, T. 4 N., R. 6 W., and the other in sec. 13, T. 3 N., R. 6 W., large surface deposits of gypsum were noted. Springs are not active at either of these places, but there is little occasion to doubt that the deposits are accumulations from spring water. How much of the displacement of the down-faulted block is due to dissolving of the gypsum beds of the Chupadera formation and consequent settling of the rocks above is indeterminate. Much of the calcium sulphate was probably taken into solution near the location of the springs, and the writer believes that the removal of gypsum by circulating waters accounts for an important part of the displacement. The absence of seeps of oil or gas near the faults would be natural provided the fissuring does not extend below the rocks of the Chupadera formation, but if the Pennsylvanian rocks are not petroliferous no seeps would occur even though strong fissures continue downward to the pre-Cambrian rocks.

The "red-bed faults" are located along the steep escarpment of the lava-capped mesa in the northern part of T. 4 N., R. 6 W. and in the vicinity of the bluffs or cuestas characteristic of the boundary between the Dakota sandstone and the Puertecito formation in the southern part of the district. The faulted appearance is due to successive horizontal tiers of great blocks of basalt and Dakota sandstone which occur in places on the escarpment surfaces. These tiers represent elongated sections of the capping rocks which have broken away from time to time as the underlying shales and sandstones have been removed by weathering and erosion. Under the influence of the same agencies they are moving slowly down the slopes. Along the mesa escarpments some of the sedimentary beds are locally much disturbed. Without doubt this faulting is purely superficial and would in no way affect the migration of oil in the underlying formations.

The fault situated west of the district near Broom Mountain was not examined. It is mentioned by Winchester' and was called to the writer's attention by Mr. A. C. Rubel. The strike of the fault is roughly north and south, and the east side is the down-throw side. Its length is reported to be several miles.

THE ANTICLINES AND ANTICLINAL DOMES.

PAYNE ANTICLINAL DOME.

The Payne anticlinal dome is one of the chief structures of the Puertecito district. It is a well-defined upfold occupying the western part of the Puertecito Basin. The anticline lies mainly in the southwestern part of T. 4 N., R. 6 W., but part of it extends into the northwestern part of T. 3 N., R. 6 W. A road from Puertecito to the Payne ranch crosses the structure near the apex of the dome. Except during the summer months this road is in fair condition. Water can be obtained from wells at the Payne ranch about one mile northwest from the apex of the dome and at the Field ranch about 2 miles southeast. One of the wells at the Field ranch yields potable water of a fair grade, but the water from most of the wells is rather alkaline.

The shape and extent of the Payne anticlinal dome are shown by the structure contours on the map of the district. It is a fairly symmetrical fold trending north-northwest. The dips on the east side are between 2° and 5°. The dips on the west side average nearly the same as those on the east side, but locally they increase to *as* much as 10° or decrease nearly to horizontal. The width of the east limb, measured from the crest line to the bottom of the syncline lying between it and the Field anticline, is about one mile, whereas the width of the west limb is at least 4 miles in the narrowest place. From the apex the axis dips to the north at an *angle* of 1° to 2° for more than a mile. Farther

Winchester, D. E., U. S. Geol. Survey Press Bull. 423, Sept. 1919.

to the north the structure is obscured by erosional products from the mesa escarpment. To the south of the apex the dip of the axis is $11/_2$° to $2^1/_2$° for about a mile. The south and southwest dips continue in these directions for an additional distance of at least 15 miles. The apex of the dome is in the NE. $1/_4$ of section 32, T. 4 N., R. 6 W. The north closing in the rocks of the Puertecito formation as shown _by the structure contour lines is at least 175 feet, while the east closing appears to be about 275 feet.

The surface rocks of the Payne anticlinal dome consist of the purplish-red shales and purplish-gray sandstones of the middle part of the Puertecito formation. The surface is roughened by numerous cuestas which are capped by the sandstone members of the formation, and the structure is excellently delineated by the successive lines of cuesta escarpments surrounding the apex. The escarpments are in places 60 feet high, but the prevailing surface elevation is quite uniform throughout and varies from 6125 to 6275 feet above sea level.

The Puertecito formation is underlain in turn by the rocks of the Chupadera formation, Abo sandstone, Madera limestone, Sandia formation, and pre-Cambrian complex. The thickness of the Puertecito formation remaining at the apex is estimated to be about 400 feet, and the total depth to the base of the Sandia formation is probably between 2700 and 3000 feet.

No igneous rocks are known near the axis of this anticlinal dome, but several small sills occur below the Dakota sandstone at the foot of the mesa to the west and intrusive rocks are found near the base of the mesa on the north. These igneous rocks are discussed on pages 22-24. No distinct evidence of deep-seated faulting was discovered, but steep dips a short distance west of the apex may have been, produced in part by surficial faulting. The outcrop of the Dakota sandstone at the foot of the mesa to the west is offset in places, the displacement being also due to surficial disturbances.

FIELD ANTICLINAL DOME.

The Field anticlinal dome is situated in the Puertecito Basin and is east of the Payne anticlinal dome. It lies in secs. 15, 16, 21, 22, 27, 28, 33, and 34, T. 4 N., R. 6 W., and secs. 3 and 4, T.

3 N., R. 6 W. The main road from Puertecito to Suwanee passes close to the apex. Wells at the Field ranch in sec. 26, T. 4 N., R. 6 W., can supply drilling water, and the water from the spring at the Pino ranch about 2 miles north is the best water for domestic use to be found in the district.

As shown by the structure-contour lines on the map of the district, the Field anticline *is* a symmetrical and notably regular northward-trending fold whose axis extends from the southern part of sec. 15, T. 4 N., R. 6 W., to the southern part of sec. 3, T. 3 N., R. 6 W. The west limb is about a mile in width throughout and the dips vary from 21/2° to 6°. The east limb has a width of one-third to three-fourths of a mile and slightly greater dips than the opposite limb. At the south end the anticlinal dome merges into the homocline proper, the south dips persisting for 12 or 15 miles beyond the structure. The apex of the dome *is* nearly at the quarter corner on the section line between sections 27 and 34, T. 4 N., R. 6 W. The axis is almost horizontal for a distance of nearly a mile north of the apex. Farther to the north it exhibits a dip angle of about 1°, but the structure is indeterminate beyond the southern part of sec. 15, T. 4 N., R. 6 W., where the sandstone escarpments cease. The north closure in the rocks of the Puertecito formation is at least 100 feet and may be somewhat greater than that. Near the east boundary of sec. 34, T. 4 N., R. 6 W., the axis of the syncline to the east approaches to within one-third of a mile of the axis of the anticline, and the closure to the east in this vicinity is apparently not more than 150 feet.

The Field anticlinal dome has many characteristics in common with the Payne anticlinal dome adjoining it on the west. The same series of Puertecito sandstones and shales crop at the surface, and the cuesta escarpments on both sides of the axis and at the ends of the anticline are very similar. The Field anticlinal dome is the narrower structure of the two. Except for the cuestas and a few arroyas, the monotony of the nearly flat basin bottom is unbroken. Elevations range from 6050 to 6175 feet. The depth to the base of the Sandia formation is estimated to be 2700 to 3000 feet, the intervening rocks belonging to the Chupadera formation, Abo sandstone, Madera limestone and Sancta formation.

Faulting seems to be entirely lacking throughout the Field anticline, and no igneous rocks are known to occur. There are, however, areas of marked igneous activity *a mile* or more to the east.

MILLER ANTICLINE.

The Miller anticline is in the eastern part of the district. A road reaches it from Puertecito, and it may also be approached from the north. Some of the neighboring arroyos are deep and make auto travel difficult. A well is situated near the north end in the SW. 1/4 of sec. 17, T. 4 N., R. 5 W., which is said to contain good water.

In the main the anticline is a distinct upward bulge having a length of 4 miles or more. It occupies all or part of secs. 18, 19, 29, 30, 31, and 32, T. 4 N., R. 5 W., and secs. 5 and 6, T. 3 N , R. 5 W. The axis, as shown on the map of the district, begins in the NW. 1/4 of sec. 5, T. 3 N., R. 5 W., and trends in a general northerly direction for about a mile, then swings to the west and takes a course of about north-northwest for a short distance, and finally swings back to a course of nearly due north which continues to the end of the anticline, in sec. 18, T. 4 N., R. 5 W.

The Miller anticline is the only anticline in the Puertocito district whose structure is reflected in the topography. The position of the anticline is marked by a hill rising 75 to 125 feet above the surrounding country, the crest of the hill corresponding in general with the axis of the anticline. This hill is the most prominent topographic feature of the eastern part of the district. In many places the dips of the strata agree with the slope angles of the hillside. The anticline is fairly symmetrical, the dips varying from 2° to 8° on both sides. The width of the upfold is 11/2 to 2 miles. In common with the other anticlines of this area the south dips continue for a number of miles in that direction. The north closing also seems to be good. The highest part of the axis is in secs. 19 and 30, T. 4 N., R. 5 E. The thickness of the sedimentary rocks above the pre-Cambrian appears to be between 2500 and 2800 feet.

The sandstones and shales of the Puertecito formation, which are the surface rocks of the Miller anticline, contain a number of large igneous sills, and are also cut by occasional dykes and intrusions of irregular shape. Faulting of small displacement has occurred in places, and in some parts of the structure the strikes and dips are subject to wide variation. An attempt was made td work out structure contours for the area occupied by the anticline, but the complications produced by the igneous rocks proved to be too great to justify showing them on the map.

LAWSON ANTICLINE.

A minor flexure designated as the Lawson anticline lies northeast of the Miller anticline in secs. 8, 17, and 20, T. 4 N., R. 5 W. Its length is about 1% miles. The axis has a trend of nearly due north, and throughout most of its length the east and west dips are distinct though at small angles. To the north the anticline merges into the homocline of the district without an apparent closing, the homocline in this vicinity dipping to the west at angles of 1° to $2^{1}/_{2}$°. Igneous intrusions are present only in small amounts throughout most of the structure at the surface, but the south end extends into an area of vigorous volcanic activity where the structure is very irregular and largely indeterminate,

RED LAKE ANTICLINE.

The Red Lake anticline lies mainly in the Red Lake valley to the west of the basalt-capped mesa. It is best reached from Magdalena by taking the Puertecito road about half way to that place, and then following a road branching to the west which continues across the Alamosa Creek and up the Red Lake valley. Red Lake is a small artificial lake in the valley bottom. Another smaller artificial lake situated 11/2 to 2 miles northeast of it and called Upper Red Lake is partly shown on the map. The valley is about 6 miles wide in the widest part but narrows to about half that width near the north boundary of the district.

The anticline is an upfold trending in a general northerly direction. It has a length of 7 miles or more. About half of the structure lies to the north of the district proper. The surface rocks in the mapped area consist mainly of shales and sandstones belonging to the lower part of the Mancos shale formation. In places the sandstones outcrop prominently, but in the main either the soft clay shales are the only surface rocks or the sandstones are obscured by valley fill. Dips in the shales and sand-

stones of several small isolated buttes are almost valueless in determining structure. In the northern part of the anticline arroyos have cut through the Mancos shale and Dakota sandstone and into the upper strata of the Puertecito formation. Near the north end several hundred feet of the Puertecito formation has been removed by erosion in places.

No detailed work was undertaken in this part of the district, and only general statements can be made regarding the structure of the anticline. Within the district it probably occurs in secs. 3, 4, 9, 10, 15, 16, 21, 22, and 28, T. 4 N., R. 7 W. The approximate position of the axis is shown on the map. The average dip of the axis to the south in secs. 9, 16, and 21, T. 4 N., R. 7 W., is about 2°. The west limb is well defined, and the strata dip to the west at angles of 3° to 6° for several miles. The east limb is clear cut in the southern part, but near the north boundary line the attitude of the sedimentary beds is not determinable accurately. The width of the east limb in the latitude of sec. 16, T. 4 N., R. 7 W., is nearly 2 miles, the average dip angle being about 21/2°.

The field evidence slightly suggests a terrace along the anticline in secs. 2, 3, 10, and 11, T. 4 N., R. 7 W., and there is a bare possibility of a north closing near the edge of the mesa or farther to the north beneath the flows. If so, the Red Lake anticline really consists of two anticlines. A more likely supposition is that the anticline changes its direction and that the axis is continuous as shown. Detailed work might lead to more positive conclusions, but the structure is in part a difficult problem. Much of the east limb lies beneath the basalt flows.

The axis of the Red Lake anticline continues to rise to the north for several miles beyond the district. Near the center of T. 5 N., R. 7 W., the axial dip appears to change to the north, resulting in the development of a dome along the axis. How much the north and east closures amount to cannot be stated, but they do not promise to be very large. In the southern part of the anticline pre-Cambrian rocks are thought to be 3600 to 4000 feet below the surface along the axis, and at the north end they are probably several hundred feet nearer the surface. No igneous intrusive rocks are known to occur along the anticline.

OTHER ANTICLINES.

A number of anticlines occur outside the boundaries of the Puertecito district. They are thought to be less favorable for oil than some of the anticlines within the district but merit brief mention. About 6 miles east of the district the outcropping rocks of the Magdalena group have been folded into a well-defined anticline with strong east and west dips. The axis has a length of several miles in a north-south direction. No closing is evident at the north end, and the remaining thickness of the sedimentary rocks above the pre-Cambrian is less than 700 feet. South of this anticline several small, poorly defined domes and anticlines occur in rocks belonging to the Chupadera formation.

South of the district the homocline is slightly undulatory and is folded in places. In the Puertecito basin near Puertecito the homoclinal structure is seemingly devoid of anticlines or domes, and no structural conditions favorable for oil accumulation were observed. A well-developed plunging anticline which begins near the south boundary of T. 2 N., R. 6 W., extends northward and northwestward into the southwestern part of T. 3 N., R. 6 W. The east limb is narrow in part, and no north closing is shown by the outcrops.

OIL AND GAS.

ORIGIN, MIGRATION, AND ACCUMULATION.

Nearly all present-day geologists attribute the origin of oil and gas to organic matter which has been buried in the sediments. To some an animal source is most acceptable, while others assume that the organic matter was mostly vegetation. Both kinds of organic matter can be made to yield oil by proper treatment, and probably both kinds have been important sources of our hydrocarbons. Much can be said in favor of the view that plant remains have been responsible for the larger part of our oil and *gas.*

At the time of deposition the organic matter must be prevented from undergoing immediate decay. After it has been deeply buried beneath later sediments it experiences a selective distillation by which it is in part converted into oil and *gas.* Assisting factors are the pressure of the overlying rocks, the presence of salt water, and moderately high temperature. The time which

may intervene between the deposition of the organic matter and the formation of oil from it may be many thousands of years. Clays and muds are the sediments in which the most abundant accumulation of organic matter suitable for the production of oil and gas takes place, and most of our hydrocarbons have originated in them. Many limestones are built up by the gradual accumulation of the hard parts of sea animals, but the soft parts of the dead animals are nearly always consumed by the living forms or else decay completely before they are buried. Sandstones scarcely ever contain enough organic matter to generate noteworthy amounts of oil and gas.

During the compacting of the clays and muds into shales the oil and gas are squeezed out, together with the included water, and migrate into any near-by porous strata. Sandstones constitute the most satisfactory porous strata, the voids or open spaces in some varieties amounting to 20 or 25 per cent of the total volume of rock. In some dolomites the percentage of open spaces is high enough so they can be regarded as porous rocks. Shales are the most impervious of the sedimentary rocks.

After entering porous strata the oil, gas, and water tend to arrange themselves according to their specific gravities. There are a number of restricting factors in ordinary porous beds, but the tendency is for the oil and *gas* 'to migrate up the slope in the porous strata while the water migrates downward. If the entire underground water supply is in slow motion the separation is greatly facilitated. Provided the porous beds were part of a homocline as defined on page 25 and cropped at the surface, eventually nearly all of the *gas* would escape. The oil would come to the surface of the ground water and would issue at the surface in springs or as seeps. When, however, the porous strata are interbedded with impervious strata and the sedimentary series is thrown into folds, the oil and *gas* migrate upward to the upper part of the folds where they are confined. Theoretically the gas should occupy the highest part of the fold, and the oil should accumulate just beneath the *gas,* but in many structures the two are found together. If the folds are of the right shape and of sufficient size very valuable accumulations of oil and gas may occur in them.

EVIDENCE OF OIL AND GAS.

In many oil fields the presence of petroleum and allied hydrocarbons was indicated by seeps of oil, escaping *gas,* mud volcanoes, asphalt-impregnated strata, or other criteria before any drilling was undertaken. Oil encountered in water wells has been in places a reliable sign of valuable accumulations at greater depth. In many districts, on the other hand, no direct evidence of oil or gas has been found until the oil-bearing sands have been penetrated by the drill.

No indisputable proof of oil or *gas* in the Puertecito district has come to the writer's attention. A number of possible indications were investigated, among them being the occurrence of so-called asphaltum; a black, slightly oily mud at several springs; and an oily-appearing film on the water from these springs. Some of the limestone members in the Puertecito formation give off a petroliferous odor when freshly broken.

The material called asphaltum was found only in sec. 4, T. 3 N., R. 6 W., near the Field ranch houses at two points several hundred feet apart, where it occurred in the loose gravel and sand at the surface of the ground. The globules range in diameter from one-sixteenth to one-half inch and do not depart greatly from a spherical shape. They resemble tar in appearance, having a black color and breaking with a conchoidal fracture: The substance contains very little impurities and burns readily with a smoky flame. The amount that could be collected was too small to permit a complete examination..Judging from simple tests made by the United States Geological Survey it is more liable to be fossil resin or even resin of recent origin altered by the heat of the sun than a true asphaltum. Its origin cannot be considered to be fully established.

The black, greasy mud found in the bottom of watering troughs supplied with water by springs at the Tres Hermanos ranch 6 miles southwest of the Field ranch and at the Yeso spring in sec. 35, T. 4 N., R. 6 W., is apparently of recent vegetable origin. In the troughs a slight oily scum collects at times at the surface of the water which is mainly iron hydroxide and not a film of oil *as* some observers 'have thought.

The fetid and strongly petroliferous odor given off from a

fresh fracture surface by some of the Chupadera limestones does not necessarily indicate that the rocks have been oil bearing. It can be regarded as an only slightly favorable sign.

According to reports, combustible gas accumulated in a well near Puertecito while it was being dug, and the water from one or two wells in the district has contained oil at various times. Granting the correctness of these reports, the amount of gas and oil involved is too small to justify attaching any importance to their occurrence.

POSSIBLE OIL AND GAS HORIZONS.

A study of the stratigraphy of the Puertecito district leads to the conclusion that the only probable oil and gas horizons are in strata of Pennsylvanian and Cretaceous age. Along the crest lines of the structures in the area with which this report deals the Cretaceous rocks are either entirely removed by erosion or have too small a thickness to justify attaching any weight to them as possible sources of oil and gas. The Pennsylvanian rocks, on the other hand, should occur throughout the district, and are thought to be moderately promising for oil and gas production.

In order to receive favorable consideration for the occurrence of oil and gas a formation should contain sufficiently large amounts of suitable organic matter to serve as the source; it should have porous members favorable for the free movement and necessary concentration of the oil and gas ; and it should have the porous strata included between others impervious enough to confine these hydrocarbons within the reservoir members. The rocks of the Pennsylvanian series or Magdalena group contain in near-by localities adequate quantities of proper organic remains to generate important amounts of oil and gas, the organic matter contained in the shales and shaly limestones of the Sandia formation being most promising in this connection. The limestones of the entire series are more or less fossiliferous; in places highly so, but the brachiopods, crinoids, and corals. constituting the bulk of the animal life are not assumed to have been prolific sources of oil or gas. Unless the voids have been filled by some cementing material, .the sandstones of the Sandia and Madera Formations are texturally eminently satisfactory for reservoirs. Their thickness is variable but should be sufficient to account for satisfactory accumulations. The pre-Cambrian rocks below the Sandia formation should prevent any escape of oil and gas in that direction. The shales in the upper part of the Sandia and throughout the Madera limestone are mainly in thin beds and are not ideal overlying impervious strata, but the limestones may act in a like capacity to prevent the escape of oil and gas by upward migration.

The distances intervening between this area and the investigated outcrops render the stratigraphy of the Pennsylvanian rocks more or less uncertain. Upon comparing the sections on all sides of the district it is logical to expect that sandstones have a greater relative total thickness here than they have to the south and east. The shales should have an equal or greater development, and the limestones have probably decreased slightly. The organic content may vary widely, but it should be sufficiently large to account for at least moderate quantities of oil and gas. The correlation of the rocks of the Magdalena group with either the Strawn or the Bend formation of the Texas oil fields gives additional weight to the oil possibilities of the Pennsylvanian rocks of this district. However, it does not necessarily follow because these formations have been remarkably prolific producers of oil in the recently developed Texas fields that their possible geologic equivalents are oil bearing near Puertecito. Undoubtedly the Pennsylvanian rocks in this locality are not as favorable in character for the generation of oil and gas in large quantities as they are in parts of Texas. The lack of strong, positive proof of the presence of oil or gas in this vicinity as well as in the surrounding country makes the rocks of the Pennsylvanian series less promising than they would otherwise be.

The Sandia formation is more promising for oil and *gas* than the Madera limestone, but the latter may prove to contain important pools. Unless valuable reservoirs are previously encountered, drilling should not be discontinued until the pre-Cambrian rocks are reached. The distances given from the surface to the pre-Cambrian at the different structures are maximum drilling depths. If oil and gas are present they may occur 500 and possibly 1000 feet above the base of the Pennsylvanian rocks.

The Permian series of rocks contains very little organic material suitable for oil generation, only indifferent reservoir sands, and a small thickness of impervious strata. The red color characteristic of the Abo sandstone, the red and pink colors exhibited by the Chupadera formation, and the great thickness of the gypsum beds point to an arid climate and active oxidation ; conditions distinctly unfavorable for plant life. Some of the limestones of the Chupadera formation are fossiliferous, but the organic remains are poorly preserved. In most of the oil fields of the Southwest the Permian rocks are not supplied with notable amounts of oil and gas, and in places where they are productive the oil and gas have probably migrated to their present position from the Pennsylvanian rocks below. The Permian rocks do not appear to be promising in this district.

The alternating shales and sandstones of the Puertecito formation are texturally favorable for migration and accumulation of oil and gas, but the beds are prevailingly red throughout and the only evidence of organic life consists of fragments of petrified wood. In the absence of a source for oil and gas within the formation, satisfactory reservoir sands and impervious beds are completely discounted, and no production can be expected from it.

The Cretaceous rocks of this part of New Mexico are distinctly promising for oil and gas. Soft clay shales containing much carbonaceous matter are interbedded with thick, porous sandstones, thus fulfilling the main conditions essential to the production of valuable reservoirs where structural conditions are good. Winchester'[1], on the basis of the physical and chemical characteristics of the rocks of the Dakota sandstone and Mancos shale, considers that the chances of finding oil of high grade accompanied by *gas are* good in these formations at an anticline located about 15 miles west of the Puertecito district.

SOME COMMON MISCONCEPTIONS REGARDING OIL AND GAS.

The present wide-spread interest in the oil possibilities of New Mexico has led many persons of little or no geological training or experience to locate placer oil claims and to become identified with the promotion of drilling projects. Some parts of the state have promising structures which are well worth prospect-

[1]Winchester, D. E.. U. S. Geol. Survey Press Bull. 423, Sept. 1919.

ing, but some of the areas being exploited are distinctly unfavorable places for any important accumulations. Without doubt our supply of knowledge dealing with oil and gas is far from complete, yet many fundamental laws have been established beyond reasonable question. Those who are endeavoring to locate valuable deposits of oil should by all means observe the generally accepted laws regarding it. The writer has found a number of misconceptions in this connection so commonly held that a few words concerning them may prove to be of value.

According to a very prevalent misconception basins are the only logical places to expect oil. A number of basins in the West have been prominently identified with important oil fields, but many of them are improbable localities for oil accumulation. Basins are either structural or topographic. Many people have the erroneous idea that the underground drainage of a topographic basin corresponds in general with the surface drainage above. They assume that oil and gas are carried by the underground circulation to an area near the lowest part of the basin where they gradually accumulate in much the same manner that a lake would form at the surface provided the basin were completely enclosed. This view disregards the fact that the direction of underground circulation is determined largely by the attitude of the porous beds, *as* well as the tendency of oil and gas to migrate in a general upward direction. If the basin is structural, oil and gas accumulation will occur in folds near its edge and not in areas of greatest structural depression. Drilling in the lower part of a topographic basin is justified only when the highest part of a large anticline or dome has been located there.

The presence of fossil beds and carbonaceous shales is often erroneously taken *as a* favorable indication for oil in that locality when the possible oil-producing beds have been completely removed by erosion from the high parts of the folds constituting the logical places to search for oil. In the same way a sandstone member may be regarded *as a* promising reservoir rock in spite of the fact that it is absent on the structure. The only formations deserving consideration are those which are below the surface along the crest lines of the promising folds. The oil-bearing strata may come to the surface only at a distance of many miles from the structures.

Strong seeps of oil and *gas* suggest that there may be important accumulations near at hand. A region in which they occur deserves investigation, but in the absence of promising structures no commercially important pools are likely to be developed. In a few oil fields inclined petroliferous beds have sealed themselves at the surface by the accumulation of the heavy oils in the pores of the rock, and oil reservoirs may occur down the dip despite the absence of folds. Lensing of the oil sands may also account for oil pools in inclined strata. Contrary to popular opinion, the immediate vicinity of seeps is a less desirable place to drill than are good structures having the same strata in which the leakage is taking place, even though they may be located a considerable distance away. Seeps near the crest line of a fold, especially if along a fault plane, may imply that the oil and gas are escaping from the structure and that no accumulation has been effected.

The oily appearing film occurring at the surface of the water of small streams, especially those fed by springs, and found on the water in troughs supplied by springs may be iron hydroxide - instead of oil. A simple test for distinguishing between the two is as follows : Touch the film with the tip of the finger. If it is oil it will not be noticeably disturbed, whereas if it is iron hydroxide it will separate into roughly polygonal sections which will move away from the finger. A true oil film usually differs from an iron hydroxide film in having an iridescent appearance, but some iron hydroxide films are also iridescent.

Gas seeps may be common in a region containing little or no oil and must not be considered an infallible indication of the presence of liquid hydrocarbons. *Gas* is given off copiously from coal seams, but very little weight is now given to the theory which accounts for any quantity of oil as one of the products of the progressive alteration of coal. Decaying vegetation of recent origin generates combustible *gas* in large quantities.

OIL AND GAS POSSIBILITIES OF THE DISTRICT.

Some of the facts and opinions presented in preceding sections of this report which are especially important in estimating the oil and *gas* possibilities of the Puertecito district may be summarized briefly as follows :

The geologic column comprises sedimentary rocks of Pennsylvanian, Permian, Triassic. and Cretaceous age. Of these, the Pennsylvanian formations are most promising for oil and gas within the district and are thought to be moderately favorable in character for the production and accumulation of these hydrocarbons. However, no positive evidence of the presence of oil or gas has been obtained.

The structure of the district is predominantly homoclinal, and the homocline is traversed by a number of anticlines and anticlinal domes of medium size.

The tilting and folding of the sedimentary beds was accompanied by very little faulting.

Intrusive rocks are common in parts of the district and in places have been injected into the strata in large amounts.

Provided the attitude of the Pennsylvanian rocks corresponds with the attitude of the rocks of the Puertecito formation at the surface, the general structure of the district is favorable for the migration of oil and *gas* and their accumulation at the more important upfolds. Any oil and gas generated in the sedimentary rocks would tend to travel up the dip in the porous beds throughout the homocline, but they would be trapped on reaching the anticlinal domes and would be prevented from migrating farther. The gathering zone of the main folds extends 15 miles or more to the south and southwest. The amount of accumulation should be dependent in part on the area of the domes proper; after the reservoir rocks become saturated in these areas. any additional oil and gas migrating up the slope would be likely to drive some of the previous accumulations from the domes at the sides where the closings are smallest. Productive areas should extend to lower elevations on the south and west sides of the domes than on the north and east sides.

It is not necessarily true that the upfolds in the Puertecito formation are underlain by corresponding folds in the Pennsylvanian rocks. Even in conformable beds, convergence may account for important differences in structure at different hori. zons. Also folds do not remain constant in intensity at all depths. In some oil fields anticlines at depth are more pronounced than they are at the surface, yet the reverse is often true. The folds

in the Pennsylvanian rocks of this district probably compare favorably with those in the Puertecito formation and can be expected to have nearly the same horizontal position.

The effect of the intrusions of basalt and andesite has depended largely on the amount of molten rock injected into the Pennsylvanian rocks near the possible oil horizons. The sills and irregular bodies in the Puertecito formation have only slightly metamorphosed the adjacent sedimentary rocks, and the same is true of the surface flows. They have had a negligible effect on any oil and gas more than a few hundred feet beneath them. If the Pennsylvanian strata of the anticlines and anticlinal domes have been intruded with igneous rocks to the same extent that the Puertecito formation has in places the probability of oil pools occurring in them is small, but they are liable to contain a much smaller amount of intrusive rocks than does the Puertecito formation. The Magdalena series consists chiefly of limestones with subordinate shales .and sandstones, while the Puertecito formation is composed mainly of soft, plastic clay shales and minor amounts of sandstone. In the Pennsylvanian rocks, molten magmas have probably risen along fracture planes or other more or less vertical openings ; but in the Puertecito rocks the shales have seemingly acted as barriers to the upward movement and have caused large quantities of the igneous rocks to follow the bedding planes, resulting in the marked development of sills. With the exception of the Miller and Lawson anticlines, the anticlinal folds of the district are free from igneous rocks at the surface and probably throughout the sedimentary rocks, and the gathering territory to the south shows only minor evidence of intrusions. The Miller anticline may owe some of its folding to local accumulation of igneous rocks, but the likelihood of the other folds being due in any degree to igneous intrusions of laccolithic nature is quite remote.

A consideration of the various favorable and unfavorable geologic conditions leads to the conclusion that there is not more than a fair possibility of finding productive reservoirs of oil and gas in the Puertecito district. So much uncertainty attaches to some of these conditions that a more definite statement is not warranted. If gas alone is found it will probably be of little value, but if oil is present it should occur in sufficiently large amounts to yield an excellent profit in spite of the unfavorable location of the field. Any oil obtained should be of good grade. In view of the large possible returns *as* compared with the cost of prospecting, testing with the drill is thought to be justified. However, only modest expectations of opening up a real oil field should be entertained.

At all of the anticlines of the district any oil present may be some hundreds of feet above the contact between the Pennsylvanian and pre-Cambrian rocks, *as* explained on pages 39-41 under "Possible Oil and Gas Horizons."

The structural features of the anticlines and anticlinal domes have been described, on pages 30-36. Of these upfolds the Payne anticlinal dome appears to be most favorable for oil and gas. It is a better-defined dome than any of the others and has a much greater relative width. The minimum closing in the rocks of the Puertecito formation is 175 feet. The anticline may extend to the north for some distance beyond the area of the structure contours. Any extension of the axial dip to the north would increase the amount of the minimum closing, and it is possible that the east closing of 275 feet is the smallest one. The most promising location for a test well is on the axis in the NE. 1/i, of sec. 32, T. 4 N., R. 6 W.

The Field anticlinal dome is more regular than the Payne anticlinal dome, and the structure is more typically anticlinal. It may also continue northward beneath the detritus completely covering the solid rocks between the area included by the structure contours and the foot of the *mesa,* but the closing of 150 feet in the Puertecito rocks on the east side in sec 34, T. 4 N., R. 6 W., would not be improved by any extension of the dip of the axis to the north. The possible productive area appears to be smaller than that of the Payne anticlinal dome. This up-fold is fairly promising for oil and *gas.* The first well should be located on the axis in the northern part of sec. 34, T. 4 N., R. 6 W., or in the southern part of sec. 27, T. 4 N., R. 6 W.

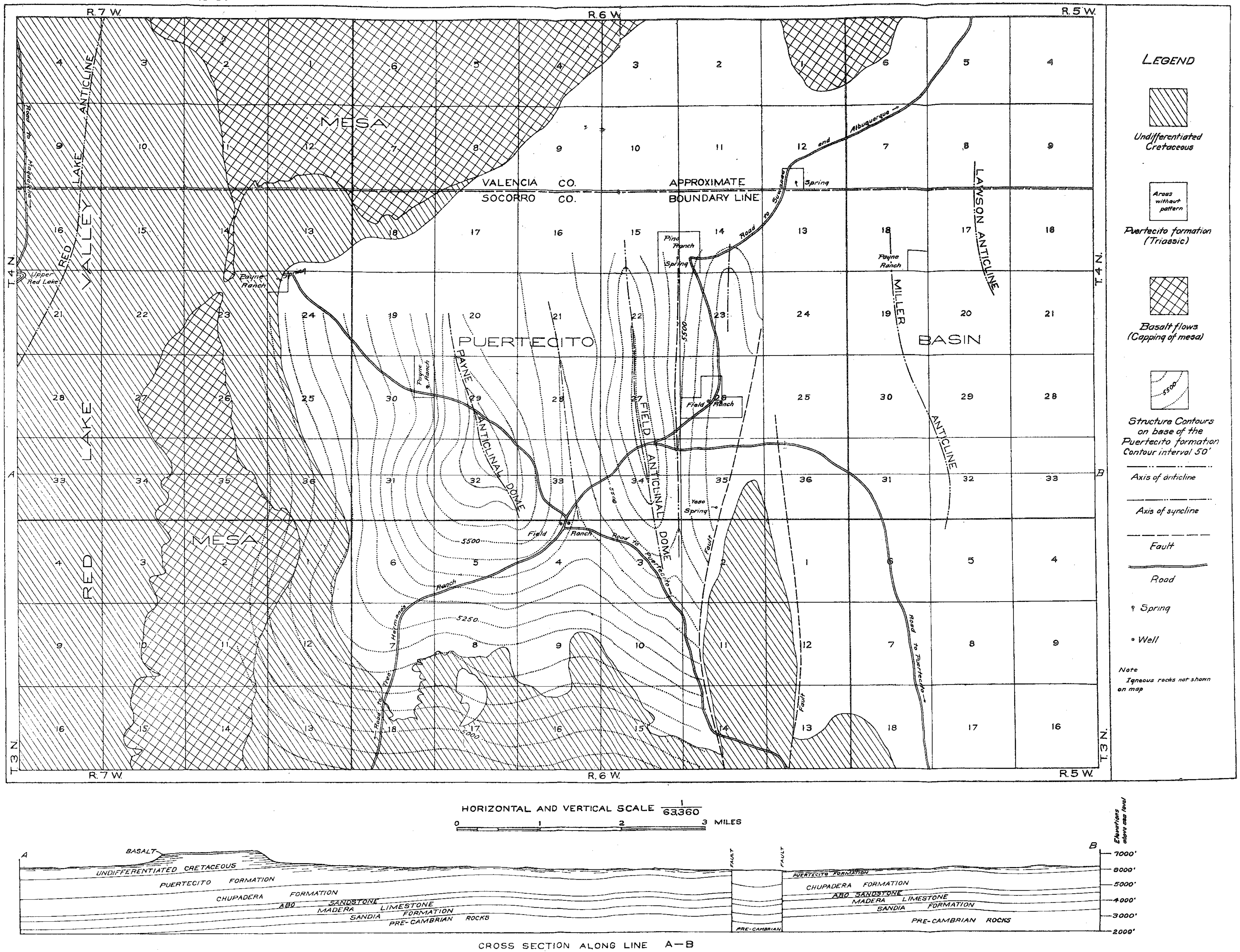
The Payne and Field anticlinal domes may be thought of as structural features of a terrace on the main homocline of the

district. The terrace extends northward from the south line of T. 4 N., R. 6 W., at least to the boundary line between Socorro and Valencia Counties. It is bounded on the east by the fault crossing secs. 23, 26, and 35, T. 4 N., R. 6 W., and sec. 2, 11, and 14, T. 3 N., K 6 W., and has a width of about 4 miles. The total area of the terrace is 12 square miles or more. The total drainage area which can be regarded as tributary to the anticlines on this terrace is at least 125 square miles.

At the Miller anticline, intrusive rocks detract strongly from the oil possibilities. It is thought likely that in this part of the district intrusions have penetrated not only the rocks of the Puertecito formation but the underlying formations as well. The Miller anticline is less encouraging than either the Payne or Field anticlinal domes. If oil is obtained at either of the other structures it will be worthy of testing, but not otherwise. The original well should probably be located on the axis in sec. 29 or 30, T. 4 N., R. 5 W.

The absence of north or south closings and the proximity of areas of great igneous activity make the Lawson anticline unpromising.

The part of the Red Lake anticline within the Puertecito district is not promising for oil and *gas,* judging from the small amount of data obtained. It is a larger structure than any of the others, and if a true dome with satisfactory closures on all sides in T. 5 N., R. 7 W., can be determined it merits a test by the drill. The great depth to the pre-Cambrian rocks is of course a disadvantage.



GEOLOGIC MAP AND SECTION OF THE PUERTECITO DISTRICT, NEW MEXICO

By E. H. Wells