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GEOLOGY AND OIL AND GAS POTENTIAL OF THE NORTHEAST OTERO PLATFORM AREA, NEW MEXICO

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INTRODUCTION

The northeast Otero platform in southern New Mexico (Fig. 1) lies between the Sacramento Mountains on the northwest and the Guadalupe and Brokeoff Mountains to the east and southeast. To the west lie the Hueco Mountains, whose dip slopes form a part of the Otero platform, and to the southwest lie the Cornudas Mountains. To the south the area merges with the Diablo plateau. Structurally, the area lies north of the Diablo plateau and across the southern extension of the buried Paleozoic Pedernal uplift. Surface structures reflect both Laramide and late Tertiary deformation. Only Permian rocks with a scattered and generally thin cover of Quaternary sand and gravel are exposed throughout the area. Tertiary intrusives locally lie at shallow depths beneath the surface in the southwest corner of the area.

The area east of the buried Pedernal uplift is part of the west and northwest shelf of the prolific, oil-producing Delaware basin. The western half of the report area is on the east flank of the little tested Paleozoic Orogrande basin. The Pedernal uplift between these two areas is in many ways similar to the Central Basin platform of the Permian basin, and appears to have had a somewhat comparable geologic history. The timing of possible oil and gas maturation, migration and entrapment on the flanks of the Pedernal uplift appears to be analogous to that of the Central Basin platform. Significant pre-Permian structural and stratigraphic traps may thus be present in this large and still virtually untested area.

Detailed subsurface mapping by the author was done in this area in 1972 and 1973 (Black, 1973). Regional stratigraphic work by Kottlowski (1960, 1963, 1965), Kottlowski and LeMone (1969) and Meyer (1966) covers parts or all of the area in a more general way.

GENERALIZED STRATIGRAPHY AND HISTORY

General Statement

Rocks from all systems of the Paleozoic Erathem are represented in the subsurface of the area, with the possible exception of the Cambrian. In contrast, Mesozoic and Tertiary sedimentary rocks are absent. Minor Quaternary deposits locally veneer the Paleozoic rocks. Figure 2 (in pocket) is a time-stratigraphic cross-section which illustrates the general stratigraphy. For clarity the Phanerozoic history is indented below to distinguish it from the stratigraphic discussion. Relevant well data is summarized in Table 1.

Precambrian Erathem

No Precambrian rocks are exposed at the surface of the report area. The nearest Precambrian outcrops are found in the southern Sacramento Mountains at the base of the Sacramento escarpment. However, numerous wells have penetrated the Precambrian basement either within the report area or nearby. Denison and Hetherington (1969) have synthesized data from outcrop and wells and have drawn a basement geologic map of this region. They define two basement types in the area: the 950 m.y. old Franklin Mountain igneous terrane, and the 950 to 1,000 m.y. old DeBaca metasedimentary terrane. Denison and Hetherington show the axis of the DeBaca terrane to be approximately parallel to the Pedernal uplift; perhaps basement structure influenced the uplift of the Pedernal positive in Late Pennsylvanian time.

Cambrian-Ordovician Systems

> It is across the eroded surface of diverse metamorphic and igneous terranes that Cambrian and Ordovician seas spread from the south, depositing the arkosic basal Bliss Sandstone. Clastic deposition of the Bliss eventually gave way to later Ordovician and Silurian deposition of El Paso, Montoya, and Fusselman carbonate rocks which, after consolidation, were beveled locally to the north on the Pefiasco dome (Armstrong, 1962) by Late Silurian and Early Devonian erosion.

The "normal" sequence of Cambrian-Ordovician rocks in southern New Mexico has been described by LeMone (1969), and these units are apparently present in the subsurface area of this report. Standard of Texas No. 1 Scarp, section 18, T. 21 S., R. 18 E., reportedly penetrated the top of the Montoya Group at 1,670 ft and passed through a normal section including the Cutter Formation, Aleman Formation, Upham Dolomite, El Paso Group and Bliss Sandstone before reaching Precambrian rocks 910 ft deeper at 2,580 ft. LeFores No. 1 Federal, section 11, T. 21 S., R. 16 E., penetrated Ordovician rocks but, unlike the Standard of Texas well, encountered only the lower half of the El Paso Group and Bliss Sandstone. The El Paso Group is overlain by a thin Permian Abo section, probably reflecting activity on a fault block of Late Pennsylvanian age from which all pre-Abo and post-lower El Paso Group rocks were eroded.

Coral Oil and Gas Warren No. 1, section 19, T. 23 S., R. 19 E., and Hunt McMillan and Turner No. 1, section 5, T. 16 S., R. 16 E., both drilled directly into the Precambrian beneath the Abo. Pre-Abo erosion on the crestal area of the Pedernal uplift apparently stripped all of the Paleozoic rocks from these areas prior to Abo deposition.

Five wells on the west side of the report area encountered the unconformity at the base of the Abo but were not drilled deep enough to penetrate the Cambrian-Ordovician rocks. These wells are: Atlantic State "AV" No. 1, sec. 16, T. 20 S., R. 15 E., Zapata Federal No. 14, sec. 14, T. 20 S., R. 14 E., Standard Oil Thorn Unit No. 1, sec. 15, T. 21 S., R. 14 E., Cambell-Spanel No. 1, sec. 7, T. 23 S., R. 16 E., and Flynn-Welch and Yates Donahue No. 1, sec. 28, T. 24 S., R. 15 E. All these wells appear to have bottomed in the Fusselman Formation with the exception of the Flynn-Welch and Yates well, which bottomed in Tertiary intrusive rocks.

Just southeast of the report area, Turner Everett permit No.

Figure 1. Apollo space photograph of Otero platform and surrounding area.

1, sec. 34, T. 22 S., R. 13 E., Paso Terro Evans permit No. 1, sec. 22, T. 24 S., R. 12 E., and Union McMillan No. 1 A, sec. 9, T. 25 S., R. 13 E., all penetrated a normal lower Paleozoic section found beneath the Permian unconformity.

Silurian-Devonian Systems

Pray (1961) has described the Silurian Fusselman Formation and the various calcareous and shaly units of the Devonian strata exposed in the Sacramento Mountains. The Fusselman Formation is Early and Middle Silurian in age and is composed of light-colored carbonate rocks containing a shallow-water fauna. It rests unconformably on the Upper Ordovician Valmont Dolomite or Cutter Formation. Some sandstone and conglomerate have been reported at the base of the Fusselman in the Sacramento Mountains. In general, the formation is not typically fossiliferous, and the upper and lower contacts are regional disconformities.

In the report area, McGlasson (1969) has described the Fusselman as being overlain unconformably by the Canutillo Formation of Devonian age. East of the Hueco Mountains the subsurface Canutillo is black chert and black limestone with a dark shale at the base and is overlain by the black Percha Shale. Farther east the unit appears to grade into the lower part of the Percha Shale. The Percha Shale is a probable correlative of the Woodford Shale of west Texas.

> By Middle Devonian time, the Otero platform area was the site of shallow seas with the low Penasco dome probably emergent to the north. Across most of this area the black and gray organic rich mud and silt of the Percha and the correlative Sly Gap were deposited; likewise to the east the black organic muds of the Woodford, also a correlative unit, were being deposited in the Delaware basin where they would become a prolific oil and gas source rock.

Mississippian System

> In Mississippian time the seas covered all the report area and extended well northward. A wide variety of Mississippian carbonate rocks were deposited in the area, including crinoidal limestone and biohermal shelf-limestone, which thicken to the southwest into the Pedregosa basin (Kottlowski, 1960) and to the southeast into the Delaware basin.

Excellent outcrops of Mississippian rocks are well exposed along the Sacramento escarpment; large bioherms of the Lake Valley Formation are prominent and form spectacular parts of the section.

Pray (1961) has pointed out the ubiquitous presence of Mississippian beds between Devonian and Pennsylvanian rocks in the Sacramento Mountains, and the same relationship is found in the wells of the report area. The Caballero is present but thins to the south in the Sacramento Mountains, while the Lake Valley Formation and younger Rancheria-Helms Formations form mutually compensating wedges of sedimentary rocks that pinch out southeast and northwest respectively (Pray, 1961).

In Zapata Petroleum Federal No. 14, section 14, T. 20 S., R. 14 E., between 4,710 and 4,740 ft and immediately overlying the Fusselman there is a light-gray to tan, medium crystalline silty limestone which is interpreted to be the base of the Mississippian and is possibly correlative with the Caballero. The Caballero is not recognized in the subsurface in Standard of Texas No. 1 Scarp, section 18, T. 21 S., R. 18 E. However, some 70 ft of section immediately below the Abo from 1,030 to 1,100 ft is tentatively identified as Mississippian and the basal 50 ft of this interval contains yellowish crypto crystalline dolomite and sandy dolomite and bright-yellow, calcareous siltstone. These beds overlie gray green shale of probable Devonian age and may be correlative with the Caballero. These correlations are quite tenuous and should be considered tentative.

The Lake Valley Formation may be absent or very thin to the southeast, as inferred by Pray (1961). The Lake Valley and its six members (Laudon and Bowsher, 1949) was not recognized in the wells of the report area.

The Rancheria Formation is believed to be present in Zapata Petroleum, Federal No. 14, section 13, T. 20 S., R. 14 E., in the interval from approximately 4,430 ft to the top of the Caballero (?) at 4,710 ft. This interval fits the general description of the Rancheria outcrops 20 mi to the northwest and includes bioclastic calcarenite, dark argillaceous limestone and chert stringers. The only well with an adequate lithologic description of the Mississippian is the Zapata well, which may or may not be representative of Mississippian rocks in the remainder of the report area.

The Helms Formation or possible lateral equivalents was not recognized in the Zapata well. However, it may be present. The Helms is a thin-bedded argillaceous limestone with yellow and gray interbedded shale. Several thin oolitic limestone beds occur near the top of the section and were described by Pray (1961).

Only a small erosional remnant of the Mississippian is present beneath the Permian in Campbell-Spanel No. 1, section 7, T. 23 S., R. 16 E., and no Mississippian has been preserved in LaFores Petroleum No. 1 Federal, section 22, T. 21 S., R. 16 E., where the Permian rests directly on the El Paso Group. Pre-Permian erosion has removed the Mississippian in Coral No. 1 Warren, section 19 T. 23 S., R. 19 E., Hunt No. 1 McMillan and Turner, section 5, T. 16 S., R. 16 E., and Turner State No. 1 Federal, section 36, T. 25 S., R. 16 E. The absence or near absence of Mississippian rocks as well as all the overlying Pennsylvanian section attests to the locally severe Late Pennsylvanian uplift of the southern Pedernal axis in this area.

Pennsylvanian System

In large areas of the report area, the originally thick Pennsylvanian section has been removed by Pennsylvanian and early Wolfcampian erosion during the emergence of the southern Pedernal landmass. The nearest outcrops of the Pennsylvanian rocks are in the southern Sacramento Mountains. Additional good exposures are found in the Hueco Mountains to the west and southwest.

In the Sacramento Mountains the Pennsylvanian is as thick or thicker (3,000 ft) than the entire underlying Paleozoic section. Pennsylvanian strata contrast with the underlying Paleozoic rocks because they contain large amounts of terrigenous elastics and show vertical and lateral lithologic changes over short distances. These lithologic changes are also seen in the subsurface and record the tectonic unrest of this period. The outcrops in the southern Sacramento Mountains indirectly record this tectonic activity and in conjunction with the limited well control available, give valuable insight into the nature of the uplifts.

Outcrop evidence suggests that deposition was essentially continuous throughout most of the Pennsylvanian in the Sacramento Mountains. This is also generally true over most of the area of this report with the exception of the areas immediately overlying the Pedernal uplift.

In the Pennsylvanian the general pattern of a periodically uplifted low and distant landmass to the north, the Peñasco dome, had begun to change, and by Middle Pennsylvanian time the Pedernal uplift had become the dominant structural feature in the area. The southern extension of this positive feature bisects the report area from north to south and played an important role in the subsequent deposition of Middle to Late Pennsylvanian and Permian sediments. In Early Pennsylvanian time the Pedernal uplift began to rise slowly from the sea floor in the areas to the north. To the east the Delaware basin was a growing negative feature which began to receive an influx of clastic material. One of the main areas being eroded during the Morrowan was the Pedernal uplift to the north of this area. It shed sand, silt and clay of the Gobbler Formation into the Delaware basin, but only minor sand and clay to the west into the incipient Orogrande basin. To the north, uplift of the Pedernal landmass continued into Atokan time with erosion stripping the higher parts of the uplift of its lower Paleozoic strata. By late Atokan time the initial uplift was reduced to low hills awash in the shallow Pennsylvanian seas, and the Pedernal uplift stayed barely awash through most of Desmoinesian time. Only minor silt and clays were supplied to most of the Delaware and Orogrande basins, but the Orogrande basin locally received some subgraywacke deltaic material. As the Desmoinesian came to a close, renewed uplift provided arkosic debris that was carried westward into the Lucero basin near Socorro.

The Gobbler Formation, which represents the oldest Pennsylvanian strata (Morrowan(?), Atokan, and Desmoinesian), was probably deposited on a marine shelf area which in Early Pennsylvanian time was receiving relatively coarse detrital material derived from the early pulses of the Pedernal uplift to the north.

The Gobbler Formation is about 1,500 ft thick in the Sacramento Mountains, and ranges in age from Morrowan (?) to middle Missourian. The Gobbler was deposited unconformably on subaerially exposed Mississippian beds. The unconformity shows considerable relief.

The Bug Scuffle Limestone Member of the Gobbler Formation lies above these dominantly clastic beds and is up to 1,000 ft thick. It is mostly limestone with layers of both calcarenite and calcilutite and is cherty in many places. The upper part of the Gobbler Formation is a clastic facies which interfingers with the Bug Scuffle Limestone and contains mostly shale, quartz sandstone and minor amounts of limestone. This facies is called the detrital facies. The Bug Scuffle Limestone Member and the detrital facies are believed to have been deposited contemporaneously in laterally equivalent areas and interfingered throughout Desmoinesian and possibly during part of Missourian time. Pray (1961) found that the top of the Bug Scuffle Limestone along the face of the Sacramento escarpment in the central and southern parts of the escarpment is near the top of the Gobbler and that a major change in thickness occurs in the formation to the south. This trend toward a carbonate dominated section in the Gobbler apparently persists into the report area, inasmuch as Zapata No. 1 Federal 14, section 24, T. 20 S., R. 24 E., contains predominantly carbonate rock with only minor amounts of quartz sand and shale. These clastic rocks are primarily in the basal and extreme upper parts of the Gobbler equivalent.

The major facies change in the Gobbler is believed to be northeast-southwest rather than north-south (Pray 1961). Within a distance of three to four miles, almost 1,000 ft of the Bug Scuffle Limestone changes to predominantly terrigenous detrital facies. Thompson (1942) believed these facies changes indicate a deltaic area to the north in the Sacramento Mountains area. However, Pray (1961) suggests that the Bug Scuffle Limestone represents a facies deposited over a broad area west of the crest of the present Sacramento Mountains, and that the detrital facies was deposited on the shoreward side of the area along the present crest of the mountains, and protruded abruptly into the general area of the carbonate facies along an axis which may have been the location of a major distributary carrying detrital material from the east or northeast. He based his opinion on his surface work, two subsurface tests drilled west of the Sacramento Mountains escarpment, and one test drilled near the crest of the range in section 5, T. 18 S., R. 23 E.

The writer favors Thompson's (1942) deltaic interpretation, which is probably closer to the type of depositional environment represented by the clastic facies, but believes Pray's (1961) directions of detrital movements are more reasonable. It seems likely that a large deltaic complex persisted through time and had its source to the east or northeast. Distributary channels running generally westerly fed into the Orogrande basin, which was subsiding to receive this influx of clastic material.

The fact that the detrital facies interfingers with the Bug Scuffle Limestone and contains an appreciable amount of carbonate suggests that deltaic sediments were moving out across a subsiding but shallow shelf area which was primarily a carbonate province. The rise of the Pedernal uplift gave birth to an eastern clastic source that in turn produced a local deltaic, and overwhelmingly detrital, environment above this regional carbonate province. This complex could be an important source of potential reservoirs in the Orogrande basin west of the Sacramento Mountains.

The lack of significant amounts of detrital clastics in Zapata No. 1 Federal, section 13, T. 20 S., R. 24 E., suggests that the Pedernal uplift was initially more active to the north of the report area in Early to Middle Pennsylvanian time, and only in the Late Pennsylvanian did the tectonic unrest of the period profoundly disturb this area. The clastic facies of the Gobbler is unknown within the report area, although it is possible that a facies change exists in the subsurface but has not been penetrated in the scattered wells drilled to date.

By Missourian time, a north-south lineation between a positive shelf area to the east and the deeper Orogrande basin had developed along what may have been a large flexure or "hinge line" along what is now the Sacramento Mountains. By Late Pennsylvanian time, the Orogrande basin had subsided greatly to receive a thick clastic Pennsylvanian section, while the shelf area east of the "hinge" had become a very shallow to emergent platform. Farther to the east in the Piñon area this platform was deformed and uplifted, with local erosion of all Pennsylvanian sediment and much of the lower Paleozoic section. In some areas all of the Paleozoic rocks were eroded and the Precambrian rocks exposed. It is this shelf and sediment source area which is dramatically demonstrated by the available well control in the report area.

Argillaceous thin-bedded limestone and interbedded calcareous shale are the dominant lithologies of the Missourian Beeman Formation. A marked increase in the thickness and number of sandstone beds occurs from west to east in the lower one-third of the Beeman Formation. The Beeman Formation is interpreted by Pray (1961) as reflecting the increased tectonic activity and the emergence of land areas to the east. The Beeman Formation is believed to be represented by the interval from 2,890 to 3,180 ft in Zapata No. 1 Federal, section 14, T. 20 S., R. 24 E., within which calcareous shale and argillaceous limestone predominate. Fine- to coarse-grained, poorly sorted quartzose sandstone and traces of "granite wash" are also reported. This section is overlain by the Permian Pow Wow Conglomerate, whose relationships indicate significant stripping of later Pennsylvanian rocks on a possible intermediate fault block or folded area.

By late Missourian time, the Pedernals had probably become a gently eastern-tilted fault-block with the western side high and steep, providing more arkosic detritus directly to the west into the Orogrande basin. Silt and clays were washed eastward into the Delaware basin. Continued significant uplift of the Pedernal landmass is evident into Virgilian time and culminated during late Virgilian and early Wolfcampian with the accumulation of arkose, subgraywacke, and red silt of the Holder Formation, which was dumped into the Orogrande basin.

The Holder Formation includes all the uppermost Pennsylvanian strata between the underlying Beeman Formation and the base of the Permian Abo Formation. The Holder Formation contains a wide variety of rock types which were generally deposited on a relatively shallow marine shelf area. Minor cyclic nonmarine strata occur in the Sacramento Mountains (Pray 1961).

Permian System

The Permian paleotectonic setting in the area was undoubtedly dominated by the same tectonic elements which gave rise to the Pedernal uplift and which were active at least sporadically through Wolfcampian time. The structure and outline of the Pedernal uplift in the report area is not well known, but the available well control suggests it was probably a narrow (6 to 10 mi) fault-bounded feature over much of its length and split the report area from north to south. To the north the Pedernal uplift appears to have been a much broader feature and was probably a highly folded as well as faulted uplift. The Huapache fault (Fig. 3; and 4, in pocket) was active to the east beyond the report area and was probably a high-angle upthrust which defined the easternmost edge of the tectonic activity in this area. The Huapache fault was active in controlling, in part, the deposition of Permian units through Wolfcampian.

Immediately to the southeast of the area, the Bone Spring flexure was active throughout the Permian. The Babb and Vittorio flexures to the south in the Sierra Diablo area were also active throughout Permian time. These three flexures were all in existence during the deposition of the Permian rocks which now overlie them. They outlined the margins of the northwest part of the Delaware basin, and in large part controlled the reef zones which ringed the basin at this time.

By middle Wolfcampian time the major uplifts were farther north, and the Pedernal uplift in the area of this report was almost buried by its own debris. Marine and nonmarine interfingering of the Hueco Limestone and the red beds of the Abo was taking place with the encroachment of the nonmarine environment from the north. On the west side of the buried Pedernal uplift, the eastward as well as northward pinch out of the Pendejo tongue of the Hueco into the Abo is seen in the wells of the area.

While the Delaware basin may have begun to subside in Early Pennsylvanian time, it did not assume a definite shape until Wolfcampian time. Even then the northwest margin of the basin was not sharply defined. The shelf to basin transition is best reflected by the broad facies change from gray calcareous and green muds of the Hueco Limestone in the shelf areas, across the lighter colored marginal carbonate mounds which would eventually become the Abo reef trend, into the dark calcareous basinal muds. Generation of oil and gas in the deeper parts of the Delaware basin from organic-rich lower Paleozoic rocks had undoubtedly already begun and would continue well into the Mesozoic.

By late Wolfcampian time almost all of the Pedernal uplift was buried beneath the Abo red beds, with a few monadnocks rising above the mud flats in the areas to the north.

The Abo Formation crops out only in the extreme northwest part of the report area. Pray (1958) measured 554 ft of Abo and described the formation in detail in section 30, T. 19 S., R. 12 E., just two miles to the south-southwest of the outcrops in this report. Bachman and Hayes (1958) also studied the Abo and other lower Permian rocks just a few miles to the southwest in the Sand Canyon area. Pray (1958) described the Abo at the south end of the Sacramento Mountains as a sequence of dark, reddish-brown mudstone and arkose with a southward-thickening tongue of gray shale, limestone and dolomite. The Abo red beds are distinctly darker than the "red beds" of the overlying Yeso Formation and are relatively easily distinguished from outcrops of the Yeso. Bachman and Hayes (1958) have divided the Abo into three units. The uppermost is a red bed sequence, which can be traced on the outcrop as far south as Culp Canyon, and consists of reddish-brown mudstone, fine-grained sandstone and siltstone. They named this unit the Lee Ranch tongue. The middle calcareous unit, which thickens to the south, is called the Pendejo tongue of the Hueco Limestone. Outcrops of this tongue of the Hueco Limestone reach as far north as T. 16 S. The basal conglomeratic red-bed tongue is designated the Danley Ranch tongue. These three divisions of the Abo can be identified and correlated in the subsurface in the western half of the report area. The Pendejo tongue generally thins from the west toward the east and completely pinches out as the Abo laps onto the Pedernal uplift. The Abo in the subsurface on the west side of the Pedernal uplift appears to have the same general relationships as those described by Bachman and Hayes (1958) on the outcrop.

The Danley Ranch tongue of the Abo contains conglomerate in the basal part of the tongue in most localities. This conglomerate was probably derived from local source areas which stood until leveled by erosion and covered by this lower tongue of the Abo. This conglomerate may be stratigraphically equivalent with the Pow Wow Conglomerate Member of the Hueco Formation (King and Knight, 1945) and appears to have the same depositional environment. Bachman and Hayes (1958), however, consider the Danley Ranch tongue of the Abo to be a separate unit because the Pow Wow is not traceable into New Mexico from its type locality. Although the Pow Wow in the type area is probably slightly older than the Abo Danley Ranch tongue, the basal Abo conglomeratic zones are apparently depositionally and environmentally equivalent to the Pow Wow and are accordingly correlated in the subsurface. This subsurface interpretation is based on the available well control and is substantiated in part by the outcrop relationships mapped and described by Bachman and Hayes (1958) to the west. Along most of the Sand Canyon outcrop the Danley Ranch tongue rests with sharp angular unconformity on the gray limestone and shale of the underlying upper Magdalena Formation. In some areas pre-Abo uplift and erosion has been so severe that the Abo rests directly on the lower Magdalena. Where these pre-Abo uplifts were so great that erosion could not entirely reduce them, the Danley Ranch tongue is absent by nondeposition and the Pendejo tongue of the Hueco rests directly on the Pennsylvanian.

The Danley Ranch tongue interfingers with the Pendejo tongue of the Hueco, and numerous thin limestone stringers of the Hueco are usually present in the upper part of the Danley Ranch. These tongues of the Hueco pinch out to the northwest or grade progressively to shaly limestone, calcareous gray

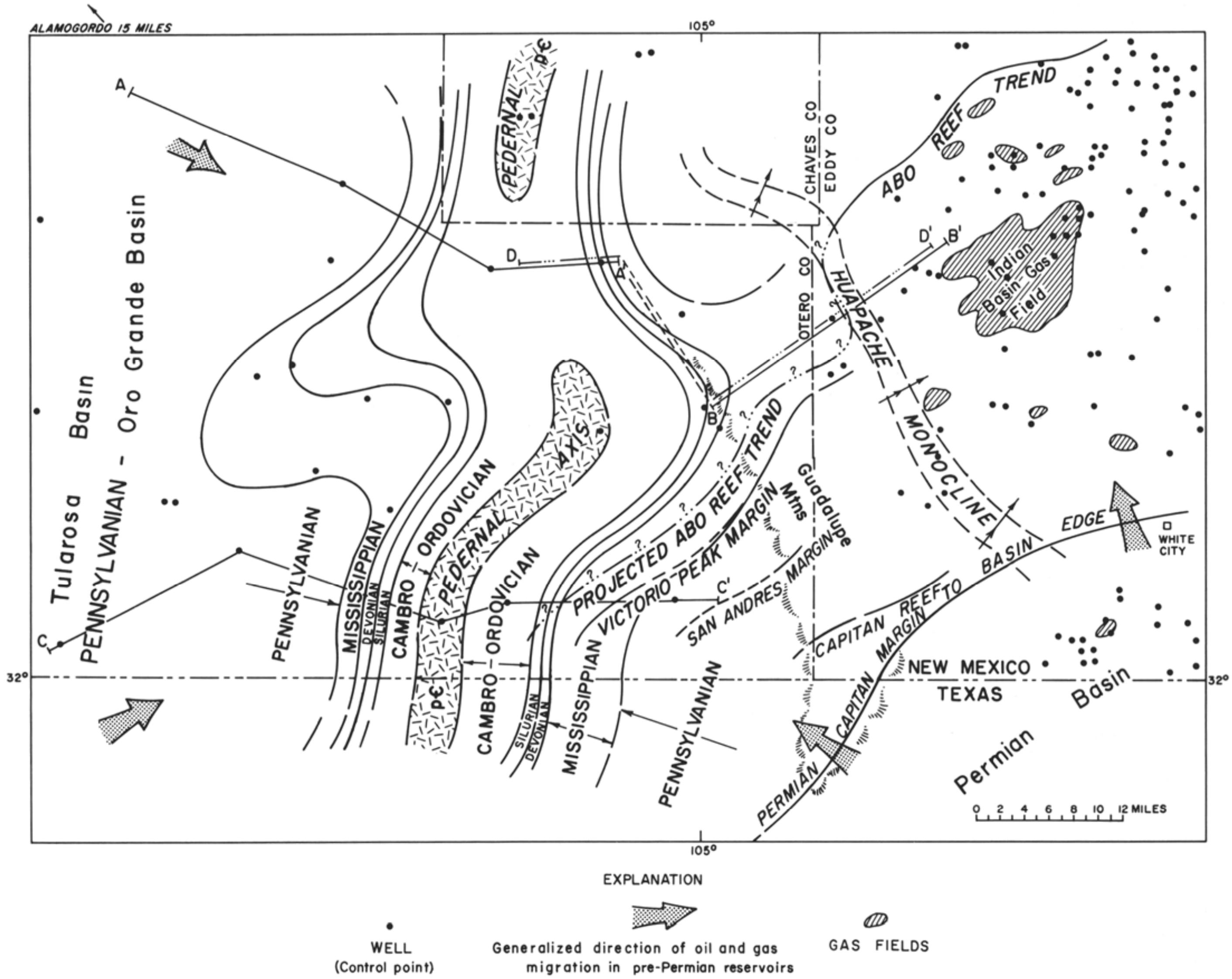

Figure 3. Pre-Permian subcrop map of the Otero platform area, Otero and Chaves Counties, New Mexico.

shale, and finally red shale as they merge into the Danley Ranch tongue.

West of the mapped area the Pendejo tongue of the Hueco Limestone is approximately one-half limestone and one-half shale with minor siltstone and sandstone. The base of the tongue, except in those areas where it lies directly on the Pennsylvanian, is unconformably underlain by the Danley Ranch tongue of the Abo into which it grades northward.

The Pendejo tongue of the Hueco is conformably overlain by the Lee Ranch tongue of the Abo. The transition here, however, is much more abrupt than its basal counterpart. The uppermost beds of the Hueco in Sand Canyon are lateral equivalents of part of the Lee Ranch tongue of the Abo, which is apparently early Leonardian (Bachman and Hayes, 1958); however, most of the Pendejo tongue is probably Wolfcampian (King and Knight, 1945; Lloyd, 1949, Jones 1953).

At the type locality in section 11, T. 20 S., R. 11 E., the Lee Ranch tongue of the Abo is 106 ft thick and is a red siltstone and shale sequence with minor sandstone. The Yeso Formation conformably overlies this tongue of the Abo, and the contact is placed at the lowest pinkish clastic bed or gypsum typical of the Yeso.

By Leonardian time most, if not all of the Abo had been deposited, and the Yeso beds of interbedded gypsum, dolomitic calcareous mud and pinkish silt and mud were being deposited as the marine environment again made its way inland over the former mud flats of the Abo environment. To the north the Yeso sediments may have locally been deposited directly on the Precambrian. In the report area the upper Yeso silt, mud and evaporites graded abruptly into calcareous mud as they passed to the south across the shelf and onto the basin margins. In the southern part of the area the upper Yeso carbonates graded abruptly into the marginal Victorio Peak carbonates which in turn graded to the south into the equivalent dark Bone Spring organic-rich calcareous mud in the Delaware basin. In the Delaware basin further subsidence in Leonard time probably took place along the line of the Bone Spring monocline. The northwest margin of the basin took on a definite form and the submarine marginal bank deposits of the Victorio Peak Limestone were laid down along the trend of the Bone Spring monocline.

In the Sacramento Mountains Pray (1958) measured 1,239 ft of Yeso near Orendorf Peak. This section is believed to be typical of the formation in the subsurface over the northern and central parts of the area. The limestone and dolomite in the upper Yeso are more abundant toward the south and interfinger with siltstone and shale along the Sacramento River outcrops on the McGregor Missile Range in section 26, T. 20 S., R. 13 E. Interfingering of carbonate and clastic lithologies suggests that interfingering of the San Andres and Yeso sections may be much more common than previously suspected. Of particular interest in the upper Yeso in the Dantes Dome area (Black, 1973) is the common very light-gray to almost white limestone which is very similar to the dirty white to light-gray limestone of the Victorio Peak Formation to the southeast.

The basal contact with the Abo is believed to be gradational, and where observed south of Grapevine Canyon it occurs within a few vertical feet.

The San Andres Formation constitutes over ninety percent of all exposures of surface rocks within the report area. Kelley (1971) recognized three members in the area to the north and northeast of this area. He named the three units in ascending order, Rio Bonito, Bonney Canyon and Fourmile Draw. The Fourmile Draw is typically evaporitic where mapped by him. This member is not recognized in the northern part of the report area, but an interval which occupies the same stratigraphic position is mapped in the extreme southern area. Here this unit is not typically evaporitic, however, and may correspond to the carbonate facies of the Fourmile Draw Member. It is predominantly a dark-brown calcareous dolomite which contains calcareous sandstone and sandy limestone in its southernmost exposures.

The Bonney Canyon is the middle thin-bedded member and is recognized in this area, as is the Rio Bonito. The Rio Bonito is a thicker-bedded basal unit that contains the last vestiges of the Glorieta Sandstone in its northern exposures.

In the extreme southeastern part of the report area, light-colored limestone of the lower Rio Bonito Member grades into the Victorio Peak Formation along the east edge of the northern Diablo Plateau. Black (1973) has inferred that the upper Victorio Peak is equivalent to both the upper Yeso and the basal San Andres as suggested by Hayes (1964, p. 24) and is the shelf margin equivalent to these units.

In the northern and northwestern parts of the area, the Glorieta Sandstone occurs in the basal Rio Bonito and is found 100 to 150 ft above the base of the San Andres. However, the Glorieta is not present in outcrop in the Chatfield Canyon section 12 mi southeast of Timberon. Three miles due east of the last outcrops of the Glorieta, Zapata Petroleum Corporation Federal 14-1 drilled in section 14, T. 20 S., R. 14 E., reported a white, medium-grained, sub-rounded, quartz sand with calcite cement from 520 to 530 ft. This sand is 110 ft above the base of the San Andres as picked in the well and is undoubtedly the Glorieta Sandstone.

The lower contact of the San Andres is a gradational interfingering of Yeso and San Andres carbonate rocks.

During latest Leonardian time Yeso sediments slightly intertongued with the San Andres carbonates along the shelf. The Leonardian-Guadalupian boundary is somewhere within this transition from the Yeso to the cherty limestone of the basal San Andres Limestone and the Glorieta Sandstone.

During Guadalupian time the progressive deposition of the Rio Bonito siliceous lime mud occurred. Later it was extensively dolomitized, probably by reflux dolomitization. The margin environment which had produced the Victorio Peak carbonate and biohermal deposition was evidently overwhelmed by a relative rise in sea level at this time, and the upper Rio Bonito calcareous mud was deposited on the shelf over the lighter-colored Victorio Peak marginal carbonate mounds and shoals. Subsequently on the shelf margin to the northwest, the widespread Bonney Canyon thin-bedded carbonates and their associated oolite banks were deposited extensively across a broad, shallow shelf. Shortly thereafter the evaporites of the Fourmile Draw were deposited over much of the shelf and indicate that a possible restriction may again have been developed in the marginal areas. Calcareous mud may have built into carbonate banks or bioherms across the margin at this time.

Erosion has removed all record of subsequent events; however, it is probable that part of the late Guadalupian Artesia Group was deposited over some of the area. It is also possible that the area was emergent by late Guadalupian and Ochoan time as minor pulses of uplift again beset the Pedernal uplift, while to the east the Delaware basin was a restricted area of salt and anhydrite deposition.

Mesozoic Erathem

There are no rocks of Mesozoic age within the mapped area. This does not, however, imply that these rocks were never present. Indeed a number of facts suggest that at least Lower Cretaceous strata were deposited over most of the area. The bulk of this evidence is found in areas that border the Otero platform on the northwest, southeast and west. Cretaceous rocks resting on Permian in the northern Hueco Mountains and the southern San Andres Mountains strongly suggests that at least a thin Cretaceous section once covered the entire platform area.

Widespread erosion of the Otero area probably took place in latest Permian and Early Triassic time, and by Late Triassic the area was essentially a low peneplain upon which the Dockum Group may have been deposited. Kelley (1971) cites the wedge-edge line of the Triassic beneath the Dakota for evidence of renewed rise of the Pedernal uplift in post-Triassic time.

Jurassic rocks, like the Triassic rocks, were progressively beveled towards the south in central New Mexico. Both the Triassic and Jurassic, as well as the underlying Paleozoic rocks are progressively stripped and are overlain by the Cretaceous Dakota from north to south. The erosional pinchouts generally occur to the southwest and seemingly parallel the Burro uplift of southwestern New Mexico. The area was undoubtedly near sea level and was being peneplaned in the Early Cretaceous, and eventually was covered by shallow Cretaceous seas. Post-Cretaceous stripping began during Laramide time when the area was uplifted by broad Laramide warping. Subsequent Eocene and Oligocene volcanic and intrusive activity took place both to the north in the Sierra Blanca area and to the south in the Cornudas Mountains, with coeval doming of Permian sediments above the probable laccolithic-cored Dantes dome (Black, 1973).

Kelley (1971) suggests the broad Pecos slope probably originated in Laramide time and that the Mescalero arch may have extended southwestward from the Ruidoso country through the east slope of the Sacramento uplift toward the town of Piñon. It is possible that a southern extension of this arching could have extended south of Piñon to affect the Otero platform as far south as the south boundary of the report area. He felt that late Tertiary Basin and Range doming and faulting may have shifted the Laramide arching westward to the present position of the Mescalero arch along the crest of the Sacramento uplift. Its present day southern extension could then possibly parallel the western front of the Otero Hills along the McGregor anticline (Black, 1973).

Tertiary System

No Tertiary rocks were recognized in the report area. It is possible that remnants of Tertiary units such as the Ogallala or

Gatuna Formations are present but unrecognized. The Tertiary Ogallala High Plains beds may well have once been continuous over much or all of the Otero platform area.

No Tertiary igneous rocks have been found on the surface within the area. However, southwest of the report area the northern Diablo plateau has been the site of laccolith, sill, and dike intrusions of probable Miocene age (Clabaugh, 1941).

Whether or not Laramide arching extended into this area, the Otero platform was block-faulted in the middle to late Tertiary, and the present structure and topography owes its existence to this Basin and Range-style of tilted fault blocks. The Pleistocene has primarily been a time of erosion, with some Holocene lake beds forming in the small closed basins and playas between the uplifts. Terracing, slumping and solution collapse have been active in Holocene times, along with alluvial fan, arroyo development and stream bed deposition.

STRUCTURE

Setting

The northeast Otero platform straddles the southern extension of the ancient buried Pedernal landmass. The western margin of the area is on the eastern flank of the Paleozoic Orogrande basin, and the eastern margin is on the western flank of the Permian basin. To the south the area is bordered by the northern Diablo platform and the Cornudas Mountains intrusions. To the north it is bounded by the Sacramento uplift and the Dun ken uplift. During the Permian much of this area occupied parts of the western portion of the northwest shelf of the Delaware basin.

Mechanics and Origin

The structural features of this area evolved during at least four periods of deformation, ranging in age from Pennsylvanian to Cenozoic. Late Paleozoic structures were produced during uplift of the Pedernal landmass in Late Pennsylvanian time. Until recently, only indirect subsurface evidence afforded by meager well control could be used to document these features; however, recent seismic work has verified the pre-Permian structures shown in Figure 4 (in pocket), although the magnitude of these structures is probably greater than indicated. Structural styles in the pre-Permian rocks of the Sacramento Mountains are presumably an excellent analog for subsurface structures in the report area.

Laramide deformation, beginning at the close of the Cretaceous, is probably responsible for many of the northwesterly and northerly trending folds. These folds were presumably formed by east-west directed compressional stress. The folds on the surface primarily involve the carbonate rocks of the San Andres Formation; however, the underlying and relatively incompetent Yeso Formation undoubtedly influenced the way the rocks yielded to stress imbalance during folding. The buried Pedernal uplift may have acted as a buffer against which the Otero and Fleming folds were pushed (Black, 1973), whereas the rocks overlying the Pedernal landmass and the areas to the east of this feature were less deformed. Laramide folding produced relatively symmetrical, gently dipping and commonly doubly plunging folds.

Unfortunately no Tertiary units overlie these structures. The peneplaned surface of the Chert plateau is, however, affected by the subtle folding. If this surface is related to the late Tertiary surface upon which the Ogallala Formation was deposited, then the folds may be post-Ogallala and are a result of late Tertiary deformation. The origin of these folds appears to be open to debate, and it is possible that they represent more than one period of tectonism.

Late Tertiary tectonism has produced the present structural form of the area, primarily through a series of tilted fault blocks, each of which is consecutively less deformed and uplifted to the south and east. These tilted fault blocks are generally outlined by major anticlines and synclines which formed by drape folding over the faulted, tilted and differentially uplifted adjacent fault blocks. The Sacramento and Orendorf anticlines and intervening Sacramento River syncline as well as the Otero syncline, McGregor anticline, Prather syncline and Prather anticline are all primarily caused by drape-folding over deep-seated fault blocks which have been gently tilted to the northeast (Black, 1973).

Direct field evidence regarding the specific origin of many of the features in the area is inconclusive. However, it is probable that the northerly trending anticlinal and synclinal features and smaller folds represent Laramide compressional deformation, which has subsequently been locally altered by late Tertiary activity. The late Tertiary deformation itself may have been subsequently altered by pene-contemporaneous or very late movements during the uplift of the adjacent Sacramento and Guadalupe Mountains. A complex structural origin is not unrealistic in view of the different tectonic events of Laramide and late Tertiary and Cenozoic age which affected this part of New Mexico.

OIL & GAS POTENTIAL

Pre-Permian production on the Central Basin platform from fields such as the Embar, Justis and Crosby field are considered to be close analogs for expected production from pre-Permian rocks on the west flank of the Pedernal uplift, and from the northwest shelf of the Delaware basin on the east flank of the Pedernal uplift.

In the Central Basin platform it is evident that even without pre-Permian seals such as the Woodford, the Permian itself acts as a more than adequate seal at the unconformity with the pre-Permian reservoirs. This can be demonstrated in the Justis field, where both the Fusselman and Montoya produce along the unconformity immediately beneath the Permian. In the Embar field the Devonian, Fusselman and Ellenburger all produce beneath the Permian unconformity where the basal Permian Abo or Wolfcamp limestones seal the unconformity on buried topographic highs.

Pre-Permian structures are also obviously present and important in the pre-Permian fields of the Central Basin platform and localize migrating hydrocarbons both into closed structures as well as along erosional highs on the paleo-topography. Post-Early Permian generation and migration of hydrocarbons from lower Paleozoic source rocks such as the Simpson and Woodford, and probably from source rocks in the Mississippian and Pennsylvanian, is evident by these field relations.

The lower Paleozoic package in the Orogrande basin is suspected to contain an analogous source-rock potential. Regional structural considerations suggest a similar timing of source-rock maturity and hydrocarbon migration for these rocks. Pre-Permian structures and topographic highs beneath the Permian unconformity, particularly where permeable facies are folded or subcrop on both the east and west flanks of the buried Pedernal uplift, may form traps over large areas of the Otero platform.

Paleo-reconstruction of a section from the northwest shelf of the Delaware basin west across the Huapache monocline, the buried Pedernal uplift and onto the east flank of the Orogrande basin (Figure 4) shows the relationship of the pre-Permian Paleozoic section to the deeper oil generating areas both to the west and east of the buried Pedernal uplift. This section dramatically demonstrates the potential directions of hydrocarbon fetch up and onto the flanks of the buried Pedernal uplift until Tertiary break-up of the area. Permian and post-Permian downwarp in both the Delaware basin to the east and in the Orogrande basin to the west has increased this dominant direction of fetch up onto the Pedernal flanks.

All present production on the north and northwest shelf areas of the Delaware basin lies east of the Huapache monocline. Exploration west of this feature has been minimal and sporadic. North of the New Mexico-Texas state line, only five wildcats have been drilled in twenty-two townships west of the Guadalupe Mountains and east of the buried Pedernal landmass.

This lack of exploration activity is remarkable inasmuch as this area has been part of the northwest shelf of the Delaware basin, and its history of oil migration and entrapment of hydrocarbons appears to have been similar to the prolific area of the shelf east of the Huapache monocline. The reasons for this lack of interest are many, not the least of which is the imposing Guadalupe Mountains escarpment. This impressive barrier rises abruptly to meet the Delaware-basin geologists working westward from out of the flats of southeastern New Mexico. Beyond its possible physical intimidation, however, lie good geologic reasons why production has not yet been found over parts of the report area.

Plio-Pleistocene uplift and erosion of the Guadalupe and Brokeoff Mountains has exposed much of the Permian section and destroyed or flushed hydrocarbon reservoirs in the Permian rocks. Erosion as deep as the Abo Formation along the Guadalupe escarpment has provided fresh water intake points and caused northeasterly directed flushing into large areas of the northwest shelf. This relatively recent tectonic activity has undoubtedly provided a mechanism for destruction of many oil and gas accumulations, particularly in the Permian section.

Hydrodynamic inflow has been an important factor limiting the production of the Abo reef trend to the west. It has also undoubtedly affected pre-Permian accumulations in a similar but probably less dramatic way under the Guadalupe Mountains. However, tectonic disruption and fresh water intake into areas west of the Guadalupe-Brokeoff Mountains is much less impressive, and the possibility of major oil and gas accumulation west of the Guadalupe Mountains and on the flanks of, or east of the buried Pedernal landmass is considered to be a distinct possibility. This is particularly true in the pre-Permian section, since the buried Pedernal uplift should act as a complete or partial barrier to hydrodynamic inflow from the exposed Paleozoic section in the Sacramento Mountains.

In Pennsylvanian time, the area west of the Huapache monocline and east of the buried Pedernal uplift was structurally high to both the Delaware basin and the other portion of the northwest shelf. The Huapache monocline was active as early as the Late Pennsylvanian and may have acted as a barrier to oil and gas migration from east to west on the shelf in pre-Permian rocks. However, the areas west of the Huapache monocline would have received the bulk of any oil and gas migration from the southeast directly out of the subsiding Delaware basin and onto the flanks of the Pedernal uplift. In effect, the Huapache monocline may have produced a "shadow" zone of little or no hydrocarbon accumulation immediately west of this feature in the pre-Permian rocks, but should not have effected areas farther west where hydrocarbon migration updip from the Delaware basin had a straight shot at stratigraphic and structural traps in the Salt basin and Brokeoff Mountain areas. On the other hand, if the tectonic features associated with the Huapache monocline were not barriers to migration of hydrocarbons, significant accumulations of pre-Permian oil and gas could be present immediately west of the Huapache monocline if they were not flushed in late Tertiary and Quaternary time.

Figure 3 illustrates the possibility of also finding Abo "reef" facies in the areas west of the Guadalupe Mountain escarpment. In this figure the generalized shelf to margin transition zone for the Capitan, San Andres, and Victorio Peak (upper Yeso-lower San Andres) is shown by the annotated dashed lines. The Capitan and San Andres trends are well documented in the Brokeoff and Guadalupe Mountains, where they have been discussed by Boyd (1958), Hayes (1964), King (1948), and others. In addition the Victorio Peak transition in the Brokeoff Mountains was recognized by Boyd (1958). Black (1973) recognized the same Victorio Peak transition west of the Salt basin on the Otero platform. It is on this basis that the trend of the Victorio Peak transition is drawn and that the underlying Abo reef trend is hypothetically projected. The Abo trend is projected northwest of the Victorio Peak trend and southeast of the Pedernal positive area across the upper Salt basin and the Guadalupe Mountains to the point where it can be documented by facies relationships seen in the more abundant well control in the vicinity of the Huapache monocline. If the Abo trend is actually present in this area, the migration of petroleum into the Abo reef facies in pre-late Tertiary time could leave Abo oil and gas accumulations trapped in shallow reservoirs somewhere beneath the north end of the Salt basin.

It is also possible that the Abo marginal facies may have "ringed" the slight positive Pedernal core area in Abo time, and the reef facies may lie at shallow depth on both sides of this old feature. Exploration for the Abo "reefing" would, however, be very difficult and would require many more control points than presently available. It is therefore a potential "bonus" but is considered a secondary objective in the Otero platform area.

REFERENCES

Armstrong, A. K., 1962, Stratigraphy and paleontology of the Mississippian System in southwestern New Mexico and adjacent southeastern Arizona: New Mex. Bur. Mines and Min. Res. Mem. 8, 99 p.

Bachman, G. 0., and Hayes, P. T., 1958, Stratigraphy of upper Pennsylvanian and lower Permian rocks in the Sand Canyon area, Otero County, New Mexico: Geol. Soc. America Bull., v. 69, p. 689-700.

Black, B. A., 1973, Geology of the northern and eastern parts of the Otero platform, Otero and Chaves Counties, New Mexico (Ph.D. dissert.): Albuquerque, Univ. New Mexico, 261 p.

Boyd, D. W., 1958, Permian sedimentary facies, central Guadalupe Mountains, New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 49, 100 p.

Clabaugh, S. E., 1941, Geology of the northwestern portion of the Cornudas Mountains, New Mexico (M.S. thesis): Austin, Univ. of Texas, 68 p.

Denison, R. E., and Hetherington, E. A., Jr., 1969, Basement rocks in far west Texas and south-central New Mexico, *in* Border Stratigraphy Symposium: New Mex. Bur. Mines and Min. Res. Circ. 104, p. 1-16.

Hayes, P. T., 1964, Geology of the Guadalupe Mountains New Mexico: U.S. Geol. Survey Prof. Paper 446, 69 p.
Jones, T. S., 1953, Stratigraphy of the Permian Basin of west Texas: West Texas Geol. Soc., 63 p.
Kelley, V. C., 1953, Regional tectonics of south-central New Mexico, *in* Southcentral New Mexico: New Mex. Geol. Soc. Guidebook 6, p. 96-104.
Kelley, V. C., 1971, Geology of the Pecos country, southeastern New Mexico: New Mex. Bur. Mines and Min. Res. Memoir 24, 73 p.
King, P. B., 1948, Geology of the southern Guadalupe Mountains, Texas: U.S. Geol. Survey Prof. Paper 215, 183 p.
King, R. E., and Knight, J. B., 1945, Geology of the Hueco Mountains, El Paso and Hudspeth Counties, Texas: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 36, 2 sheets.
Kottlowski, F. E., 1960, Depositional features of the Pennsylvanian of south-central New Mexico: Roswell Geol. Soc., Guidebook, 1960 Fall Field Conf., p. 97-130.
Kottlowski, F. E., 1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 79, 100 p.
Kottlowski, F. E., 1965, Sedimentary basins of south-central and southwestern New Mexico: New Mex. Bur. Mines and Min. Res., Reprint Ser. 19, p. 2120-2139.
Kottlowski, F. E. and LeMone, D. V., 1969, Border Stratigraphy Symposium: New Mex. Bur. Mines and Min. Res. Circ. 104, 123 p.
Laudon, L. R., and Bowsher, A. L., 1949, Mississippian formations of southwestern New Mexico: Geol. Soc. America Bull., v. 60, p. 1-88.
LeMone, D. V., 1969, Cambrian-Ordovician in El Paso border region, *in* Border Stratigraphy Symposium: New Mex. Bur. Mines and Min. Res. Circ. 104, p. 17-25.
Lloyd, E. R., 1949, Pre-San Andres stratigraphy and oil producing zones in southeastern New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 29, 79 p.
McGlasson, E. H., 1969, Siluro-Devonian of west Texas and southeastern New Mexico, *in* Border Stratigraphy Symposium: New Mex. Bur. Mines and Min. Res. Circ. 104, p. 26-37.
Meyer, R. F., 1966, Geology of Pennsylvanian and Wolfcampian rocks in southeast New Mexico: New Mex. Bur. Mines and Min. Res. Mem. 17,123 p.
Newell, N. D., Rigby, J. K., Fischer, A. G., Whiteman, A. J., Hickox, J. E., and Bradley, J. S., 1953, The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico, A study in paleoecology: San Francisco, W. H. Freeman and Co., 236 p.
Pray, L. C., 1958, Stratigraphic section, Montoya Group and Fusselman Formation, Franklin Mountains, Texas: West Texas Geol. Soc., Guidebook of Franklin and Hueco Mountains, p. 30-42.
Pray, L. C., 1961, Geology of the Sacramento Mountain escarpment, Otero County, New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 35, 144 p.
Thompson, J. L., 1942, Pennsylvanian System in New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 17, 90 p.

Table 1. Oil and gas tests drilled in and adjacent to this report area.

WELL NAME	Location	Elev. T.D.	Scout Ticket	Sample Log	Elec. Log	Gamma Ray-Neutron Log	Sonic Log	Micro Log	Mud Log	Paleo. Data	DST Data	Oil(o) and gas(G) shows (depth)
Humble Oil & Ref. State 1-Y	Sec. 33 T11S-R27E	3708′ 7430′	x	x	x					x	x	
Socony Mobil White Ranch Co. #1, #3	Sec. 34 T11S-R29E	3792′ 8775′	x	x	x	x					x	
Malco Ref., Inc. Waller No. 1	Sec. 35 T12S-R28E	3669′ 8820′		x	x	x			x	x	x	
Magnolia Petro. Co. Shaw—Fed. #1	Sec. 6 T13S-R31E	4031′ 12072′	x	x	x			x		x	x	
Southern Prod. Co. Cloudcroft Unit Fed. 1	Sec. 5 T17S-R12E	9374′ 4708′	x	x	x					x		
Texas Prod. Dunken Dome No. 1	Sec. 29 T17S-R18E	5340′ 4900′	x	x						x		
Gulf Oil Co. Chavez State No. 1-U	Sec. 10 T18S-R16E	6300′ 3147′	x	x	x	x					x	
Kewanee Oil F-M Unit No. 1	Sec. 26 T18S-R18E	5218′ 6562′	x	x	x					x	x	
Sun Oil Company Pinon Unit No. 1	Sec. 19 T19S-R17E	6989′ 1911′	x	x								
Plymouth Fed. No. 1	Sec. 15 T20S-R9E	4044′ 7585′	x	x	x			x		x		
Sun Oil Company Pearson No. 1	Sec. 35 T20S-R10E	6989′ 1911′	x	x	x					x		
Zapata Petro. Co. Federal No. 14	Sec. 14 T20S-R14E	6918′ 5043′	x			x						
Atlantic Ref. Co. State "AV" No. 1	Sec. 16 T20S-R15E	6298′ 4027′	x		x			x			x	
Stanolind Oil & Gas Thorn Unit No. 1	Sec. 15 T21S-R14E	6310′ 4646′	x			x						

Table 1—continued.

WELL NAME	Location	Elev. T.D.	Scout Ticket	Sample Log	Elec. Log	Gamma Ray-Neutron Log	Sonic Log	Micro Log	Mud Log	Paleo. Data	DST Data	Oil(o) and gas(G) shows (depth)
Lefors Petrol. Co. Federal No. 1	Sec. 16 T21S-R16E	5386′ 2252′	x			x						
Standard Oil Co. Scarp Unit No. 1	Sec. 18 T21S-R18E	5386′ 2664′	x	x	x				x			1185-1210(G)
Standard Oil Co. State No. 1-E	Sec. 16 T21S-R22E	4464′ 11,312′	x	x	x	x				x		
Otero Oil Co. McGregor & Son No. 1	Sec. 5 T22S-R10E	? 1751′	x	x						x		
Fred Turner No. 1 Everett Permit	Sec. 34 T22S-R13E	4745′ 3945′	x	x						x		
Campbell Herley No. 1	Sec. 30 T22S-R14E	4605′ 2433′	x			x						2191(G) 2225(G)
Continental Oil Co. Bass No. 1	Sec. 5 T22S-R21E	5515′ 5889′	x	x	x				x		x	
Campbell Liberman No. 1	Sec. 7 T23S-R15E	4290′ 2695′	x			x						2370(o)
E. P. Campbell, et al No. 1 Spanel	Sec. 7 T23S-R16E	? 2682′	x				x					
Coral Oil & Gas Co. No. 1 Warren	Sec. 19 T23S-R18E	? 2353′	x									
Weaver Thompson No. 1	Sec. 9 T23S-R19E	4547′ 3848′	x			x						2479-91(o) 2560-2618(G) 2830-40(o)
Campbell McMillan No. 1	Sec. 15 T23S-R19E	4329′ 3189′	x			x						2417(o) 3189(o)
Humble Oil & Ref. Huapache Oil Co. #2	Sec. 23 T23S-R22E	4455′ 12,594′	x	x	x	x					x	
Gulf Oil Co. N. Caverns Unit #1	Sec. 11 T23S-R24E	4009′ 11,515′	x		x							
Texaco, Inc. Remuda Basin No. 1	Sec. 24 T23S-R29E	3045′ 15,141′	x		x	x					x	
Paso-Tero Oil No. 1 Evans Permit	Sec. 22 T23S-R29E	5002′ 3763′	x	x								373 & 410 (G) 1390-1796 (numerous shows of o&G)
Flynn-Welch & Yates Donahue No. 1	Sec. 28 T24S-R12E	4550′ 1688′	x	x								
Union Oil Co. Fed.-White No. 1	Sec. 17 T24S-R22E	5709′ 6745′	x	x	x			x				
Turner State "F" No. 1	Sec. 36 T25S-R16E	4323′ 5198′	x		x							
Dunigan Alpha Fed. No. 1	Sec. 31 T25S-R19E	3804′ 4998′	x		x	x						o & G reported; depths unknown
Sea Board Oil Trigg-Fed. No. 1	Sec. 18 T26S-R11E	5309′ 5597′	x	x	x				x	x	x	2590-2640 & 5080-5300(G) 3390-4934 (many shows of o)
Hunt Oil Co. McMillan & Turner #1	Sec. 5 T26S-R16E	4240′ 2176′	x	x								
Earnest, E. H. et al Located Land Co. #1	Sec. 20 T25S-R7E	4100′ 1251′	x	x								
Union Oil Co. McMillen No. 1-A	Sec. 9 T25S-R13E	5051′ 5215′	x	x						x		3211 (o)