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Stratigraphy and Oil-Producing Zones of the Pre-San Andres Formations of Southeastern New Mexico

A PRELIMINARY REPORT

By

ROBERT E. KING

With an Explanatory Note by Robert L. Bates

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THE STATE BUREAU OF MINES AND MINERAL RESOURCES

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

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EXPLANATORY NOTE

By
ROBERT L. BATES

During the past two years much attention in southeastern New Mexico has been focused on the exploration of rocks below those that up to now have been the source of this State's great production of oil and gas. Prior to the campaign of deep drilling, no commercial production of oil or gas in southeastern New Mexico had been obtained from beds older than the San Andres formation or from depths much greater than 5000 feet. Pre-San Andres formations have been revealed to be several thousand feet thick and to contain numerous commercial accumulations. Their exploration is continuing.

Drilling for oil and gas at unexplored depths below proven pools is as truly wildcatting as drilling in areas that are laterally removed from producing fields. In each case the procedure is from the known to the unknown. If exploration continues, new information keeps accumulating and is used as a means to direct future drilling. The acquisition of new evidence continues so long as drilling continues, but has an element of decreasing value—the evidence from the first dozen new wells drilled in a wildcat area is generally much more valuable than that from the tenth dozen. Reports issued early in the drilling history of an area have considerable value as guides, references and records of progress.

The accompanying bulletin is in the nature of things a preliminary or tentative report. It is issued in the belief that it is wise to attempt a general systematizing of available knowledge relatively early, so as to aid in future work. Statements of finality have been avoided and the way is left open for further reports, in which there will almost certainly be corrections, refinements, or additions to the present one.

King's report may be considered a supplement to Bulletin 18 of this series, in which are treated in some detail the oil and gas resources of southeastern New Mexico in the San Andres and younger formations.

The difficulties of applying to deep subsurface rocks a stratigraphic terminology carried in from surface outcrops tens or hundreds of miles away are multiplied in southeastern New Mexico by the fact that correlatives of most of the pre-San Andres formations crop out both to the east in Texas and to the west in central New Mexico and have received different names in the two states. King has met these difficulties by using the stratigraphic terms that seem to him the most reasonable, not restricting himself to terms from either state. Noting this, pre-publication critics have remarked on the absence of a Texas-New Mexico correlation chart. Such a chart is certainly desirable, but it is felt that our stratigraphic knowledge at present is so incomplete that indication of the exact equivalence of Texas pre-San Andres units with those of New Mexico would be better left for a future progress report on exploration of the deep formations of southeastern New Mexico.

Stratigraphy and Oil-Producing Zones of the Pre-San Andres Formations of Southeastern New Mexico

A PRELIMINARY REPORT

By

ROBERT E. KING[1]

INTRODUCTION

Since the beginning of 1944, exploration for oil in formations older than the San Andres has been greatly accelerated in southeastern New Mexico, and has resulted in several important discoveries in Lea County. At the present early stage of development, there are considerable differences among geologists in the nomenclature of the formations. The purpose of the present paper is to attempt standardization of names and correlations of the older subsurface units in southeastern New Mexico, and to compare the names used with those established for the surface outcrop sections in the State. It is recognized that southeastern New Mexico is a part of a regional geological province, the South Permian Basin, more than half of which lies in Texas; but a full study of the pre-San Andres formations within the whole of that province is beyond the scope of this report. The area here considered is chiefly restricted to the New Mexico counties of Chaves, Eddy and Lea, although sections are described from Socorro, Torrance, Guadalupe, DeBaca, Lincoln and Roosevelt counties.

In order to demonstrate the lateral relations of the rock units, three stratigraphic cross sections are attached to the present paper. They are aligned on sea-level datum because it is believed that in spite of small relative horizontal scale some conception of the regional structure may be gained from such an arrangement. Most of the logs on the cross sections have not appeared on any previously published section. The logs include representatives from each of the areas of deep production and all deep wildcat tests on which information was available before July 1, 1945. By "deep" is meant deep stratigraphic penetration rather than depth from the surface.

The logs used in the cross sections were obtained from a variety of sources, and the writer particularly acknowledges with thanks the cooperation of geologists of the Atlantic Refining Company, Magnolia Petroleum Company, Richfield Oil Corpora-

[1] Formerly consulting geologist, Carlsbad, New Mexico.

tion, Standard Oil Company of Texas, and Amerada Petroleum Corporation. The fact that the logs are based on sample examination by a number of geologists results in some differences in lithologic interpretation. There is, in addition, considerable variation in the quality of the well samples: some logs were prepared from excellent sets of samples, whereas others, particularly for some of the rotary wells in Lea County, were prepared from poor sets, and allowance could not be made for all the effect of contamination by recirculated cuttings. Insofar as possible, an attempt was made to interpret the logs in order to eliminate recirculated material and to generalize the minor alternations of different types of lithology. It would have been preferable to show all the separate layers of different composition in the section by patterns extending horizontally the entire width of each column, but on the small vertical scale used thin units could be shown only by means of percentage.

Most of the correlations shown are based on lithology, but some correlations in the Lower Permian and Pennsylvanian are based on the determination of fusulinids by various paleontologists. Fusulinids are known to be the most useful fossils in that part of the section, particularly in well cuttings where the larger fossils are generally broken into small unidentifiable fragments. Unfortunately, complete paleontological information on all wells containing fusulinids was not available for the present study, as much of this information is of confidential nature. Some of the paleontological data received were conflicting, because the faunas were composed of long-ranging types; the more distinctive short-ranging forms being absent.

The writer is indebted to E. Russell Lloyd, R. V. Hollingsworth, Ronald K. DeFord, and John M. Hills, geologists of Midland, Texas, for reading the paper critically. The report was prepared under the direction of Robert L. Bates of the New Mexico Bureau of Mines and Mineral Resources.

STRATIGRAPHY

PERMIAN SYSTEM

GENERAL STATEMENT

Subdivisions of the Permian system that are used in classification of the subsurface section of the Permian Basin are, with few exceptions, taken from surface outcrops. Some difficulty is experienced in correlating these subdivisions from their distant type localities into the subsurface section, as there is a notable lack of lithologic and faunal uniformity between surface and subsurface, and breaks in deposition and local uplifts in the marginal areas took place at the same time with nearly continuous deposition within the Permian Basin. Different lithologic and faunal facies follow trends roughly parallel to the margins of the Delaware Basin, through which the Permian epicontinental sea connected With the open ocean, and to the margins of the lands bordering the epicontinental sea. After Permian time, the Permian rocks were exposed to erosion in the marginal facies of central Texas and central New Mexico, and in the transition facies to the Delaware Basin in the mountain ranges of westernmost Texas and Eddy and Otero counties, New Mexico.

In the deeper parts of the Permian Basin there are many easily recognizable markers in the section, which permit accurate correlations from field to field and to wildcat tests in intervening areas. Difficulties in correlation generally arise in the attempt to extend the formational names from distant outcrop areas into this easily divisible section. Major unconformities in the surface sections may not coincide with breaks recognizable in the subsurface; and the stratigraphic breaks in marginal facies in different part of the. basin were not everywhere of the same magnitude, so that possibly interruptions of deposition on the Texas side of the Permian Basin may not have coincided at all with those on the New Mexico side.

The established classification of the Permian is into series, based on the chief faunal and lithologic subdivisions in the highly fossiliferous sections of the Delaware Basin and its bordering reef zone, and into formations, most of which have their type localities in areas marginal to the Permian sea. The series are time-stratigraphic units, whereas the formations are lithologic subdivisions which, so far as possible, are correlated as time zones where the names are extended into lithologic facies unlike those at their type localities. The series in upward sequence are Wolfcamp, Leonard, Guadalupe, and Ochoa. The formations of the marginal areas are lithologically unlike those in the Delaware Basin and the reef zone. Some of the formations are almost unfossiliferous, and those with fairly rich faunas contain assemblages that can be correlated with the reef and basin faunas only with some difficulty.

In attempting to classify the subsurface Permian sections according to the series and formation names of the outcrop sections there is, therefore, difficulty not only in correlating the exact boundaries of the formations of the marginal region but also in correlating these formations into the four standard series. In the present paper these difficulties are solved insofar as possible, but, as will be seen in succeeding pages, the exact correlation of some of the named stratigraphic units into the Central Basin Platform section is at present not possible.

GLORIETA SANDSTONE

Surface outcrops of the Glorieta sandstone have been described by Needham and Bates (1943, pp. 1662-1664). At the type locality, in Glorieta Mesa near Rowe, San Miguel County, it consists of 136 feet of white, gray, and buff medium-coarse sandstone. At the surface the sandstone thins progressively from

278 feet near Willard in Torrance County to 12 feet near Bent in the northern Sacramento Mountains. The Glorieta is a wedge of clastic sediments derived from islands in the Permian sea, the remnants of the Ancestral Rocky Mountains, in north central New Mexico. It is generally correlated with the San Angelo sandstone of the central Texas section, and both are regarded as transgressive deposits initiating the San Andres cycle of deposition.

In surface sections in central New Mexico the Glorieta overlies the Joyita sandstone member of the Yeso, from which it is distinguished chiefly by the orange and pink color of the latter. The Joyita is apparently a regressive sand deposited by the retreating Yeso sea, although no unconformity between the two sandstones is distinguished at the surface.

In Guadalupe County the Glorieta is 100 feet thick in the Bellevue No. 1 McMullen near Vaughn (Plate III), and is underlain by 20 feet of dolomite at the top of the Yeso, above the Joyita sandstone. In DeBaca County (Plate III) the Glorieta is 120 feet thick in the Matador No. 1 Woods, 180 feet in the Transcontinental No. 1 McWhorter, and 90 feet in the Land Owners No. 1 State. In all these tests the Glorieta is a white medium-grained pyritic sandstone with some large well-rounded frosted quartz grains. Distinction from the underlying Yeso is easy because the Glorieta and Joyita sandstones are separated by a dolomite layer. This dolomite is dense and light gray, a characteristic type of lithology and color generally associated with the Glorieta-San Angelo part of the Permian section, and distinguished by the letter "D" on the plates.

In southwestern Chaves County (Plate II) the Glorieta is 70 feet thick in the Texas No. 1 State-Wilson on the Dunken dome, but in the Humble No. 1-N State on the Manning dome there is uncertainty whether the Glorieta-Joyita contact should be placed at 100 feet, at the boundary between 20 feet of gray and light brown sandstone and underlying red sandstone, or at 150 feet at the top of a thin dolomite layer.

In Eddy and Lea counties the distinction between the Glorieta sand and the upper sands of the Yeso is difficult because the Glorieta thins southeastward from its source in north central New Mexico, and dolomite and anhydrite wedge into the Joyita member of the Yeso. The criteria for distinguishing the two sand units at and near the surface outcrops are here not usable. In general, subsurface geologists identify the base of a sand 150 feet or more below the top of the Glorieta as the top of the Yeso. Because of the known southeastward thinning of the Glorieta, the possibility must be considered that only the highest sand, in places less than 10 feet thick, of the so-called Glorieta of Lea County may actually be equivalent to the type Glorieta, and that the remainder of the sandy zone may be Joyita (upper Yeso). It is even possible that the Glorieta wedges out completely toward the southeast, .and that the top of the so-called Glorieta sand of most of Lea County is the top of the Yeso. Many geologists, noting that the subsurface Glorieta of Lea County is much more similar to the Yeso in the lithology of its interbedded sands and dolomites than it is to the overlying San Andres, refer to the top of the Glorieta as the top of the Yeso.

It is here concluded that in Eddy and Lea counties the horizon termed the top of the Glorieta should continue to be so termed, but that until more subsurface control is available for establishing an exact correlation no attempt should be made to identify the Glorieta-Yeso contact.

YESO FORMATION

The type section of the Yeso formation, near the Mesa del Yeso in Socorro County, has been described in detail by Needham and Bates (1943, pp. 1657-1661) . The formation there is 592 feet thick, and consists of an upper cross-bedded sandstone, the Joyita member; a thick gypsum, the Callas member; a succession of thin limestones, gypsum, silt, and sandy shale; and a basal clastic zone characterized by pink and orange sandstone. The Yeso thickens southeast from the type section; in the northern San Andres Mountains it is 900 feet thick, and in the northern Sacramentos 1050 feet.

Near the Permian land masses in north central New Mexico the Yeso sea was brackish, and elastic sediments were deposited (see log of the Petrol No. 1 State, Plate III). To the southeast the sea was highly saline, and in southwestern Guadalupe County and in DeBaca County a high proportion of the Yeso is salt, which is interbedded with anhydrite, sandstone which is chiefly red, and dolomite (Hills, 1942, Fig. 4) . Still farther southeast is a facies of dolomite, limestone, anhydrite, and red clastics, and near the margin of the reef zone bordering the Delaware Basin the Yeso is cherty dolomite with thin layers of gray sandstone and anhydrite.

In its saline facies in Guadalupe and DeBaca counties the Yeso is between 1895 and 2120 feet thick. On the Manning dome in Chaves County it is 1760 feet thick and on the Dunken dome 1985 feet. Here the section is of dolomite and limestone, anhydrite, and red elastics. In the more calcareous facies of southeastern Chaves, northeastern Eddy, and northern Lea counties the thickness from the top of the Glorieta to the top of the Abo is between 2075 and 2350 feet.

In central New Mexico the Yeso is bounded above by the base of the Glorieta sandstone and below by the top of the Abo formation. In the subsurface of southeastern New Mexico, where there is uncertainty regarding the base of the Glorieta, the upper limit of the Yeso cannot, be defined accurately; and in Eddy and Lea counties south of T. 16 S. typical Abo is not recognizable because of southward gradation to limestone and dolomite.. There is no satisfactory basis from available data for correlating the Yeso southward beyond where the Abo grades into carbonates, and the formational name cannot be used with precision beyond this transition.

The name Clear Fork is frequently used among subsurface geologists for that part of the Leonard series below the base of the Glorieta in eastern Lea County. This is not a satisfactory alternative to use of the name Yeso where the Abo shales are absent, because the base of the Clear Fork in its type area in north central Texas is the top of the upper Wichita, which is of early Leonard age. Correlation of the top of the Wichita group from north central Texas to southeastern Lea County is even less feasible at present than correlation of the top of the Abo into the same area.

The best natural division within the beds of early Leonard age in the subsurface of southeastern Lea County and adjacent parts of West Texas is the top of the Drinkard, sandy member (see Fig. 1), which is discussed below. This clastic zone has not, however, been correlated into the surface sections on which our present classification is based, and it is only known that the Drinkard member occurs within the Yeso and the Clear Fork. It is concluded that in southeastern Lea County no natural subdivision of the Leonard would coincide with the boundaries of either the type Yeso or the Clear Fork. Rather than introduce new names into the already complex nomenclature of the Permian Basin, it is recommended that throughout southeastern New Mexico the part of the Leonard series above the Drinkard sandy member and below the Glorieta be referred to as upper Yeso; that north of T. 16 S., the section between the top of the Drinkard and the top of the Abo shales be termed lower Yeso ; and that south- of T. 16 S., where the Abo shales grade into carbonates, the section lying between the top of the Drinkard and the top of the Wolf camp be called lower Leonard.

This subdivision of the Leonard is a matter of convenience and is not intended to have formal stratigraphic rank; it does not correspond with the subdivisions of the Leonard series in geological papers dealing with other areas, such as the Glass Mountains of Texas.

Upper Yeso.—The Joyita sandstone member of the upper Yeso can be recognized with certainty in the subsurface only in Guadalupe, DeBaca, and southwestern Chaves counties. In these areas it is separated from the Glorieta sandstone by up to 20 feet of dense dolomite, in places sandy and argillaceous. South-eastward from the Bellevue No. 1 McMullen in Guadalupe County, the Joyita grades from a solid sandstone to alternating anhydrite, salt, dolomite, and red shale, with red sandstone layers. As stated in the discussion of the Glorieta, an undetermined amount of the sandy zone commonly called Glorieta in the

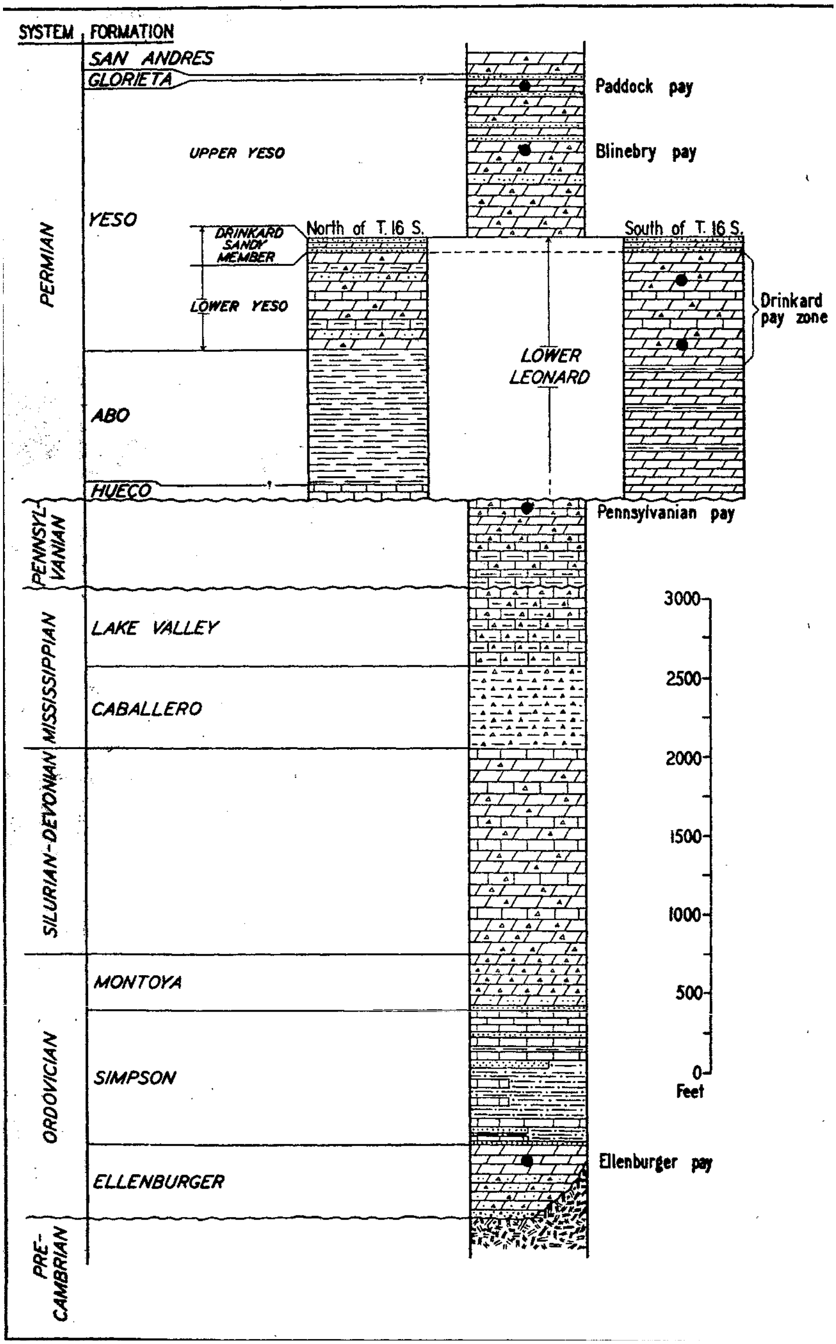

FIGURE 1.-Generalized stratigraphic section of pre-San Andres rocks in eastern Lea County, showing pay zones. Symbols in column are the same as those used on plates.

subsurface of Eddy and Lea counties may prove to be equivalent to the Joyita.

The Callas gypsum member of the Yeso is an easily distinguished unit in the surface sections of central New Mexico, but in the much thicker subsurface sections, with evaporites interbedded throughout, it is not separately recognizable.

In southeastern Lea County the Glorieta sandstone and sandy dolomite are underlain by brown finely crystalline and dense dolomite, in part sandy, with layers of gray shale and thin fine-grained sandstones. Between 270 and 400 feet below the top of the Glorieta is the top of a 60- to 170-foot zone of fine-grained sandstone interbedded with sandy dolomite. In northern Eddy County the upper Yeso section in the Yates No. 3 Evans and the Sanders No. 1 Hultman (Plate II) is thicker and more clastic, and the interval from the top of the Glorieta to the top of this sandy zone is 550 feet. The sandy zone is a commonly used marker in subsurface correlations.[2]

Below the upper Yeso sandy zone in eastern Lea County is 550 to 630 feet of brown cherty crystalline dolomite, in part slightly sandy, to the top of the Drinkard sandy member. In the two deep tests in northern Eddy County shown on Plate II the thickness is 630 and 680 feet, and numerous layers of fine-grained sandstone are interbedded with the dolomite.

Drinkard sandy member.--The name Drinkard sandy member of the Yeso formation is here given to a widespread clastic zone in the middle or lower part of the Yeso or "Clear Fork" that is a stratigraphic marker easily recognized in much of the South Permian Basin (Fig. 1) . The names, "Fullerton sand" and "Tubb sand" (Moore, 1944, p. 1542) have been in general use among Permian Basin geologists for this unit; the former is derived from the Fullerton oil field in northwestern Andrews County, Texas, and the latter from the Tubb Ranch in the Sand Hills oil field in Crane County, Texas. However, although the Drinkard sandy member is believed identical with the "Fullerton sand" of the Fullerton field, the name Fullerton is preoccupied; and the name Tubb is not thought applicable because some geologists express uncertainty as to the exact equivalence of the unit in question with the "Tubb sand" of the Sand Hills field.

The type section of the Drinkard sandy member is designated as that penetrated in The Texas Company No. 1 Blinebry, 660 feet from the south line and 1980 feet from the east line of sec. 19, T. 22 S., R. 38 E.., in the Drinkard area, Lea County. Samples from this well are on file in the offices of most of the major oil companies that operate in southeastern New Mexico.

In eastern Lea County the Drinkard sandy member is 90 to 110 feet thick, and consists of very fine-grained calcareous and

[2] Geologists of one company refer to the zone as the San Angelo, which they thus place below the Glorieta. This is contrary to generally accepted correlations.

argillaceous gray and brown sandstone and sandy shale, in part pyritic, interbedded with brown sandy dolomite. In the two northern Eddy County wells shown on Plate II it is 135 and 140 feet thick, with a higher proportion of sandstone than in eastern Lea County. In the Yates No. 3 Evans one sample was slightly lignitic. In the Sanders No. 1 Hultman the sandstone is fairly coarse and contains some large round grains. The Drinkard member .may have been encountered in two tests west of the Pecos River in Eddy County—from 2724 to 2847 feet in the Stroup, Yates and Flynn No. 1 Hartz-State in sec. 16, T. 21 S., R. 23 E., 'and from 2532 to 2565 feet in the Truett and Tallmadge No. 1 Rudahl in sec. 8, T. 20 S., R. 24 E. In these tests the sand-

Sample Description of Drinkard Sandy Member of Yeso Formation in Texas No. 1 Blinebry, Sec. 19, T. 22 S., R. 38 E., Lea County, New Mexico

YESO FORMATION

Depth in Feet	Percent	Description
6080-90	90	gray finely crystalline dolomite
	10	chert
6090-6100	95	dolomite
	5	gray shale
Drinkard sandy member 6100-6210		
6100-10	65	gray dolomite with dark carbonaceous spots
	30	gray fine-grained argillaceous sandstone
	5	gray shale
6110-20	70	gray dolomite with dark carbonaceous spots
	30	gray fine-grained argillaceous sandstone
6120-30	70	gray and light brown finely crystalline dolomite
	15	chert
	10	black shale
	5	fine-grained sandstone
6130-40	85	gray and light brown finely crystalline dolomite
	15	fine-grained sandstone
6140-50	90	slightly porous dolomite
	10	fine-grained sandstone
6150-60	100	porous gray and brown dolomite
6160-70	100	porous gray and brown dolomite, oil-stained
6170-80	100	finely crystalline porous brown dolomite with anhydrite inclusions; oil-stained
6180-90	95	brown finely crystalline porous dolomite
	5	black shale
6190-6200	90	brown finely crystalline porous dolomite
	5	black shale
	5	fine-grained sandstone
6200-10	90	brown finely crystalline porous dolomite
	10	fine-grained sandstone
		trace black shale
6210-30	95	brown finely crystalline partly porous dolomite
	5	shale

stone is fine- to medium-grained. The correctness of correlation of the Drinkard sandy member in these wells may be questioned because of the thinness of the section between it and the top of the Glorieta — 792 and 828 feet respectively. However, it is significant that the facies of upper Yeso in the Hartz-State and Rudahl tests is similar to that of the Drinkard area, showing that south of the Sanders test and the Yates No. 3 Evans and north of the reef zone bordering the Delaware Basin a facies of the Yeso like that of the Central Basin Platform is present.

In the Texas No. 1 State-Wilson on the Dunken dome the Drinkard sandy member is correlated from 2235 to 2380 feet. It is a coarse sandstone with frosted grains. The upper half is gray and the lower red, with red and gray shale interbedded below 2335 feet. In the Humble No. 1-N State on the Manning dome the Drinkard member is believed to lie between 1365 and 1530 feet. It is red and contains frosted grains in the upper part. In the Land Owners No. 1 State, southeastern DeBaca County (Plate III) , sandstone between 3615 and 3785 feet is correlated with the Drinkard member. It is coarse, with rounded to sub-rounded frosted grains, and contains layers and inclusions of salt. In the three logs on Plate III northwest of the Land Owners log, red sand and sandy shale below the main salt beds of the Yeso are correlated in general with the Drinkard sandy member.

Lower Yeso.—The character and thickness of the Drinkard sandy member, topmost unit of the lower Yeso, are discussed above. In Guadalupe and DeBaca counties about 330 feet of anhydrite, salt, red sandstone, and thin layers of dolomite lie between the base of the Drinkard member and the top of the Abo shales. On the Dunken and Manning domes (Plate II) are 380 feet of anhydrite, dolomite, and sandstone. In the northern Eddy County logs on Plate II, between the Drinkard member and the Abo are 575 and 620 feet of brown dolomite, sandy in the upper part and shaly and anhydritic in the lower 200 feet.

Although beds of lower Yeso equivalence are included in the unit designated lower Leonard in this report, the lower Leonard also includes equivalents of the Abo formation; hence discussion of the lower Leonard is deferred until after discussion of the Abo.

ABO FORMATION

The type section of the Abo formation in Abo Canyon, Valencia and Torrance counties, has been described in detail by Needham and Bates (1943, pp. 1654-1657). There and in most exposures in central New Mexico the formation is about 60 percent red shale and about 40 percent sandstone, arkose, and conglomerate. At the type locality the Abo is 915 feet thick and overlies an unnamed basal Permian limestone.

In subsurface correlations there is some uncertainty as to where the lower limit of the Abo should be placed. To judge from the type section, the base should probably be put at the top of the highest fossiliferous limestones, even though red clastic beds occur intercalated with these limestones. In Guadalupe and DeBaca counties (Plate III) and in Roosevelt County (Plate I) the thickness of the Abo varies from 940 to 1115 feet; the formation is mostly red shale with some green layers. Variable amounts of dolomite are interbedded, together with beds of arkosic sandstone that thin and become less arkosic southeastward from the Bellevue No. 1 McMullen. In the DeKalb No. 1 White, in eastern Chaves County, the Abo is 920 feet thick and consists of red shale, some light green shale, and thin layers of dolomite.

In the Humble No. 1-N State (Plate II) on the Manning dome, the section between the top of the Abo and the top of the probable pre-Cambrian, about 2000 feet in thickness, is entirely shaly arkose except for a few layers of dolomite and limestone. The upper, half of this section is red and the lower gray, and the upper 1000 feet more or less may be correlated with the Abo. In the Texas No. 1 State-Wilson, on the Dunken dome, the Abo consists of 965 feet of red and green shale with layers of conglomeratic red sandstone and layers of dolomite that are thickest in the lower 300 feet. In the Sanders No. 1 Hultman (Plate II), the Abo is 1095 feet thick and consists of purple, green, and red shale, with layers of dolomite that comprise 50 percent of the lower half of the formation.

There is no certainty that the top and base of the Abo are time boundaries. The Abo shales grade southward to dolomite and limestone, as shown by the absence of all shale except thin green laminae in southeastern Lea County sections and by the highly dolomitic character of the lower Abo in the Sanders No. 1 Hultman, near Artesia, the southernmost typical Abo section yet drilled. The change in carbonate rocks from dolomite to lime-stone, here used as a criterion for the base of the Abo, did not necessarily occur at the same time throughout the region. However, it is likely that the upper and lower limits of the Abo as here drawn are close to, if not exactly, time boundaries because of the limited range in thickness of the Abo and of the stratigraphic units above and below it.

The Abo has been placed in the Wolfcamp series by practically all writers on Permian Basin geology except P. B. King (1942, pp. 674-677, 689-690, 7.38-741), who pointed out that the Abo overlies beds with Wolfcamp fossils in the Sacramento Mountains and that the formation itself contains no fossils other than plants of Leonard affinities, and vertebrates of Admiral and Belle Plains (upper Wolfcamp) age. The most convincing evidence of Wolfcamp age of the Abo was the fact that the upper Abo could apparently be traced south into the Deer Mountain redbeds of the Hueco Mountains, and that lime-tone above those redbeds contained the Wolfcamp fusulinid

Pseudoschwagerina (P. B. King, 1943, pp. 676-677). Thompson (1942, Plate II) has shown an apparent complete transition from the Abo to the Hueco limestone, of Wolfcamp age.

The age of the Abo now deserves reconsideration because of (1) our knowledge from recent deep drilling that in parts of southeastern New Mexico more than 300 feet of fossiliferous Wolfcamp beds underlie the Abo, and (2) the fact that only about 600 feet of dolomite intervenes between the Drinkard sandy member and the top of the Abo in northern Eddy County, whereas in the Fullerton field of Andrews County, Texas, Leonard fusulinids occur as much as 1200 feet below the Drinkard. It is now suggested that the possibility of the Leonard age of the Abo has not been sufficiently considered by most geologists in the South Permian Basin, and that the supposed arguments favoring Wolfcamp age may be subject to another interpretation. The Abo may perhaps be correlated lithologically with the lower Clear Fork (Arroyo) redbeds overlying the Lueders limestone of the Wichita in north central Texas. The equivalents in the New Mexico section of beds of upper Wichita age, the lowest Leonard of the east side of the South Permian Basin, cannot be proved from information now available. If the Abo is lower Clear Fork, some of the underlying limestone here classed for convenience as Hueco may be Wichita.

LOWER LEONARD OF SOUTHEASTERN LEA COUNTY

In southeastern Lea County wells, between 1040 and 1550 feet of dolomite with layers of limestone and thin beds of shale occur between the base of the Drinkard sandy member and the base of the Permian (Fig. 1). The dolomite is mostly finely crystalline, brown and gray, and the limestone dense and finely crystalline. The shale is black in the upper several hundred feet and green in the lower part; the green shale possibly represents thin tongues of the Abo shale which is believed to replace much of this section toward the north.

The base of the lower Leonard rests on the eroded surface of the pre-Permian formations, ranging in age from Pennsylvanian to pre-Cambrian. Irregularities in the topography of this surface at the beginning of Permian time probably account for part of the variation in thickness of this interval. No important clastic zone separates the Permian from the pre-Permian sedimentary rocks, but in the Texas No. 1 Blinebry (Plate I) there is a basal conglomeratic member above the pre-Cambrian. No paleontological information is available to show whether the lower part of this interval is Wolfcamp or Leonard, correlations of the deep pay of the Skaggs area as Wolfcamp having proved erroneous. In some deep tests drilled in Texas it has been found that several hundred feet of limestone at the base of this part of the section contain upper Wolfcamp fusulinids, and it is here concluded that a small amount of Wolfcamp may be present in some of the southeastern Lea County wells, but that much of the western part of the Central Basin Platform was above sea level in Wolfcamp time.

HUECO FORMATION

The type locality of the Hueco limestone is in the Hueco Mountains of El Paso and Hudspeth counties, Texas. The formation has been defined by P. B. King (1942, pp. 556-562) and restricted to rocks of Wolfcamp age. The name Hueco has been used by Thompson (1942, Plate II) and Bates (1942, pp. 40-41) for rocks of Wolfcamp age in New Mexico. It is here recommended that the name continue to be used for the Permian strata below the Abo, because use of the, series name Wolfcamp implies that the strata so named are exactly equivalent to the Wolfcamp series, whereas our present data do not permit an exact, correlation of the upper boundary of the Wolfcamp.. The Wolfcamp-Leonard contact may occur at the top of the Abo, as it has generally been correlated in the past, or below the top of the Hueco as the term is here used, if the upper Hueco includes strata of upper Wichita age.

As here used, the name Hueco formation is applied to the strata from the top of the highest calcitic limestone below the Abo shale or dolomite to the base of the Permian. In the Sanders No. 1 Hultman (Plate II) this is the interval from 5245 to 5570 feet, consisting of cherty and argillaceous limestone interbedded with gray-green shale. Between 5550 and 5570 feet the lime-stone is apparently conglomeratic, and this is possibly a basal conglomerate of the Permian. Fossil fragments occur throughout the section. Fusulinids of Wolfcamp or early Leonard age have been identified from 5442 to 5528 feet. It is possible that this limestone is of upper Wichita age; if so the Wolfcamp would be absent from this section.

In the DeKalb No. 1 White (Plate III) lithologic correlation suggests that the Hueco lies between 6460 and 6800 feet. It is chiefly gray granular and fine- to medium-crystalline gray and brown limestone, in part cherty. Thin layers of gray shale are included, and a red shale from 6785 to 6800 feet is regarded as basal Permian. Crinoidal fragments are abundant, and some undetermined fusulinids are present.

In the Texas No. 1 State-Wilson on the Dunken dome (Plate II) the interval from 3730 to 4170 feet is regarded as Hueco. It consists of interbedded limestone and red shale; a layer of arkose from 4155 to 4170 feet may mark the base of the Permian. In the Shell No. 1 Harwood, Roosevelt County (Plate I), the Hueco consists of about 140 feet of cherty limestone with Wolfcamp fusulinids, underlain by a basal conglomerate resting on pre-Cambrian quartzite. In the Land Owners No. 1 State (Plate III) the Hueco is correlated as the interval from 5055 to 5550 feet, which contains limestone alternating with red and gray shale, with coarse micaceous sand at the base. Wolfcamp fusulinids have been identified between 5086 and 5366 feet (P. B. King, 1942, p. 676). In the remaining three wells in DeBaca and southwestern Guadalupe counties shown on Plate II, the position of the Permian-Pennsylvanian contact is questionable. The 670 to 950 feet of sedimentary rocks between the Abo and the pre-Cambrian are fossiliferous limestone interbedded with arkose and red, gray, and brown sandy shale. Thompson (1942, p. 11 and Plate I) reports that determination of the fusulinids shows that the Upper Pennsylvanian Virgil series rests directly on the pre-Cambrian in the Transcontinental No. 1 McWhorter and that at least 670 feet of Pennsylvanian is present in the Matador No. 1 Woods. Lacking more precise information, it is concluded that probably between 100 and 300 feet of Hueco is present between the Abo and the Pennsylvanian, and on Plate III arbitrary correlation lines are drawn. In the Petrol No. 1 State, on the flank of the Pedernal Hills, the Abo directly overlies the pre-Cambrian, and it is believed that both the Wolfcamp and the Pennsylvanian wedge out northwestward along the line of the section on Plate III.

PENNSYLVANIAN SYSTEM

In southeastern Lea County (Plate I) Pennsylvanian strata have so far been encountered only in the Dublin and Skaggs fields and in the El Paso No. 1 Ginsberg.

In the Continental No. 2 Skaggs B-23, Permian dolomite overlies Pennsylvanian porous cherty dolomite and limestone at 7695 feet. From 77.70 to 7920 feet is porous dolomite, with some, sand between 7905 and 7920 feet; then cherty and argillaceous limestone to 8220 feet. Most of the interval from 7695 to 8220 feet is glauconitic. Fusulinids of Des Moines age occur from the top of the unit to 8130 feet, and it is believed that the Pennsylvanian rests unconformably on the Devonian at 8220 feet. Evidence of the presence of Mississippian strata is lacking. The Pennsylvanian pay of the Skaggs area was at first believed to be of Wolfcamp age, as reported by Giesey and Raish (1945, p. 754).

In the Humble No. 1 Federal-Leonard, in the Dublin field, 650 feet of brown, gray, white, and black, argillaceous somewhat cherty limestone, from 8020 to 8670 feet, is believed to be Pennsylvanian. In the El Paso No. 1 Ginsberg brown crystalline argillaceous cherty glauconitic limestone, with thin beds of glauconitic sandstone, is believed to be Pennsylvanian. Ostracodes and fusulinids occur between 8000 and 8100 feet. The Pennsylvanian-Permian contact is at 7960 feet, but the top of the Mississippian is not definitely determinable and may be tentatively placed at 8430 feet, at the top of a very cherty limestone. The fusulinids from these tests are reported to be of Atoka, or Derry, age.

In this region only Lower and Middle Pennsylvanian strata are known, and beds younger than Des Moines are thought to be absent. They were probably deposited on the eroded edges of folded pre-Pennsylvanian rocks and were in turn warped and eroded before the Permian was laid down. These events may have occurred throughout much of late Pennsylvanian and Wolf camp time. As a consequence, the Pennsylvanian limestones occur on only a few of the higher structures and may be generally confined to synclines and to anticlines flanking the main uplifts.

Outside of Lea County the Pennsylvanian has been encountered in the subsurface of southeastern New Mexico in the Sanders No. 1 Hultman, probably in the Texas No. 1 State-Wilson (Plate II), and in most of the wells on Plate III. In the Hultman test, 1191 feet of Pennsylvanian limestone and shale, mostly green and gray but partly red, were drilled. Virgil (Upper Pennsylvanian) *Triticites* are reported from 5630 to 6307 feet. In the DeKalb No. 1 White the section from 6800 to 7515 feet, the total depth, is classed as Pennsylvanian. The upper part is gray and brown finely crystalline limestone with layers of gray and red shale that become more numerous downward. Virgil fusulinids have been identified between 6870 and 7261 feet. From 7260 to 7270 feet conglomerate was cored. From 7270 to 7350 feet is soft gray shale, underlain by finely crystal-line oolitic glauconitic limestone with layers of gray and red shale in the lower part. Fusulinids and bryozoans occur in the limestone. Des Moines fusulinids have been determined from 7500 to 7510 feet. The Missouri series is evidently thin, occurring, if present at all, in part of the interval from 7270 to 7 500 feet.

In the Texas No. 1 State-Wilson on the Dunken dome the section below 4170 feet may be Pennsylvanian, but no paleontological data are available. This section is arkose, red and black shale, and conglomerate to 4690 feet, limestone to 4830 feet, and shale, limestone, and dolomite to 4900 feet, the total depth.

Thompson (1942, p. 11 and Plate I) reports Pennsylvanian fusulinids in Guadalupe and DeBaca County wells, with Virgil upon the pre-Cambrian in the Transcontinental No. 1 McWhorter and 670 feet or more of Virgil, Missouri, and Des Moines in the Matador No. 1 Woods (Plate III). This portion of the section is alternating limestone, red and gray shale, and arkose, overlying the pre-Cambrian. As stated in the discussion of the Hueco, the placing of the Permian-Pennsylvanian contact here can be made only arbitrarily until more data are available:

The Pennsylvanian has been drilled in too few tests in southeastern New Mexico to permit many valid generalizations regarding its thickness and character. It is known that in the western part of the Central Basin Platform in southeastern Lea County only a thin Pennsylvania limestone is present. It is probably absent from most of the higher uplifts, and strata of

Missouri and Virgil age have not been found. In Eddy, Chaves, and DeBaca counties the Virgil directly underlies the Permian, and the, complete thickness of Pennsylvanian has been drilled only in wells in western DeBaca and southwestern Guadalupe counties, where less than 700 feet of it is present, probably because of overlap on the Pedernal land mass (Thompson, 1942, Plate I). Whether or not a basin of thick Pennsylvanian strata will be found in Eddy and Chaves counties will not be known until more deep tests are drilled there.

Thompson (1942, p. 22) states as follows:

> Gordon (1907) proposed the term Magdalena group for all sedimentary rocks present in the Magdalena Mountains and other areas of central New Mexico between the Kelly limestone (Mississippian) below and the Abo formation (Permian) above. . . . Almost all Pennsylvanian rocks recognized in other areas of America have correlatives in the Pennsylvanian rocks of the Magdalena Mountains. The term Magdalena, therefore, seems to be essentially synonymous with the systemic term Pennsylvanian. Since 1907 Gordon's proposal has been generally accepted, and all rocks of Pennsylvanian age in New Mexico have been referred to as the Magdalena group, the Magdalena limestone, or the Magdalena formation . . . , and it seems inadvisable to attempt to preserve this well established term by merely restricting the name in any sense to a small portion of the Pennsylvanian of New Mexico. I am not using the term Magdalena in the stratigraphic nomenclature of the Pennsylvanian rocks of New Mexico.

Some geologists have considered that the name Magdalena is applicable to a limestone facies of the Pennsylvanian, but in most published papers the clastic facies of the, Pennsylvanian in northern New Mexico is included in the "Magdalena group". P. B. King (1942, pp. 674-677) referred to the Hueco equivalent in the mountains of southern New Mexico as "the upper part of the Magdalena group", but suggested that "future work will no doubt indicate the desirability of shifting the unit from the Magdalena to the Manzano group" (Abo, Yeso and San Andres). Such a change has, however, not only not been made but the unfortunate name Magdalena has become more deeply entrenched in recent geologic literature published by the U. S. Geological Survey, in which the Hueco is continued to be classed as Magdalena. The names Pennsylvanian and Hueco are fully adequate for designation of those strata, and it is recommended that the term Magdalena, a relic of an antiquated type of stratigraphic nomenclature, be permanently abandoned.

MISSISSIPPIAN SYSTEM

Strata of Mississippian age have so far been encountered only in the southeast corner of Lea County in the western Central Basin Platform. In the Humble No. 1 Federal-Leonard, in the Dublin field (Plate I), gray finely crystalline argillaceous cherty dolomite from 8670 to 8900 feet and black splintery shale from 8900 to 9218 feet are classed as Mississippian. In the El Paso No. 1 Ginsberg, brown glauconitic finely crystalline argillaceous very cherty limestone from 8430 to 8905 feet and black siliceous shale with layers of limestone and dolomite from 8905 to 9415 feet are correlated with the Mississippian of the Dublin area. The black shale contains abundant *Sporangites*. The cherty glauconitic limestone and underlying black siliceous shale are found in various deep tests on the Central Basin Platform in West Texas. The limestone is correlated on the basis of lithology with the Lake Valley limestone of central New Mexico and the Chappel limestone of central Texas, both of Osage age. The maximum thickness of the Lake Valley at the surface is 700 feet in the northern Sacramento Mountains (Bowsher and Laudon, *in* Bates, 1942, pp. 24-29). The lower siliceous shale of the Mississippian is believed to be Kinderhook, and to correlate with the Woodford of Oklahoma and the Caballero formation of south central New Mexico. The Caballero, 30 to 80 feet thick, is a nodular cherty limestone with calcareous shale and silt partings. The lower part of the siliceous shale unit here placed in the Mississippian may possibly be equivalent to the Upper Devonian Percha black shale of central New Mexico.

DEVONIAN AND SILURIAN SYSTEMS

Limestones identified as Devonian and Silurian occur in southeastern Lea County in the western part of the Central Basin Platform. In the middle and southern Central Basin Platform in Andrews, Winkler, Ector, Crane, and Ward counties, Texas, there are marked lithologic differences between rocks of the two systems (R. E. King et al., 1942, pp. 544-545 Jones, 1944). In the Lea County wells that have encountered this section the Devonian is less cherty than to the southeast, and a green shale in the upper part of the Middle Silurian farther southeast is lacking. No paleontological evidence of the age of these beds has yet been brought forth in the New Mexico section. For these reasons accurate separation of the two systems is not attempted in the present paper.

In the Dublin and Skaggs fields and in the El Paso No. 1 Ginsberg, where Mississippian or Pennsylvanian beds occur above the Devonian and thus no appreciable erosion has occurred, the Devonian-Silurian thickness is 1132, 1170, and 1280 feet respectively. In the Humble No. 1 Federal-Keinath and the Olsen No. 1 Langlie, where the Devonian was eroded prior to Permian deposition, the thickness of the Devonian-Silurian is 600 and 835 feet, but in the Stanolind (Ohio) No. 1 Jones it reaches its maximum thickness, 1470 feet, though the Devonian is unconformably overlain by Permian strata.

The upper or Devonian (?) portion of the section is gray, pink, tan, and white finely crystalline and granular siliceous glauconitic limestone and dolomite. Some fossil fragments are observable in cuttings. Northern sections are almost entirely dolomite, while to the south limestone predominates. The lower, or Silurian (?) portion, probably averaging 250 feet thick, is white, gray, and pink finely and coarsely crystalline glauconitic very cherty dolomite and limestone.

The most definite paleontological evidence for accurate correlation of the Devonian-Silurian section has been presented by Jones (1944) , who shows that in the Humble No. 1 Carter, in central Andrews County, a 940-foot interval of glauconitic limestone and dolomite, about 5 percent cherty, contains brachiopods and corals identified by M. A. Stainbrook as Helderberg (Lower Devonion). It overlies white dolomite with *Pentamerus (?)*, a Silurian fossil. Unpublished correspondence between Stainbrook and several petroleum geologists indicates that the fossils may not be sufficiently diagnostic to prove that they are of Helderberg rather than of Niagaran (Middle Silurian) age. Jones notes that southward on the Central Basin Platform the Devonian becomes more cherty, and that toward the north it becomes less cherty and more dolomitic.

The highly cherty Devonian of the southern Central Basin Platform in Texas has generally been believed equivalent to the Caballos novaculite of the Marathon Basin, which, chiefly be-cause of its similarity to the Upper Devonian Arkansas novaculite of the Ouachita Mountains, has been placed in the Upper Devonian. The paleontological evidence given by Jones shows that the less cherty Devonian (?) of the middle and northern parts of the Central Basin Platform is not younger than Helderberg (Lower Devonian). The relation of the Lower Devonian (?) to the highly cherty Upper Devonian is not fully understood, and it may prove that the Upper Devonian chert overlaps the Lower Devonian (?) limestone northward.

No Lower Devonian formations are known at the surface in either West Texas or New Mexico, although Helderberg and Onondaga limestones (Pillar Bluff and Stribling formations) occur in the Llano uplift of central Texas (Barnes, Cloud, and Warren, 1945). The Devonian of New Mexico surface sections is entirely Upper and late Middle Devonian (Stevenson, in Bates, 1942, pp. 22-24), or about the same age as that assumed for the Caballos novaculite of West Texas. The subsurface Lower Devonian (?) is quite similar lithologically to the upper part of the Fusselman limestone of central New Mexico and the El Paso region. Fossils determined from the Fusselman indicate its Niagaran age, but further collecting may reveal that its upper part is Helderberg, as the correlation of the Fusselman is largely based on collections of fossils from its lower part. The subsurface formation identified as Helderberg in the middle and northern Central Basin Platform finds its nearest correlative in the upper Hunton limestone of Oklahoma, and it is assumed that the formations probably were deposited in one sedimentary basin. However, it has probably not been conclusively disproved that the entire sequence may be Niagaran (Middle Silurian), and correlative with the Fusselman and the lower Hunton of Oklahoma.

The Silurian is in general distinguishable from the Lower Devonian (?) by the predominance of white dolomite and' lime-stone and by the presence of coarsely crystalline , members. Evidence from other parts of the Central Basin Platform (Decker, 1942) indicates that this unit is Middle Silurian. It correlates with most or all of the Fusselman limestone of the surface sections in south central New Mexico and westernmost Texas.

ORDOVICIAN SYSTEM

MONTOYA LIMESTONE

The Montoya is brown, gray, and white, finely to coarsely crystalline very cherty limestone and dolomite. It is more cherty than the Silurian, has little glauconite, and lacks the pink dolomite and limestone, characteristic of the Silurian. At its base a calcareous sandstone is generally present, and the overlying dolomite and limestone are sandy. This sandy interval is commonly placed in the upper Simpson by subsurface workers, but it is more logical to regard it as a basal clastic member of the Montoya, particularly because the Montoya has a basal sand in most surface sections. The Montoya is 425 feet thick in the Olsen No. 1 Langlie and it thins northward to 300 feet in the Humble No. 1 Federal-Keinath. Evidence of Montoya or Upper Ordovician age of this interval is based on its lithologic resemblance to the surface Montoya and Maravillas formations, and on its position between the Silurian and the Middle Ordovician.

SIMPSON FORMATION

The Simpson thins northward from 1060 feet in the Dublin field, where it rests on the Ellenburger, to 590 feet in the Skaggs field and 579 feet in the Stanolind (Ohio) No. 1 Jones, at both of which places it directly overlies the pre-Cambrian. The upper 30 to 40 percent of the Simpson is brown and gray finely crystalline and dense calcitic limestone with layers of green shale and some fine-grained sandstone. Fragments of brachiopods and ostracodes are common. This part of the Simpson is lithologically like the Bromide or upper Simpson of Oklahoma. The remainder of the Simpson is alternating brown and green shale, fine- to coarse-grained sandstone, and thin layers of limestone. Laminae of red shale are present, the first appearance of these being directly below the limestone of Bromide age. The sandstones contain abundant large round frosted grains, and the shales are generally sandy. At the base of the Simpson is a layer of sandstone.

The Simpson is identified as such in the South Permian Basin because of its close lithologic similarity to the Middle Ordovician Simpson group of Oklahoma and because Middle Ordovician fossils have been identified from it in wells on the

Central Basin Platform in Texas. So far, no paleontological data are available on New Mexico tests that have penetrated the Simpson. No strata of Middle Ordovician age have been positively identified in New Mexico surface sections.

ELLENBURGER FORMATION

The Ellenburger is white, gray, and brown, coarsely to finely crystalline dolomite, the lower half of which is very cherty and sandy. At the base is a conglomerate of reworked pre-Cambrian rocks. The formation is 445 feet thick in the Olsen No. 1 Langlie (Plate I), 300 feet in the Humble No. 1 Federal-Keinath, and absent in the Skaggs field and southeast of Hobbs, where the Simpson rests on the pre-Cambrian. The formation is correlated with the Lower Ordovician Ellenburger dolomite because of its lithologic character and position in the section. The name Ellenburger is preferred to El Paso, the name applied to Lower Ordovician limestones in south central New Mexico, because it is in general use in the South Permian Basin.

The Lower Ordovician thins northward from more than 1000 feet in the Franklin Mountains near El Paso to 250 feet in the Sacramento Mountains southeast of Alamogordo, and it wedges out completely in the southwestern Oscura Mountains. On the Central Basin Platform and the eastern side of the Midland Basin in Texas the Ellenburger thins northward from 1500 to less than 200 feet. The observed wedging-out of the Ellenburger in Lea County (Plate I) is part of the regional northward thinning of the Lower Ordovician.

PRE-CAMBRIAN

The pre-Cambrian rocks encountered in drilling in south-eastern New Mexico are of heterogeneous character. Quartzite was encountered in three tests drilled to the pre-Cambrian in Lea and Roosevelt counties, schist in most of those near the Pedernal Hills, basic plutonic rock (or a Tertiary laccolith) in the Humble No. 1-N State on the Manning dome (Plate II), and acid plutonic rocks, possibly all granite, in the remainder.

OIL-PRODUCING ZONES

The highest oil pay in the pre-San Andres formations of southeastern New Mexico is in the Drinkard area, in porous dolomite directly below the Glorieta sandstone (Fig. 1). This zone has commonly been referred to as the Holt pay after the zone of that name in the North Cowden field in Ector County, Texas. While the pay in the Drinkard area may be in the same general part of the section as the Holt pay of Ector County, there is no certainty that the two are exactly equivalent. It is here proposed that the zone be referred to as the Paddock pay, the name being taken from the Gulf No. 1 Paddock. This well, in sec. 1, T. 22 S., R. 37 E., was completed with an initial production of 610 barrels per day of 38.4-gravity oil and 362,000 cubic feet of gas from the Paddock pay from 5200 to 5230 feet. The pay was treated with 6000 gallons of acid; production .is through 180 perforations in the casing.

A second producing zone in the upper Yeso section lies some 440 feet below the top of the Glorieta sandstone. Like the Pad-dock pay, this zone consists of porous dolomite. It is here termed the Blinebry pay, from the Texas No. 1 Blinebry in sec. 19, T. 22 S., R. 38 E., in the Drinkard area. This well produced 79 barrels of fluid in 12 hours, cut 15 percent by basic sediment and water, and 11,000,000 cubic feet of sweet gas per day, through 215 casing perforations between 5580 and 5625 feet, after treatment with 12,000 gallons of acid.

Two pay zones have so far been found in the lower Leonard of southeastern Lea County, one about 200 feet and the other 600-850 feet below the top of the Drinkard sandy member. Both zones consist of porous dolomite. The upper zone is the same as the Permian pay of the Fullerton field in western Andrews County, Texas. The lower one was encountered in the Gulf No. 1 Andrews-State, sec. 32, T. 22 S., R. 38 E., which produced 487 barrels of 38.3-gravity oil in 19 hours through 445 casing perforations between 6925 and 7000 feet after treatment with 22,000 gallons of acid. Although these two zones may prove to be unconnected and thus to merit separate names, the possibility exists that they are parts of a common reservoir. Consequently they are not individually named, but are here termed the Drinkard pay zones (Fig. 1). It is believed that no undue confusion will result from using the term Drinkard for the sandy member at the top of the lower Leonard and for the pay zones that lie beneath it.

The pay in the Skaggs deep pool is in Upper Pennsylvanian limestone and dolomite, directly below the unconformity at the base of the Permian. This zone may be termed the Pennsylvanian pay where present in eastern Lea County. It is well developed in the Continental No. 2 Skaggs B-23, in sec. 23, T. 20 S., R. 37 E., which had an initial daily production of 269 barrels of 42.3-gravity oil, with a gas-oil ratio of 150/1, produced through 75 casing perforations between 7700 feet and the plugged-back depth of 7725 feet.

The deepest zone so far productive in southeastern New Mexico is in the upper part of the Ellenburger formation of the .Dublin field and may be termed the Ellenburger pay (Fig. 1) . The discovery well of this pay is the Humble No. 1 Federal. Leonard in sec. 12, T. 26 S., R. 37 E., which had an initial daily production of 297 barrels of 49.8-gravity oil, with a gas-oil ratio of 2465/1, through 380 casing perforations between 11,890 and 11,933 feet after treatment with 2800 gallons of acid.

A second producer from the Ellenburger is the Penrose

No. 1 Federal Fee in sec. 9, T. 22 S., R. 37 E. The pay is coarsely crystalline dolomite, in part brecciated, underlying the Simpson at 7950 feet.

FUTURE POSSIBILITIES FOR PRE-SAN ANDRES PRODUCTION

Adequate porosity in the upper Yeso and Drinkard pay zones is probably present in much of the western Central Basin Platform and possibly in a belt parallel to the northwest border of the Delaware Basin across central Lea and northern Eddy counties. Porosity in the Drinkard pay zones occurs in a platform facies of the lower Leonard, and is apparently absent in the reef facies bordering the Delaware and Midland basins. Toward the north porosity in these zones is probably inhibited by the introduction into the section of anhydrite and clastic sediments. Where Abo shales are present, the overlying section correlative with the Drinkard pay zones also contains anhydrite, shale, and sand. Dolomite pays in the lower Leonard are not likely to be found in this facies.

As noted in the discussion of the Drinkard sandy member, a carbonate facies of the Yeso-lower Leonard, such as that in the middle and western parts of the Central Basin Platform, occurs between the southern occurrences of Abo in the Artesia and Square Lake areas and the north edge of the reef zone bordering the Delaware Basin. This belt is likely to contain porosity in the equivalent of the Drinkard pay zones. The Stroup, Yates and Flynn No. 1 Hartz-State, in sec. 16, T. 21 S., R. 23 E., was abandoned in the possible equivalent of the Drinkard pay zones, after encountering sulfur water. Much of the area from the Vacuum field west through the Maljamar, Grayburg-Jackson, and Artesia fields, and thence west and southwest across the Pecos River, is likely to be favorable for exploring the equivalent of the Drinkard pay zones.

Upper Yeso pays will probably be found farther north than pays in the lower Leonard possibility of such production as far north as east central Chaves County is suggested by the occurrence of porosity and oil staining in dolomite 360 to 610 feet below the top of the Glorieta in the DeKalb No. 1 White (Plate III) . In the same test porosity was encountered in limestones here classified as upper Hueco, between 6490 and 6550 feet. Upper Yeso pays will probably be found in Eddy County northwest of the reef zone bordering the Delaware Basin. Oil shows were found in several parts of the upper Yeso in the Truett and Tallmadge No. 1 Rudahl in sec. 8, T. 20 S., R. 24 E.

The distribution of the Pennsylvanian in the western Central Basin Platform in southeastern Lea County is probably erratic, as beds of this age are absent from many of the structurally high areas. Porous Pennsylvanian limestone and dolomite are, however, likely to be found in a number of other parts of the region. As stated on preceding pages, the thickness and distribution of the Pennsylvanian in southeastern New Mexico are inadequately known, but shows of oil in the Pennsylvanian were found in the Sanders No. 1 Hultman near Artesia.

The distribution of pre-Pennsylvanian formations is unknown north of the Stanolind (Ohio) No. 1 Jones southeast of the Hobbs field in east central Lea County (Plate I), These formations are known to be absent in the only pre-Cambrian test drilled in Roosevelt County, in the DeBaca and Guadalupe County pre-Permian tests, and on the Manning dome in southwestern Chaves County. Between Hobbs and these deep tests is an area 80 or more miles across, in northern Lea, Eddy, and eastern Chaves counties, in which no tests have reached the pre-Pennsylvanian. Because of the northward wedging-out of the Ellenburger it is possible that the Ellenburger is absent throughout much of this region, and pre-Pennsylvanian objectives are in the higher formations. The Simpson, a prolific pay in Oklahoma and in part of Pecos County, Texas, has not shown evidence in New Mexico of being oil-bearing, possibly because its sands are too tightly cemented. The Montoya has not yet produced oil in the South Permian Basin. Pre-Pennsylvanian objectives in the unknown territory northwest of Hobbs may be limited to the Silurian, Devonian, and Mississippian.

In southeastern Lea County, in the western part of the Central Basin Platform, the Mississippian has not had significant shows. The Devonian and Silurian have been porous and contained shows of oil in several wells, and are likely to prove productive in the future. These formations may produce either on the crests of anticlines or on the flanks of anticlines on which older formations underlie the Permian along the axis, as for example in the Drinkard area. More Ellenburger fields will probably be found in the future, though the area, in which these may occur is possibly limited to the western part of the Central Basin Platform south of the wedging-out of the Ellenburger.

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

PLATE I

CROSS SECTION FROM SOUTHERN ROOSEVELT COUNTY TO SOUTHEAST CORNER OF LEA COUNTY

PLATE II

CROSS SECTION FROM TYPE SURFACE SECTIONS OF ABO & YESO TO NORTHERN LEA COUNTY

PLATE III

CROSS SECTION
FROM FLANK OF PEDERNAL HILLS,
TORRANCE COUNTY, SOUTHEAST TO
EASTERN CHAVES COUNTY