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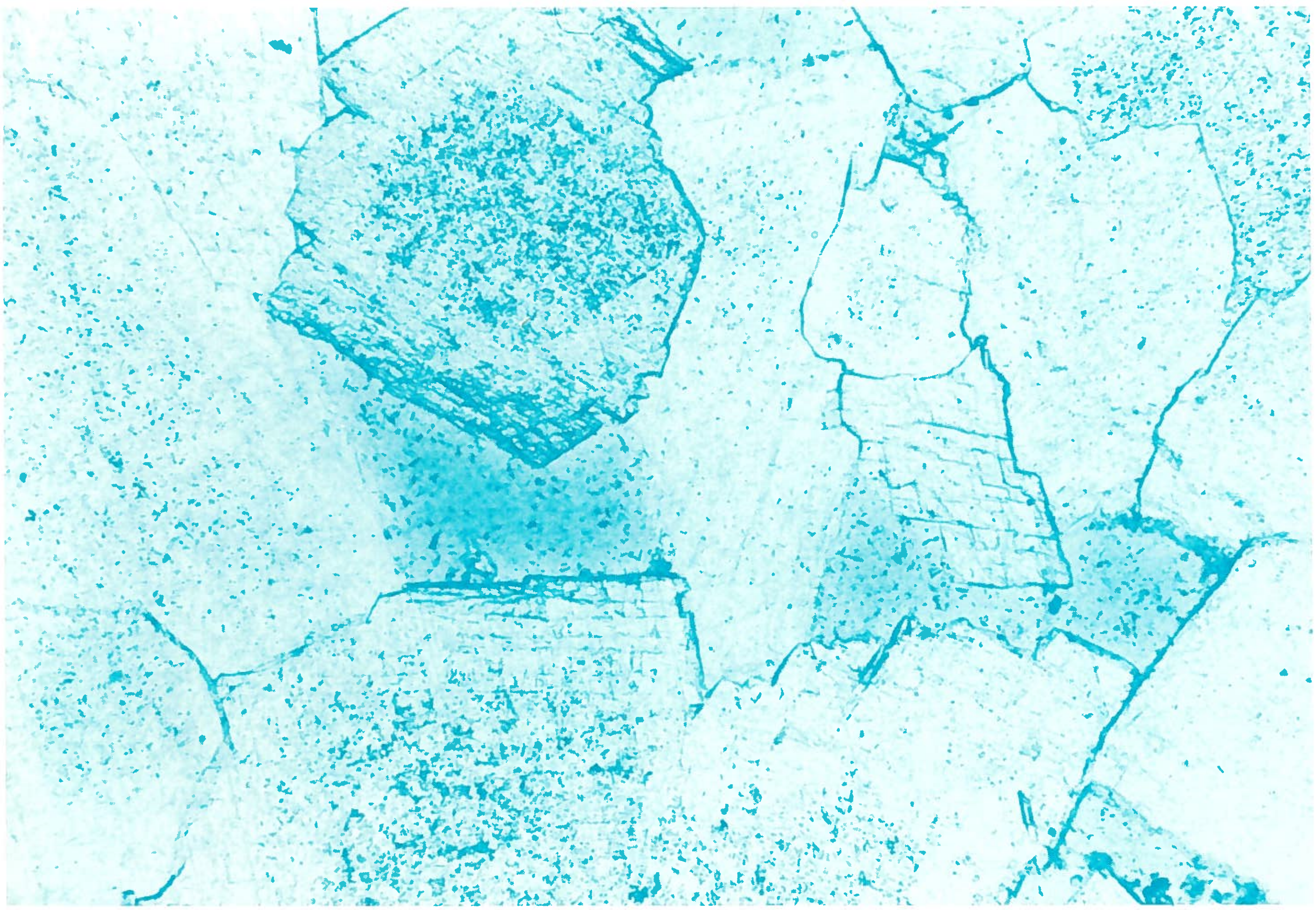

BULLETIN 119 New Mexico Bureau of Mines & Mineral Resources 1988

A DIVISION OF

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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SOCORRO 1988

Original Printing

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Services, December 1988

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801

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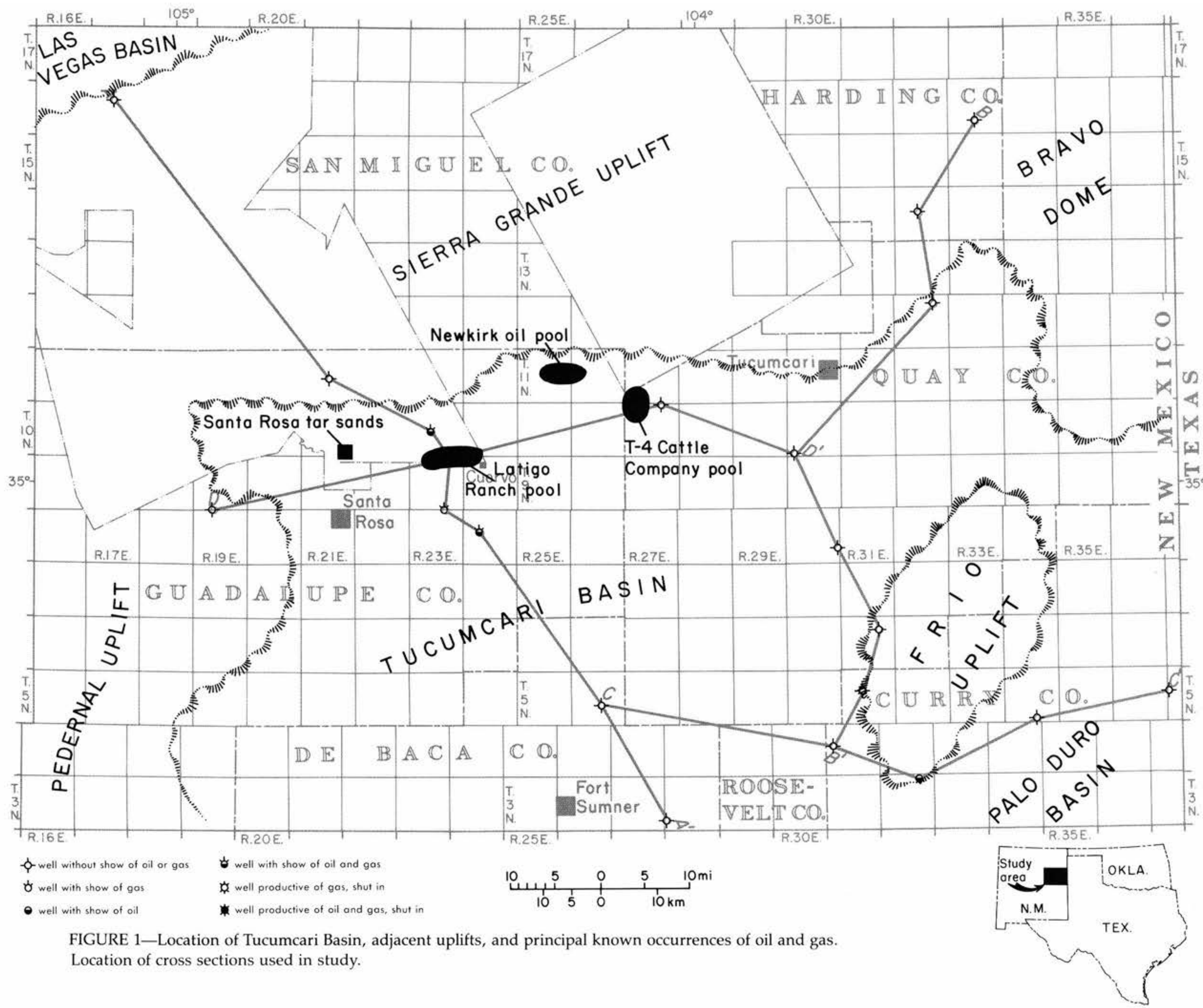

FIGURE 1—Location of Tucumcari Basin, adjacent uplifts, and principal known occurrences of oil and gas. Location of cross sections used in study.

Abstract—The Tucumcari Basin of east–central New Mexico is an asymmetric structural depression that existed as a depositional basin from Strawn (Middle Pennsylvanian) until late Wolfcampian (Early Permian) time. Depth to Precambrian ranges from 6,500 ft in the southern part of the basin to more than 9,000 ft in the northern part of the basin. High-angle faults form the northern, western, and eastern margins of the basin. Faults cut Pennsylvanian and Wolfcampian strata but do not generally offset post-Wolfcampian strata. To the north and west, the basin is bounded by the Sierra Grande and Pedernal Uplifts. To the east, the Frio Uplift separates the Tucumcari Basin from the Palo Duro Basin of the Texas panhandle. No major structural discontinuities separate the basin from a shallow shelf to the south.

Correlations between fusulinid biostratigraphic data, geophysical logs, cores, and drill cuttings indicate the facies and thickness patterns of Pennsylvanian and Wolfcampian strata are structurally controlled. Coarse-grained arkosic sandstones that were deposited in the northern and western parts of the basin were derived from the highlands of Precambrian granitic rocks that formed the northern and western margins of the basin. These sandstones are good reservoirs and exhibit both primary and secondary porosities. High-energy limestones of Pennsylvanian through Wolfcampian age were deposited in the southern part of the basin and are possible reservoirs. Dissolution porosity may have developed in the limestones that are truncated by a basin-wide unconformity at the top of the Pennsylvanian. Porous dolostones of Wolfcampian age cover the Frio Uplift on the eastern side of the basin and are good reservoirs.

Thermally mature oil-and-gas source rocks are Pennsylvanian and Wolfcampian marine shales that were deposited throughout the Tucumcari Basin. Post-Wolfcampian strata are thermally immature.

Two presently noncommercial to marginally commercial pools of oil and gas, the Latigo Ranch and the T-4 Cattle Company pools, have been discovered in Strawn sandstones in the northern part of the basin. Oil generated in upper Paleozoic strata has migrated vertically through faults into Triassic strata; two accumulations of heavy oil, the Santa Rosa tar sands and the Newkirk oil pool, are in Triassic sandstones and have combined reserves of 153 million bbls of oil.

Introduction

The Tucumcari Basin of east—central New Mexico (Fig. 1) is a structural depression that initially developed during Middle Pennsylvanian (Desmoinesian) time. It is bounded to the north by the late Paleozoic Sierra Grande Uplift and Bravo Dome and to the west by the late Paleozoic Pedernal Uplift. The Frio Uplift, a subsurface horst block, separates the Tucumcari Basin from the Palo Duro Basin of the Texas panhandle. The Tucumcari Basin merges gradationally southward with the northwest shelf of the Permian Basin and the Roosevelt Dome (Matador Arch of Texas terminology). Depth to Precambrian ranges from less than 2,000 ft on the Sierra Grande Uplift to more than 9,000 ft near the towns of Cuervo and Tucumcari.

The Tucumcari Basin contains a Precambrian basement overlain by sedimentary rocks of Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary age (Fig. 2). Precambrian and Mississippian units are pre-basinal. Pre-Mississippian Paleozoic strata are not present; they have not been reported in subsurface data and are not exposed. Major structural development of the basin occurred from Desmoinesian (Middle Pennsylvanian) through Wolfcampian (Early Permian) time. Bounding basinal faults cut Strawn (Desmoinesian), Canyon (Missourian), and Wolfcampian strata and control thickness and fades distributions within these units. Few faults cut middle and Upper Permian units.

The Tucumcari Basin is a frontier area that has not produced commercial quantities of petroleum to date. Petroleum exploration wells have been drilled in the basin since the 1920s. Density of wells that penetrate the Pennsylvanian or Precambrian is approximately one well for every two townships; approximately two-thirds of the townships within the basin have no deep wells. Two major accumulations of heavy oil, the Santa Rosa tar sands and the Newkirk oil pool (Fig. 1), are known to exist in Triassic sandstone reservoirs, but do not produce because of technical and economic factors. The Santa Rosa tar sands were mined for road-surfacing material in the 1930s. Shows of oil and gas have been encountered in Pennsylvanian and Permian sandstones and carbonates, but commercial production has not been established. Since 1980, two shut-in pools of oil and gas, the Latigo Ranch and the T-4 Cattle Company pools (Fig. 1), have been discovered in Pennsylvanian strata.

This report concentrates on Pennsylvanian and Lower Permian strata for two reasons. First, some of the most promising shows of oil and gas in the basin have been encountered in Pennsylvanian and Lower Permian reservoirs. Second, sedimentary rocks deposited from Desmoinesian (Strawn) through Wolfcampian time form a syntectonic package deposited during the major structural evolution of the basin.

The purpose of this report is to describe and analyze petroleum occurrences, reservoirs, and source rocks in the Pennsylvanian and Lower Permian and to analyze the relationships between basin structures, reservoirs, source rocks, and traps. Most data used in the study are from petroleum exploration wells. Structural analyses were synthesized from drill-hole data, gravity and aeromagnetic maps, and published surface geologic maps. Data relating to stratigraphy and reservoirs were obtained from geophysical logs, cores, drill cuttings, scout reports, and descriptions of drill cuttings and cores on file at the New Mexico Bureau of Mines and Mineral Resources. Thin sections of drill cuttings and cores were made to facilitate analyses of reservoirs. Fusulinids collected from drill cuttings were identified to provide stratigraphic control. Fusulinid biostratigraphy is especially important for analysis of Pennsylvanian strata, which are traditionally subdivided into time-rock units, rather than lithostratigraphic units. This report uses western Texas nomenclature to stratigraphically subdivide the Pennsylvanian into the Morrowan, Atokan, Strawn (Desmoinesian), Canyon (Missourian), and Cisco (Virgilian) Series.

Acknowledgments—Frank E. Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, suggested and supported this study. Ben Donegan, William Seager, George Verville, and George Sanderson thoroughly reviewed the manuscript and offered constructive advice and criticism. Robert G. McKinney provided much stimulating and knowledgable discussion of the geology of the Tucumcari Basin. Jennifer Boryta edited the manuscript. Lynne McNeil typed the manuscript and Michael W. Wooldridge, Charles Ferguson, and Rebecca J. Titus drafted the illustrations.

Stratigraphic units				Lithology	Thickness (ft)	Description	Petroleum occurrences	Reservoir quality	Petroleum potential
Tertiary and Quaternary		Pecos Valley seds. / Ogallala Fm.			0-400[1]	Unconsolidated sands and gravels with caliche caps			Very low
Cretaceous	Upper	Dakota Sandstone			0-30[1]	Quartzose sandstone, conglomeratic sandstone, minor carbonaceous silty mudstone		Fair	Very low
Cretaceous	Lower	Purgatoire Fm.			0-60[1,3]	Fine-to coarse-grained conglomeratic quartzose sandstone, and gray mudstone		Poor	Very low
Cretaceous	Lower	Tucumcari Shale			0-80[1,3]	Gray mudstone, yellowish-brown clay, minor sandstone, and minor marine limestone		Poor	Very low
Jurassic		Morrison Fm.			0-400[2]	Greenish-gray to reddish-brown mudstone, minor lenticular sandstone		Poor	Very low
Jurassic		Exeter (Entrada) Sandstone			0-228[2]	Fine-grained well-sorted sandstone		Excellent	Very low
Triassic	Upper	Chinle Fm.	Redonda Mbr.		0-450	Orange fine-grained sandstone, argillaceous limestone, red mudstone		Poor-Fair	Very low
Triassic	Upper	Chinle Fm.	upper shale mbr.		350+[1]	Red mudstone, minor fine-grained sandstone		Poor	Very low
Triassic	Upper	Chinle Fm.	Cuervo Sandstone Mbr.		13-203	Fine- to medium-grained sandstone, red mudstone	◒	Fair	Low
Triassic	Upper	Chinle Fm.	lower shale mbr.		50-250	Red mudstone, minor fine-grained sandstone		Poor	Very low
Triassic	Upper	Santa Rosa Sandstone	upper sandstone unit		7-150	Fine-to medium-grained sandstone, red mudstone	●	Good	High
Triassic	Upper / Middle	Santa Rosa Sandstone	middle mudstone unit		0-144	Red mudstone, minor fine-grained sandstone		Poor	Low
Triassic	Middle	Santa Rosa Sandstone	lower sandstone unit		18-140	Fine-to medium-grained sandstone, red mudstone	◒	Good	High

[1]Kelley (1972a) [2]Foster et al (1972) [3]Kelley (1972b)

FIGURE 2—Stratigraphic chart of Phanerozoic sedimentary units in the Tucumcari Basin and adjacent uplifts, and a summary of

Stratigraphic units				Lithology	Thickness (ft)	Description	Petroleum occurrences	Reservoir quality	Petroleum potential
Permian	Guadalupian	Artesia Group	Yates-Tansill unit		0-276	Red mudstone, fine-grained sandstone		Poor	Low-moderate
Permian	Guadalupian	Artesia Group	Seven Rivers Fm.		50-350	Anhydrite, red mudstone		Poor	Low
Permian	Guadalupian	Artesia Group	Grayburg-Queen unit		140-400	Red mudstone, fine-grained sandstone		Poor	Low-moderate
Permian	Leonardian	San Andres Fm			400-1,200[2]	Dolostone, anhydrite, salt, limestone		Fair-good	Moderate
Permian	Leonardian	San Andres Fm	Glorieta Sandstone Mbr.		0-300	Fine- to medium-grained sandstone			
Permian	Leonardian	Yeso Fm.			400-2,000[2]	Orange fine-grained sandstone, orange mudstone, anhydrite, dolostone, salt		Fair	Low-moderate
Permian	Wolfcampian	Abo Fm.			0-2,372	Red mudstone, coarse-grained conglomeratic arkosic sandstone; fine-grained sandstone in upper part		Good	Moderate
Permian	Wolfcampian	Hueco Fm.			0-1,847	Red mudstone, gray mudstone, coarse-grained conglomeratic arkosic sandstone, marine limestone. Bedded dolostone in southeast.		Good	Moderate-high
Pennsylvanian	Canyon	Magdalena Group			0-1,709	Marine limestone, coarse-grained conglomeratic arkosic sandstone, and gray to red mudstone		Fair-good	Moderate-high
Pennsylvanian	Strawn	Magdalena Group			0-1,136	Marine limestone, coarse-grained conglomeratic arkosic to quartzose sandstone, and gray mudstone		Fair-good	High
Pennsylvanian	Atokan	Magdalena Group			0-100	Gray mudstone, minor fine-grained sandstone		Poor	Low
Mississippian		Arroyo Peñasco Fm.			0-280	Marine limestone, gray mudstone, and basal sandstone		Poor-fair	Low
Precambrian						Granitic igneous rocks, metavolcanics, schist, metaquartzite		Poor	Very low

hydrocarbon occurrences, reservoir quality, and petroleum potential (after Broadhead, *in* Grant and Foster, in press).

Structure

The Tucumcari Basin (Fig. 1) is an asymmetric structural depression that existed as a depositional basin from Desmoinesian (Middle Pennsylvanian) through Wolfcampian (Early Permian) time. The basin is bordered on its northern, western, and eastern sides by uplifts of the ancestral Rocky Mountains. To the north and northwest, the Sierra Grande Uplift separates the Tucumcari Basin from the Las Vegas Basin. To the northeast, the Bravo Dome separates the Tucumcari Basin from the Dalhart Basin of the northern Texas and the Oklahoma panhandles. To the west, the Pedernal Uplift separates the Tucumcari Basin from the ancestral Estancia Basin. On the eastern side, the Frio Uplift (Roberts et al., 1976) separates the Tucumcari Basin from the Palo Duro Basin of the Texas panhandle. To the south, the Tucumcari Basin rises gently upward and merges with the northwest shelf of the Permian Basin and the Roosevelt Dome (Matador Arch of Texas terminology; Portales Arch of Pitt and Scott, 1981). There is no sharp tectonic boundary between the Tucumcari Basin and the northwest shelf of the Permian Basin and the Roosevelt Dome.

Detailed surface structures of the Tucumcari Basin and surrounding uplifts have not been reported in the literature. Dobrovolny et al. (1946) mapped gentle folds and a solitary northeast-striking fault (Bonita Fault) within the central part of the basin. Gorman and Robeck (1946) mapped several north-trending folds on the northern edge of the basin in north—central Guadalupe County. Wanek (1962) mapped some northeast-trending, gentle folds on the Sierra Grande Uplift in northeastern San Miguel County. On the Sierra Grande Uplift in western San Miguel County, Dane and Bachman (1965) mapped several north—northwest-trending faults that are roughly parallel to the eastern edge of the Sangre de Cristo Mountains.

Kelley (1972a) mapped the southwestern part of the area covered in this report. The only major faults that he found are north-trending, high-angle faults in T2-8N R16E. The largest of these is the Vaughn Fault, which is 25 mi long. Vertical displacement on the Vaughn Fault is down to the west and may be as large as 500-1,000 ft in T6N R16E. Vertical displacement may be 500 ft in the northern part of T3N R16E. North of T8N, the Vaughn Fault passes into a pair of gentle folds that consist of an anticline to the east and a syncline to the west. These folds continue northward to the boundary of T8N and T9N. Minor east—west- and northeast—southwest-trending normal faults occur in and around Pintada Canyon in T8N R16-19E.

The city of Santa Rosa is situated in the northern part of a large, circular collapse structure (Kelley, 1972a, b). The collapse structure is approximately 6 mi in diameter, has a maximum depth of 400 ft, and is bounded by concave normal faults that alternate with monoclinal flexures. Collapse was initiated by solution of middle to Upper Permian limestones, gypsums, and salts.

Little information about the Tucumcari Basin can be garnered from surface geologic studies where gentle surface structures only vaguely mimic large-scale, deeper basinal structures. To show major subsurface structures of the Tucumcari Basin, structure-contour maps were drawn primarily from well data on the Precambrian surface (Fig. 3), the Abo Formation (Fig. 4), and the San Andres Formation (Broadhead, 1984a). Most stratigraphic tops were determined from geophysical logs and confirmed with sample logs or sample descriptions of drill cuttings, which are on file at the New Mexico Bureau of Mines and Mineral Resources. Where data from geophysical logs were missing, tops were determined from sample logs and drill cuttings. The presence of varied igneous and metasedimentary rocks made the use of sample logs and drill cuttings especially important for confirmation of the Precambrian top. Other data sources used to aid contouring of the structure-contour maps were the Bouguer gravity anomaly map (Keller and Cordell, 1983) and the aeromagnetic anomaly map (Cordell, 1983) of New Mexico. Also utilized were a previously published structure-contour map of the Precambrian surface (Foster et al., 1972), published surface geologic maps (Dane and Bachman, 1965; Dobrovolny et al., 1946; Wanek, 1962; Kelley, 1972a), and aeromagnetic maps of parts of San Miguel and Harding Counties (Dempsey et al., 1963a, b).

Proprietary profiles of seismic lines were examined. Although the seismic data were not used to make the structure-contour maps, they were used to confirm the contouring. Comparison of the seismic lines with the contours reveals that the structure-contour maps (Figs. 3, 4) reflect the structural style of the basin; they fairly accurately portray major structures that are present within the basin. Because of the relatively low well density in the basin, structure-contour maps that show relatively minor structures (which could be important oil and gas traps) and exact locations of major structures can be made only if seismic lines are used for contouring.

The Precambrian structure-contour map (Fig. 3) reflects the geologic structure of the Tucumcari Basin. The basin is approximately 72 mi long and 51 mi wide. The deepest parts of the basin are in grabens along the southern side of the Sierra Grande Uplift in northeastern Guadalupe and central Quay Counties. In these grabens, the depth to Precambrian basement is approximately 9,000 ft and the elevation of the Precambrian surface is 4,000-5,000 ft below sea level. In the southern part of the basin, the depth to Precambrian basement is approximately 6,500-7,000 ft and the elevation of the Precambrian surface is 2,000-2,500 ft below sea level.

The northern, western, and eastern parts of the basin are complexly faulted. Faults of large vertical displacement separate the Tucumcari Basin from the Sierra Grande, Pedernal, and Frio Uplifts. In the northwestern part of the basin, most faults trend east—west. In the southwestern part of the basin, most faults trend north—south and are parallel to the Pedernal Uplift. In the eastern part of the basin, most faults trend northeast—southwest. Northwest-trending faults cross the Sierra Grande Uplift in eastern San Miguel County and form a northwest-trending horst-and-graben system. Northwest-trending, down-to-the-basin stairstep faults separate the Bravo Dome from the Tucumcari Basin.

The geometry and attitude of individual fault planes can not be determined directly from available data. However, three lines of evidence can be used to infer that the faults are high-angle normal and reverse faults; they are not low-angle thrust faults. First, no major low-amplitude gravity and magnetic anomalies extend underneath the Sierra Grande, Pedernal, and Frio Uplifts and the Bravo Dome. Second, in the Cities Service No. 1 Driggers, sec. 22 T11N R21E, Guadalupe County, 1,321 ft of Precambrian granitic rocks were drilled. This well lies less than 2'/2 mi north of a major fault that forms the edge of the Tucumcari Basin, but exhibits no evidence of a repeated or thrust-faulted Precambrian or Paleozoic section. Third, stratigraphic data presented in other parts of this report indicate the faults developed contemporaneously with the deposition of sediments during the Pennsylvanian and Early Permian. Proximal alluvial-fan deposits are preserved on the downthrown sides of many of the faults. If the faults had low-angle planes and formed thrust sheets, then the proximal alluvial-fan facies would be buried underneath thrust sheets of Precambrian basement. If thrust faults are present in the Tucumcari Basin or on the Sierra Grande Uplift, they are relatively small, localized features that have not caused any major amount of crustal shortening.

At least some of the faults appear to have components of reverse motion. In the Baker and Taylor No. 1 T-4 Cattle

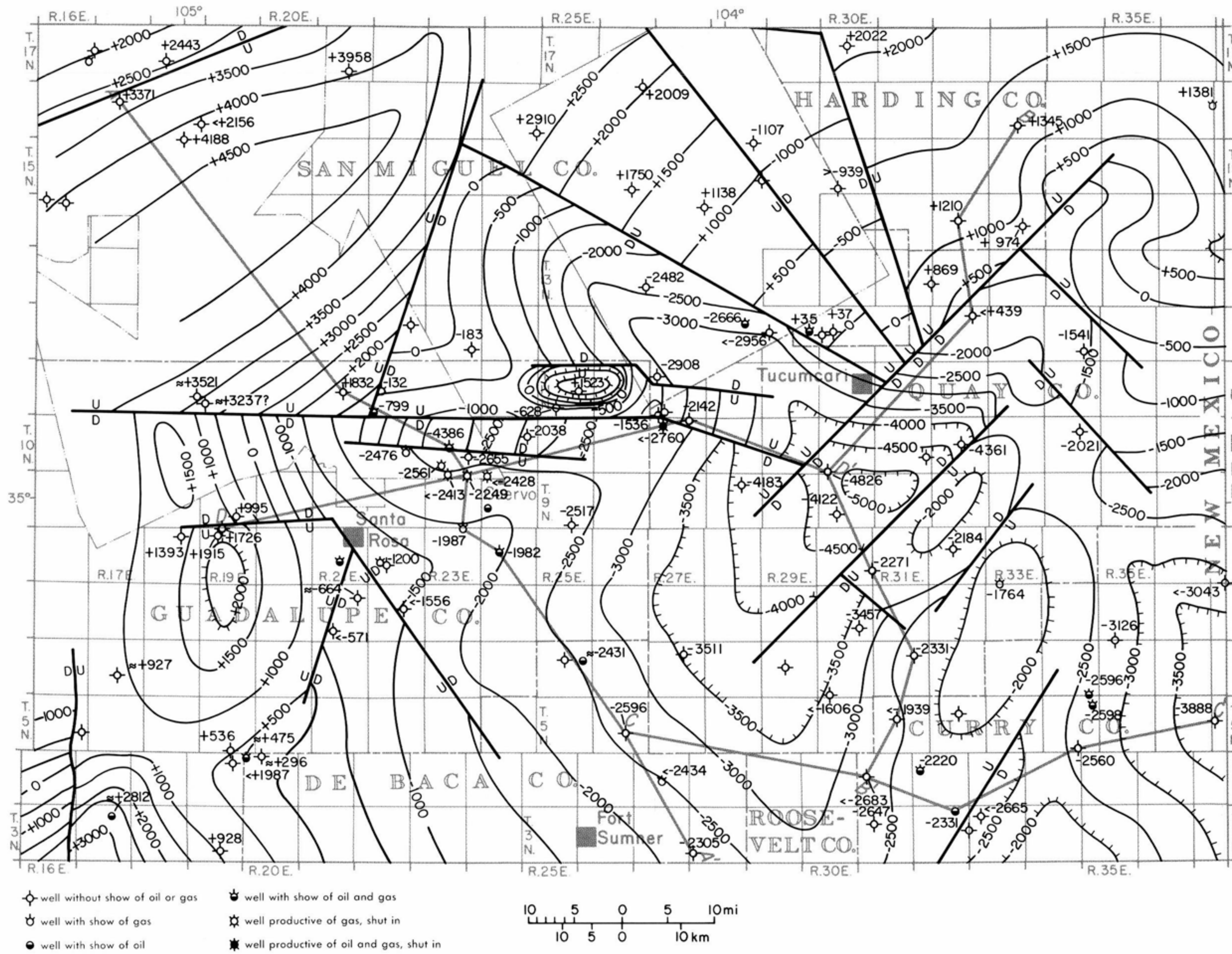

FIGURE 3—Structure of Precambrian basement, Tucumcari Basin and adjacent uplifts. See text for discussion of contouring methods. Contour interval = 500 ft.

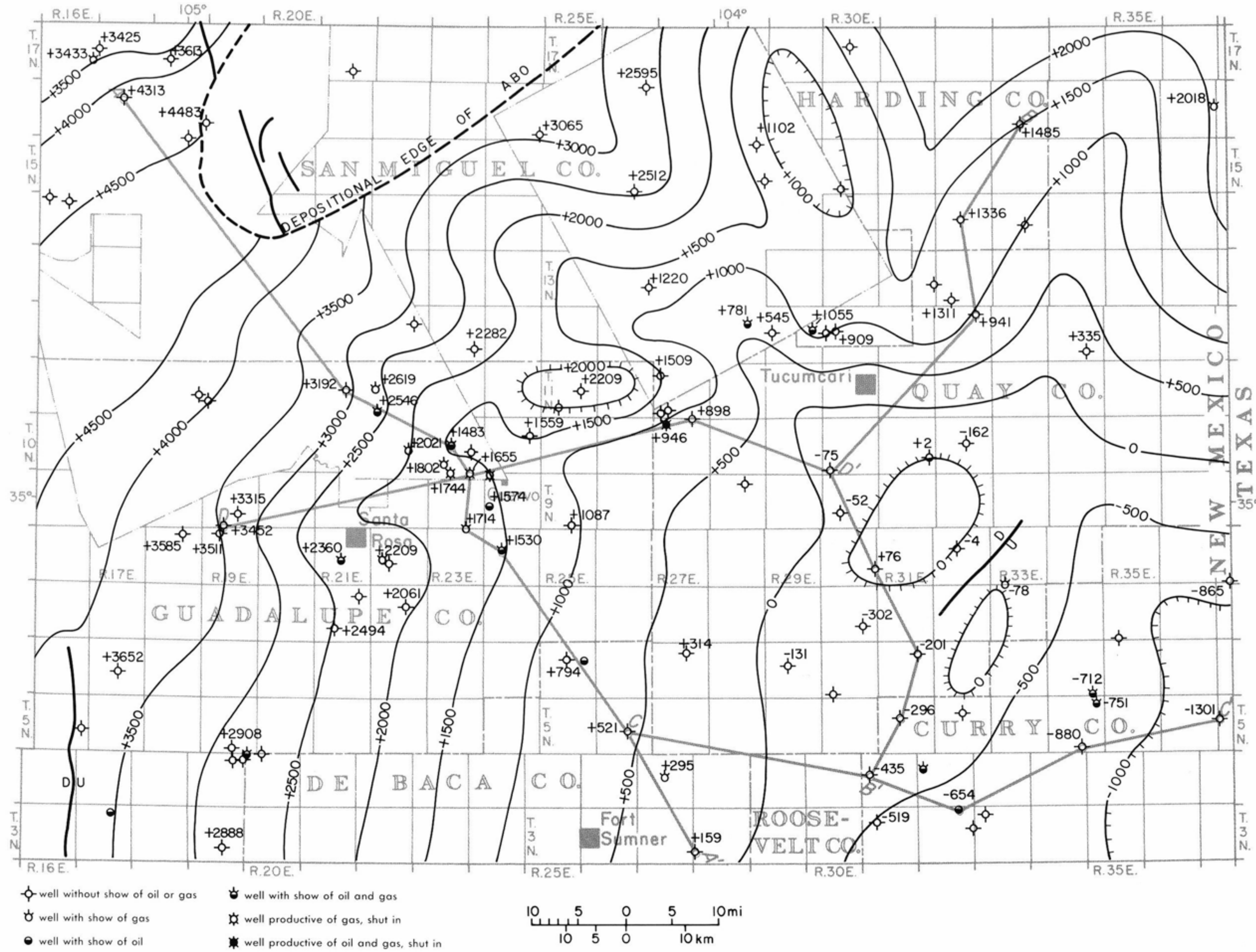

FIGURE 4—Structure on top of Abo Formation (Permian), Tucumcari Basin and adjacent uplifts. See text for discussion of contouring methods. Contour interval = 500 ft.

Company, sec. 7 T11N R27E, San Miguel County, an anomalously thick lower Canyon section was drilled (see discussion in stratigraphy and reservoir geology section). In this well, the lower Canyon is folded and is characterized by steep dips; the lower Canyon may be repeated by one or more reverse faults.

The southern part of the Tucumcari Basin does not appear to have any major faults. Strata on the south flank of the basin dip gently northward into the basin center.

Major faulting that led to the formation of the Tucumcari Basin is Desmoinesian (Middle Pennsylvanian) through Wolfcampian (Early Permian) in age. As discussed in the section on stratigraphy and reservoir geology, major coarse-grained clastic wedges were shed off the Sierra Grande and Pedernal Uplifts and the Bravo Dome from Strawn (Desmoinesian) through Abo (Wolfcampian) time. By late Abo time, however, major structural movement in the basin and on surrounding uplifts had stopped; only fine-grained clastics were deposited. Basinal faults do not appear to cut the upper Abo or shallower formations.

This interpretation of the timing of major structural movement in the Tucumcari Basin is supported by the structure-contour maps (Figs. 3, 4; Broadhead, 1984a). Contours drawn on the Precambrian surface (Fig. 3) clearly indicate the faulted basinal structures. However, contours drawn on the Abo (Fig. 4) and San Andres Formations (Broadhead, 1984a) show gentle southeastward dips off the Sierra Grande and Pedernal Uplifts. Deeper basinal structures and the outline of the Frio Uplift are only vaguely mimicked in the Abo and San Andres, indicating that the Tucumcari Basin had been mostly filled with clastic sediments by the close of Abo time.

Structural features of the Abo and San Andres Formations (Fig. 4; Broadhead, 1984a) appear to have developed mostly during the Laramide (Late Cretaceous-early Tertiary) orogeny. The regional southeastward dip of the Abo and San Andres is structurally continuous with the Pecos Slope of east-central and southeastern New Mexico. The Pecos Slope is Laramide in age (Kelley, 1971); therefore, it appears that regional southeastward tilting occurred during the Laramide. The vague basinal structures of the Abo and San Andres shown on the structure-contour maps may have partially resulted from differential compaction of synorogenic Pennsylvanian and Lower Permian strata in the deeper parts of the basin. **It** is assumed that compaction is preLaramide, Laramide, and post-Laramide in age.

Reactivation of some basinal structures also occurred during the Laramide (McKallip, 1984, 1985; Broadhead, 1984a). Structural features on the western part of the Pedernal Uplift (west of the area covered by this report) appear to have been rejuvenated during this time (Kelley, 1972a).

No major structural features have been superimposed on the Laramide structures. Therefore, it appears that the Laramide orogeny marked the last stage of major deformation in the Tucumcari Basin.

Paleontology

Since the stratigraphic section of most interest to us is the Pennsylvanian and Lower Permian, drill cuttings from critically important wells were examined for fusulinids. In many drill cuttings, fusulinids were found and used to correlate age relationships of Pennsylvanian and Lower Permian strata throughout the Tucumcari Basin. Some of the better specimens of fusulinids are illustrated in Figs. 5-7. A composite of fusulinid fragments, which is not illustrated, also helped to determine many age relationships.

The John D. Hancock Exploration Company, Ltd. No. 1 Sedberry well of San Miguel County, sec. 25 T17N R16E, is located in the extreme northwestern part of the study area. Fusulinids found in the well's drill cuttings occur in the interval from 3,940 to 4,770 ft. Though the fusulinid fragment recovered from 3,940 to 3,950 ft is not diagnostic, except to be able to state that the interval is Strawn (Desmoinesian) or older, the fusulinids from 4,050 to 4,770 ft indicate an early Strawn age. Several specimens present are referred to *Wedekindellina euthysepta* (Henbest) (Fig. 7, nos. 15, 16), a diagnostic early Strawn species. In addition, *Beedeina* cf. *B. leei* (Skinner) (Fig. 7, no. 5) and two other *Beedeina* spp. (Fig. 7, nos. 9, 10), which can not be identified to species, are present in the Strawn interval.

Drill cuttings from the Monument Energy Corporation No. 2 Sedberry, sec. 25 T17N R16E, San Miguel County, were examined for fusulinids, but none was found.

The Continental Oil Company No. 1 Shoemaker-Reed, sec. 28 T17N R18E, San Miguel County, is also in the northwestern part of the study area. Three fragmental, poorly preserved fusulinid specimens were recovered from the well's drill cuttings, but none was sufficient to allow more than speculation regarding ages. Fusulinids from 3,490 to 3,500 ft and from 3,570 to 3,575 ft seem to exhibit an alveolar keriothecal wall structure, which would indicate that they are of post-Strawn age. A single specimen from 4,065 to 4,070 ft has a diaphanothecal wall structure, which would indicate that it is of Strawn or Atokan age. On the basis of the degree of septal fluting, it is speculated that the latter fusulinid is Strawn in age. None of the fusulinid specimens from the No. 1 Shoemaker-Reed was well-preserved, and consequently none would photograph satisfactorily for illustration.

The Cities Service No. 1 Driggers, sec. 22 T11N R21E, Guadalupe County, is in the west-central part of the investigation area. Drill cuttings from 2,850 to 2,870 ft contain fragments of *Triticites* sp. (Fig. 6, no. 8), which are possibly Wolfcampian. In the interval from 3,110 to 3,140 ft is *Beedeina euryteines* (Thompson) (Fig. 6, nos. 20, 21), which is Strawn in age. In the interval from 3,150 to 3,160 ft, a tiny fragment of a fusulinid, which may be *Fusulinella* of the Atokan, was found.

The Sunray Mid-Continent Oil Company No. 1 R. Padilla, sec. 4 T8N R19E, Guadalupe County, is located in the west-central part of the study region. In the interval from 3,230 to 3,240 ft, a fragment of *Triticites* sp. (Fig. 6, no. 9) was found and is assigned to the Wolfcampian. Identification of other fusulinid fragments indicates post-Strawn beds extend downward to at least 3,490 ft. In the interval from 3,700 to 3,729 ft, *Beedeina* cf. *B. erugata* (Waddell) of Strawn age (Fig. 7, nos. 7, 8) occurs in slightly caved drill cuttings.

The Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, is an important well in the central part of the investigation area through which cross sections A-A' and D-D' pass (Figs. 1, 8, 11). Drill cuttings from 4,900 to 7,150 ft were examined, and the fusulinids identified have delineated two major fusulinid zones. From 5,420 to 5,560 ft, a zone of Canyon (Missourian) fusulinids of the general morphological character of *Triticites* cf. T. *kawensis* Thompson (Fig. 6, no. 10) occurs. The other zone, which is Strawn in age, extends from 6,240 to 6,340 ft and is characterized by *Beedeina leei* (Skinner) (Fig. 7, nos. 1, 2, 4). From 6,240 to 6,260 ft, *Beedeina* sp. (Fig. 7, no. 12) and *Beedeina* cf. *B. erugata* (Waddell) (Fig. 7, no. 8) occur.

The Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, is situated in the south-central part of the study area and contains abundant fusulinids. There are eight intervals from 5,600 to 5,960 ft which bear fragmental fusulinids. On the basis of the assemblage of *Schwagerina* sp. (Fig. 5, no. 6) and *Triticites* sp., these intervals are assigned to the Hueco Formation of the Wolfcampian. No Cisco (Virgilian) fusulinids were found. Canyon fusulinids occur from 6,110 to 6,120 ft, from 6,160 to 6,170

FIGURE 5

(All magnifications x 10)

1 *Schwagerina* sp. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,140-6,150 ft

2, 3 *Schwagerina* aff. *S. grandensis* Thompson, 1954. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,250-6,260 ft and 6,320-6,330 ft, respectively

4 *Schwagerina* cf. *S. campensis* Thompson, 1954. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,360-6,370 ft

5 *Schwagerina* sp. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,500-6,510 ft

6 *Schwagerina* sp. Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 5,950-5,960 ft

7 *Schwagerina emaciata* (Beede, 1916). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,770-7,780 ft

8 *Schwagerina* sp. Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,940-7,950 ft

9-12 *Triticites ventricosus* (Meek and Hayden, 1858). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,230-7,240 ft, 7,410-7,420 ft, 7,740-7,750 ft, and 7,7507,760 ft, respectively

13, 14 *Triticites aff. T. creekensis* Thompson, 1954. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,220-6,230 ft and 6,560-6,570 ft, respectively

15 *Triticites* aff. *T. meeki* (Killer, 1879). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 8,020-8,030 ft

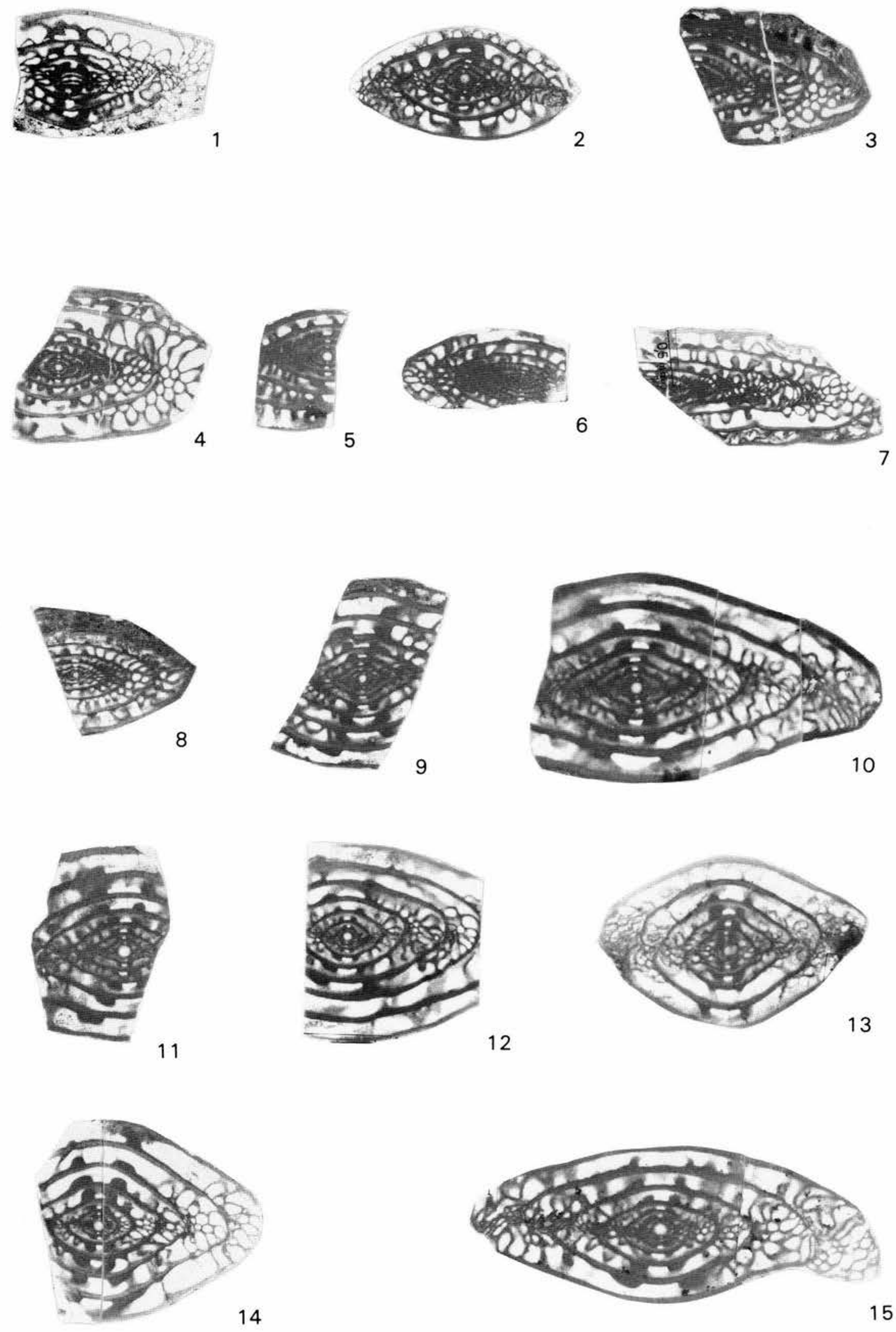
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FIGURE 6

(All magnifications x 10)

1-3 *Triticites* aff. T. *meeki* (Moller, 1879). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,484-7,490 ft, 7,690-7,700 ft, and 7,820-7,830 ft, respectively

4 *Triticites pointensis* Thompson, 1954. Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,570-7,580 ft

5 *Triticites* aff. *T. meeki* (Moller, 1879). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,760-7,770 ft

6 *Triticites* sp. Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,610-7,620 ft

7 *Triticites* sp. Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,430-7,440 ft

8 *Triticites* sp. Cities Service No. 1 Driggers, sec. 22 T11N R21E, Guadalupe County, 2,860-2,870 ft

9 *Triticites* sp. Sunray Mid-Continent Oil Company No. 1 R. Padilla, sec. 4 T8N R19E, Guadalupe County, 3,230-3,240 ft

10 *Triticites* cf. T. *kawensis* Thompson, 1957. Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, 5,430-5,440 ft

11 *Triticites* sp. Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 8,040-8,050 ft

12 *Triticites* aff. *T. meeki* (Moller, 1879). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,770-7,780 ft

13 *Triticites cf. T. collus* Burma, 1942. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,780-6,790 ft

14 *Triticites* sp. Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,160-6,170 ft

15 *Leptotriticites hughesensis* (Thompson, 1954). Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,590-6,600 ft

16 *Leptotriticites cf. L. eoextentus* (Thompson, 1954). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,910-7,920 ft

17 *Leptotriticites* cf. *L. americanus* (Thompson, 1954). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,800-7,810 ft

18, 19 *Leptotriticites fivensis* (Thompson, 1954). Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, 7,370-7,380 ft and 7,490-7,500 ft, respectively

20, 21 *Beedeina euryteines* (Thompson, 1934). Cities Service No. 1 Driggers, sec. 22 T11N R21E, Guadalupe County, 3,110-3,120 ft and 3,130-3,140 ft, respectively

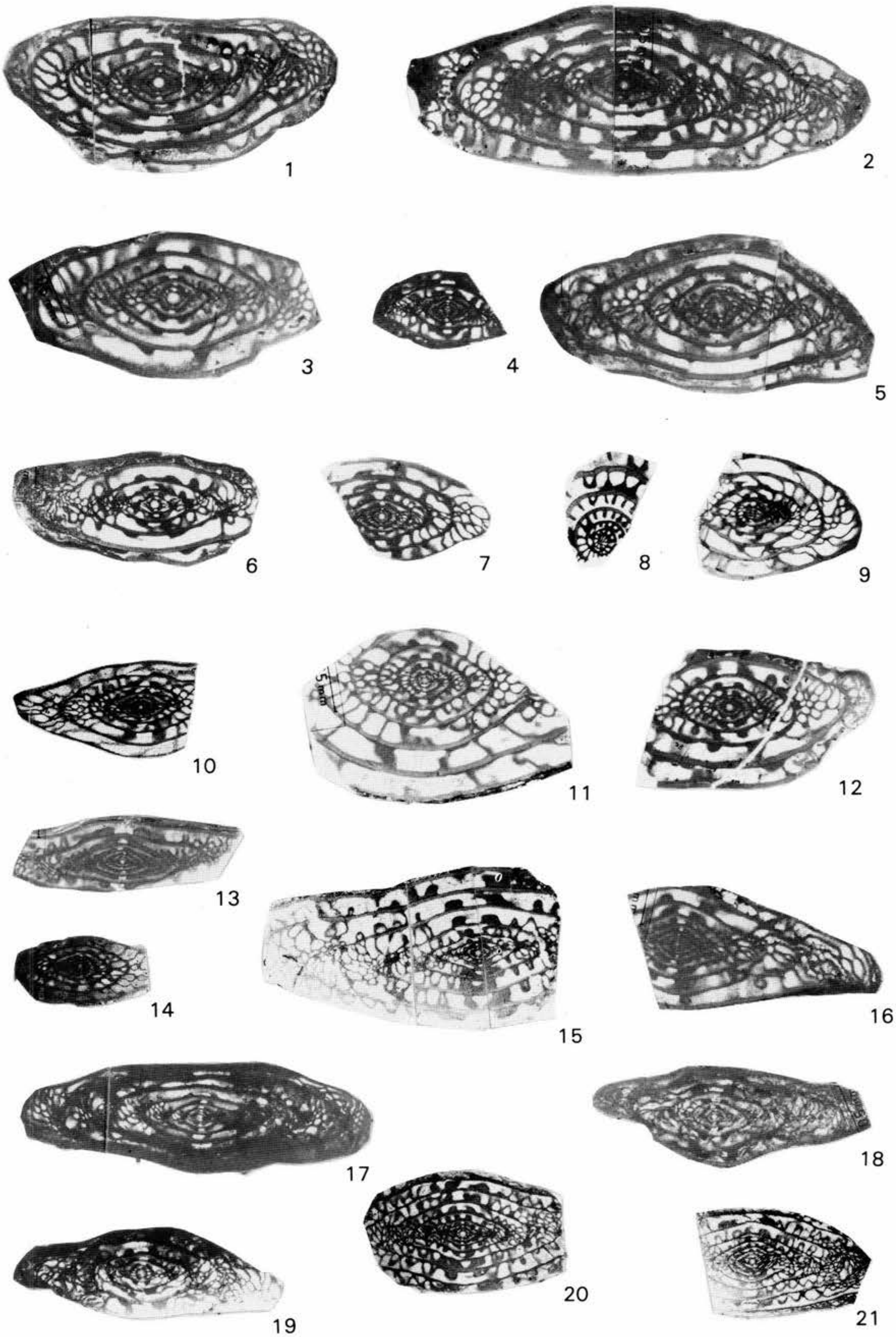
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FIGURE 7

(All magnifications x 10,
except 15-21 which are x 20)

1, 2, 4 *Beedeina leei* (Skinner, 1931). Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, 6,240-6,250 ft, 6,330-6,340 ft, and 6,250-6,260 ft, respectively

3 *Beedeina leei* (Skinner, 1931). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,810-6,820 ft

5 *Beedeina cf. B. leei* (Skinner, 1931). John D. Hancock Exploration Company, Ltd. No. 1 Sedberry, sec. 25 T17N R16E, San Miguel County, 4,760-4,770 ft

6 *Beedeina rockymontana* (Roth and Skinner, 1930). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,930-6,940 ft

7 *Beedeina cf. B. erugata* (Waddell, 1966). Sunray Mid-Continent Oil Company No. 1 R. Padilla, sec. 4 T8N R19E, Guadalupe County, 3,710-3,720 ft

8 *Beedeina* cf. *B. erugata* (Waddell, 1966). Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, 6,250-6,260 ft

9, 10 *Beedeina* sp. John D. Hancock Exploration Company, Ltd. No. 1 Sedberry, sec. 25 T17N R16E, San Miguel County, 4,120-4,130 ft

11, 13, 14 *Beedeina* sp. Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,530-6,540 ft, 6,580-6,590 ft, and 6,810-6,820 ft, respectively

12 *Beedeina* sp. Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, 6,240-6,250 ft

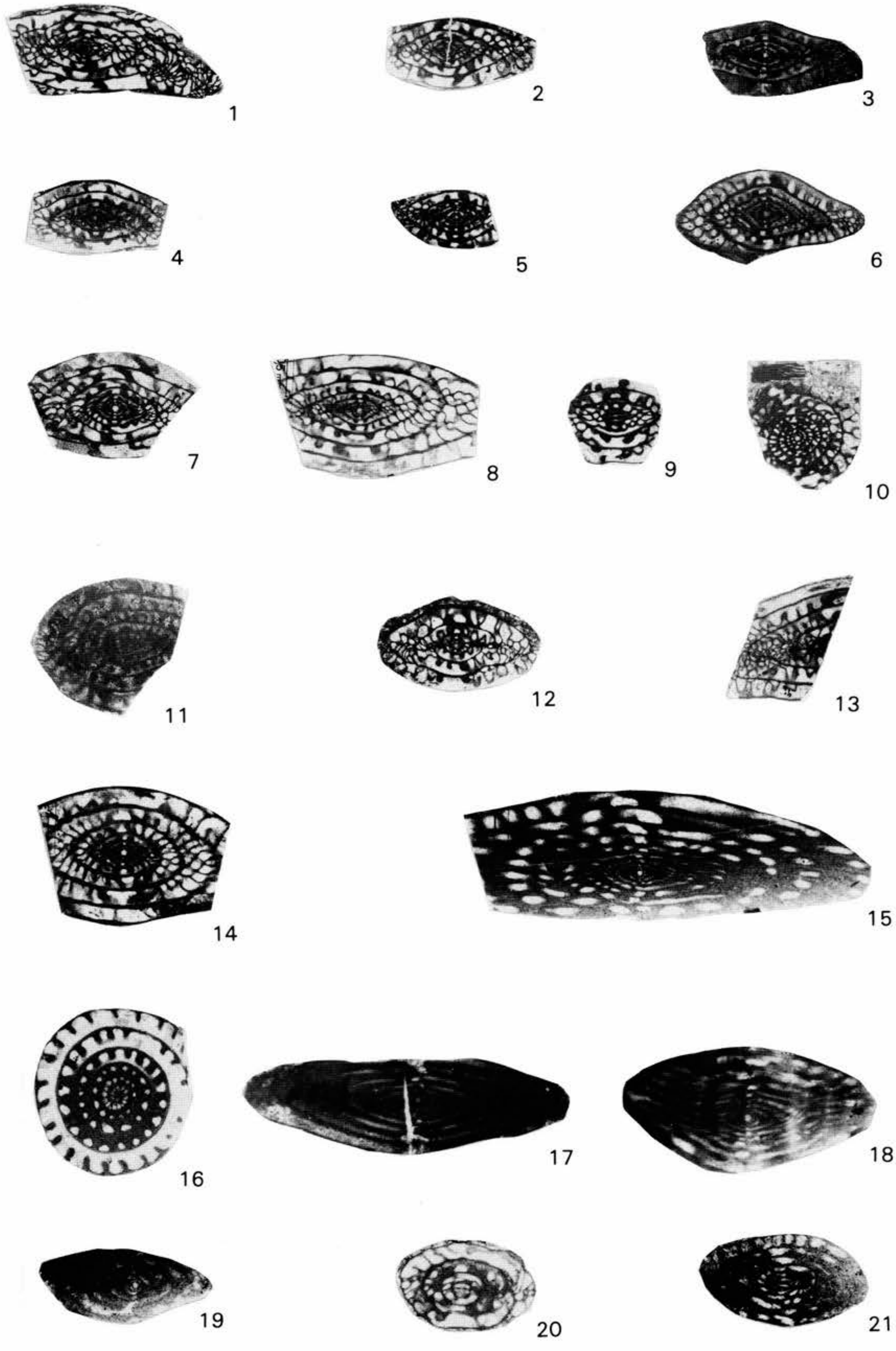
15, 16 *Wedekindellina euthysepta* (Henbest, 1928). John D. Hancock Exploration Company, Ltd. No. 1 Sedberry, sec. 25 T17N R16E, San Miguel County, 4,280-4,290 ft and 4,050-4,060 ft, respectively

17 *Wedekindellina euthysepta* (Henbest, 1928). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,930-6,940 ft

18 *Wedekindellina* sp. Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,830-6,840 ft

19 *Profusulinella cf. P. fittsi* (Thompson, 1935). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 7,000-7,010 ft

20, 21 *Profusulinella* sp. Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,960-6,970 ft and 7,020-7,030 ft, respectively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ft, and from 6,190 to 6,200 ft. A specimen of *Triticites* sp., which occurs in these intervals, is shown in Fig. 6, no. 14. The early Strawn fusulinids *Beedeina* and *Wedekindellina* are present in twelve intervals from 6,530 to 6,940 ft. Some of the representatives of this Strawn zone are illustrated: *Beedeina leei* (Skinner) in Fig. 7, no. 3; *Wedekindellina euthysepta* (Henbest) in Fig. 7, no. 17; *Wedekindellina* sp. in Fig. 7, no. 18; *Beedeina rockymontana* (Roth and Skinner) in Fig. 7, no. 6; and *Beedeina* sp. in Fig. 7, nos. 11, 13, 14. At the base of the Pennsylvanian strata, from 6,960 to 7,030 ft, *Profusulinella* cf. *P. fittsi* (Thompson), as illustrated in Fig. 7, no. 19, occurs. *Profusulinella* sp. (Fig. 7, nos. 20, 21) is also present.

In the southeastern part of the Tucumcari Basin, the Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, is an informative well. From 6,140 to 6,600 ft a characteristic Wolfcampian fusulinid assemblage of *Schwagerina, Triticites,* and *Leptotriticites* occurs. *Schwagerina aff. S. grandensis* Thompson (Fig. 5, nos. 2, 3) is present, as are *Schwagerina* cf. S. *campensis* Thompson (Fig. 5, no. 4) and *Schwagerina* sp. (Fig. 5, nos. 1, 5). *Triticites* aff. T. *creekensis* Thompson (Fig. 5, nos. 13, 14), an important component of the assemblage, and *Leptotriticites hughesensis* (Thompson) (Fig. 6, no. 15) are present. It is believed that an interval of Canyon fusulinids, as represented by *Triticites* cf. *T. collus* Burma (Fig. 6, no. 13) and many other *Triticites* fragments suggestive of this age, occurs from 6,780 to 6,860 ft.

The easternmost well, the Union Producing Company No. 1 Jones, is in sec. 18 T5N R37E, Curry County. Drill cuttings with fusulinid occurrences range from 7,130 to 8,050 ft. The well has the most prolific numbers of fusulinids of any well examined, and the fusulinids identified indicate the entire zone is Wolfcampian. A large assemblage of *Schwagerina, Triticites,* and *Leptotriticites* occurs, and some of the better specimens are illustrated in Figs. 5, 6. *Schwagerina emaciata* (Beede) (Fig. 5, no. 7) and *Schwagerina* sp. (Fig. 5, no. 8) are abundant. *Triticites ventricosus* (Meek and Hayden) is illustrated in Fig. 5, nos. 9-12. *Triticites* aff. *T. meeki* (Moller) (Fig. 5, no. 15; Fig. 6, nos. 1-3, 5, 12) is a common Wolfcampian fusulinid. *Triticites pointensis* Thompson (Fig. 6, no. 4) and *Triticites* sp. (Fig. 6, nos. 7, 11) complete the assemblage of this genus. *Leptotriticites fivensis* (Thompson) (Fig. 6, nos. 18, 19), L. cf. *L. americanus* (Thompson) (Fig. 6, no. 17), and L. cf. *L. eoextentus* (Thompson) (Fig. 6, no. 16) are all characteristic Wolfcampian species of genus *Leptotriticites.*

In summary, the Pennsylvanian and Lower Permian stratigraphic sections in these wells can be subdivided and reliably correlated on the basis of their fusulinid faunas.

Stratigraphy and reservoir geology

Strata in the Tucumcari Basin were analyzed using geophysical logs, cores, drill cuttings, and petrographic thin sections of cores and drill cuttings. Most data were obtained from geophysical logs and drill cuttings. Environmental interpretation of reservoirs and other rocks was aided by core descriptions and petrographic examinations of cores and drill cuttings. Reservoir geology was evaluated using descriptions of cores, drill cuttings, and logs and petrographic analyses of thin sections of cores and drill cuttings. Most thin-section samples were impregnated with blue epoxy in order to facilitate study of pore systems.

Precambrian

Igneous and metasedimentary rocks constitute the Precambrian in the Tucumcari Basin and on adjoining uplifts. The igneous rocks are granite, quartz diorite, monzonite, gabbro, and rhyolite. Metasediments are schists and quartzite. Granite predominates the Sierra Grande Uplift and metasediments, rhyolite, and gabbro predominate elsewhere. Details of the Precambrian geology are beyond the scope of this report. Interested readers are referred to Callender et al. (1976), Flawn (1954), Foster et al. (1972), Gonzalez and Woodward (1972), and Bauer and Williams (1985).

Mississippian

Mississippian strata assigned to the Arroyo Peñasco Formation unconformably overlie Precambrian basement and occur as scattered erosional outliers throughout the subsurface of the Tucumcari Basin. Thickness varies from 0 to 300 ft and is less than 150 ft in most wells studied (Figs. 811). The unit consists chiefly of dense oolitic limestones (Fig. 12) and green or greenish-gray siliciclastic mudstones. Dense, fine- to medium-grained arkosic sandstones (Fig. 13) are locally present in the lower part of the unit. Assignment of the unit to the Arroyo Peñasco is based on: (1) stratigraphic position, (2) lithologic similarity to the Arroyo Peñasco of the Sangre de Cristo Mountains (Armstrong, 1967; Foster et al., 1972), and (3) the presence of an unconformity between it and overlying Pennsylvanian rocks (Figs. 8-11).

Pennsylvanian

Eight lithofacies comprise the Pennsylvanian and Lower Permian sections in the Tucumcari Basin (Tab. 1). The lithofacies are significant for the study of regional reservoir distribution because they are defined by the presence or absence of distinct rock types, all of which have different reservoir properties. These environmentally dependent rock types

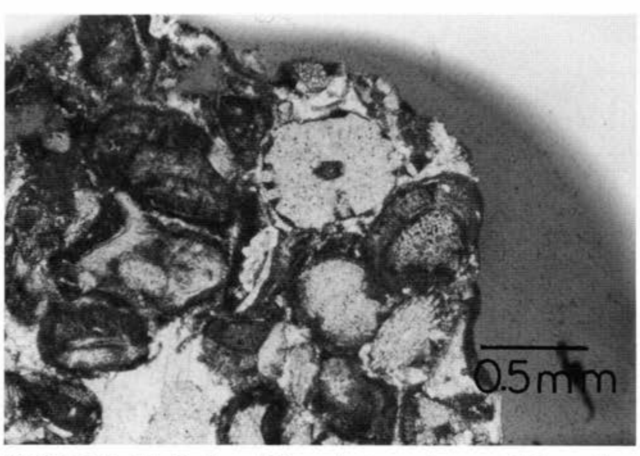


FIGURE 12—Bioclastic–oolitic grainstone, Arroyo Peñasco Formation (Mississippian). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 7,090–7,100 ft.

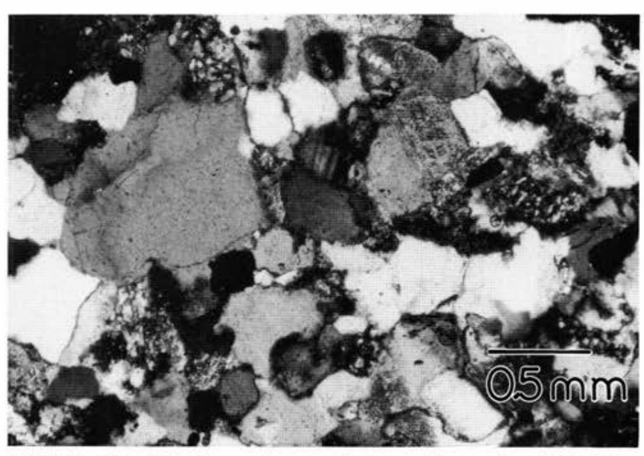


FIGURE 13—Subarkose, Arroyo Peñasco Formation (Mississippian). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 7,120–7,130 ft.

TABLE 1—Lithofacies and rock types that comprise the Pennsylvanian and Lower Permian sections in the Tucumcari Basin. **M**, major; **m**, minor or absent; **A**, absent.

	Rock types					
Lithofacies	Mudstone	Fine-grained sandstone	Fine- to coarse-grained sandstone	Limestone	Dolostone	Anhydrite or salt
Fine sandy facies	M	M	A	m	m	m
Coarse sandy facies	M	A	M	m	m	A
Muddy clastic facies	M	A	m	m	m	m
Proximal marine limestone facies	M	A	M	M	A	A
Proximal marine dolostone facies	M	A	M	A	M	A
Mixed marine facies	M	A	m–M	M	M	A
Marine limestone facies	M	A	m	M	m	A
Marine dolostone facies	M	A	m	m	M	A

are mudstone (shale), fine-grained sandstone, fine- to coarse-grained sandstone and conglomerate, limestone, dolostone, anhydrite, and salt.

Strawn and Atokan Series—The Strawn (Desmoinesian) and Atokan Series (Figs. 14A, B) are mapped and discussed together because the Atokan is a thin unit, generally less than 100 ft thick, which is not lithologically distinct and separable from the Strawn throughout the Tucumcari Basin. Fusulinid determinations and log correlations (Figs. 8-11) indicate most of the section is Strawn in age. The Atokan is apparently absent from large parts of the basin; therefore, it is probable that an unconformity separates the Strawn from the Atokan.

The Strawn-Atokan section is thickest in the structurally deepest, downfaulted parts of the Tucumcari Basin (Figs. 3, 14A); it thins over uplifts that border the basin and is absent from the highest parts of the Sierra Grande, Pedernal, and Frio Uplifts. On the Sierra Grande and Pedernal Uplifts, pinchout of the Strawn is erosional and the contact of the Strawn with overlying strata is unconformable. Fusulinid and lithologic correlations of the Cities Service No. 1 Driggers, sec. 22 T11N R21E, Guadalupe County, in the west-central part of the basin (Fig. 8) indicate the lower Strawn is unconformably overlain by Hueco (Wolfcampian) sediments; the upper Strawn and Canyon sections have been removed by erosion. A similar situation occurs in northwestern San Miguel County on the north flank of the Sierra Grande Uplift where lower Strawn sediments are unconformably overlain by Abo (Wolfcampian) sediments (Fig. 8).

The contact of the Strawn with the overlying Canyon Series is conformable in most of the central and southern parts of the Tucumcari Basin. In these areas, fusulinid determinations indicate an essentially continuous faunal record from Strawn through Canyon time. Lithostratigraphic correlations (Figs. 8-11) also do not indicate any major unconformities between the Strawn and the Canyon. In most of the central and southern parts of the Tucumcari Basin, the top of the Strawn coincides approximately with a prominent, electrically resistive, limestone marker bed (Figs. 8-11).

Strawn facies (Fig. 14B) generally show a transition from the *coarse sandy facies* and *proximal marine limestone facies* in the northern part of the Tucumcari Basin to the *marine limestone facies* in the southern part of the basin. The presence of abundant coarse-grained arkosic sands in the northern part of the basin and on the south flank of the Sierra Grande Uplift and west flank of the Frio Uplift indicates the Precambrian granitic core of the Sierra Grande Uplift was emergent during Strawn time; it was the source of the coarse-grained arkosic sands. The presence of thick wedges of coarse-grained arkosic sands on the downthrown sides of major faults in this northern region indicates the faults were active during Strawn time. The presence of a thin band of arkosic sands on the west flank of the Frio Uplift indicates this uplift was also emergent during Strawn time but did not contribute as much arkosic detritus to the basin as the Precambrian granitic core of the Sierra Grande Uplift. On the western side of the Tucumcari Basin, marine facies pinch out on the east flank of the Pedernal Uplift (Fig. 14B); the pinchout is erosional and appears to have been caused by post-Strawn movement of the Pedernal Uplift. No evidence indicates the Pedernal Uplift was emergent during Strawn time; however, proximal sands may have been removed by post-Strawn erosion.

Sandstones in the *coarse sandy facies* of the Strawn are light to medium gray, fine to very coarse grained, and conglomeratic. They are composed predominantly of quartz, granitic rock fragments, and feldspars (Fig. 15). Most feldspars have been partially altered to clays. Altered feldspars are generally ductile and have been bent around more competent quartz grains. Visual porosity ranges from a trace to 20%. Primary porosity is generally negligible; it has been reduced to near zero in most samples by mechanical compaction, syntaxial overgrowths on quartz grains, and poikilotopic calcite cement. Virtually all porosity in Strawn sandstones is secondary; secondary porosity was created by dissolution of feldspars (Fig. 15) or calcite and quartz cements. Occasionally, a second generation of calcite cement has filled the secondary pores (Fig. 16). Where secondary porosity is preserved, however, Strawn sandstones are good reservoirs.

Strawn sandstones in the *coarse sandy facies* were deposited in marginal-, shallow-, and nonmarine environments. Some of the sandstones were probably deposited in alluvial fans or by rivers that flowed southward into the Tucumcari Basin. However, Strawn sandstones that were cored in the northern part of the basin (App. B) exhibit sedimentary structures that signify deposition in shallow, marginal-marine environments: low-angle cross-laminations and abundant planar to wavy horizontal laminations, flaser bedding, intercalation with fossiliferous marine mudstones, and conformable and nonerosional contacts with intercalated siliciclastic mudstones. Some of the sandstones have hummocky bedding and vertical-escape burrows, which indicate deposition by storms on a shallow-marine shelf. Other sandstones are coarse grained and contain marine fossils, indicating deposition in a high-energy, marginal- or shallow-marine environment.

Mudstones constitute a subordinate part of the *coarse sandy facies* of the Strawn. They are medium gray, black, and red in color. Some bear a fauna of brachiopods, crinoids, and algae and are obviously marine in origin. Other mudstones do not contain marine fossils; the only evidence of their marine origin is their intercalation with marginal- and shal-

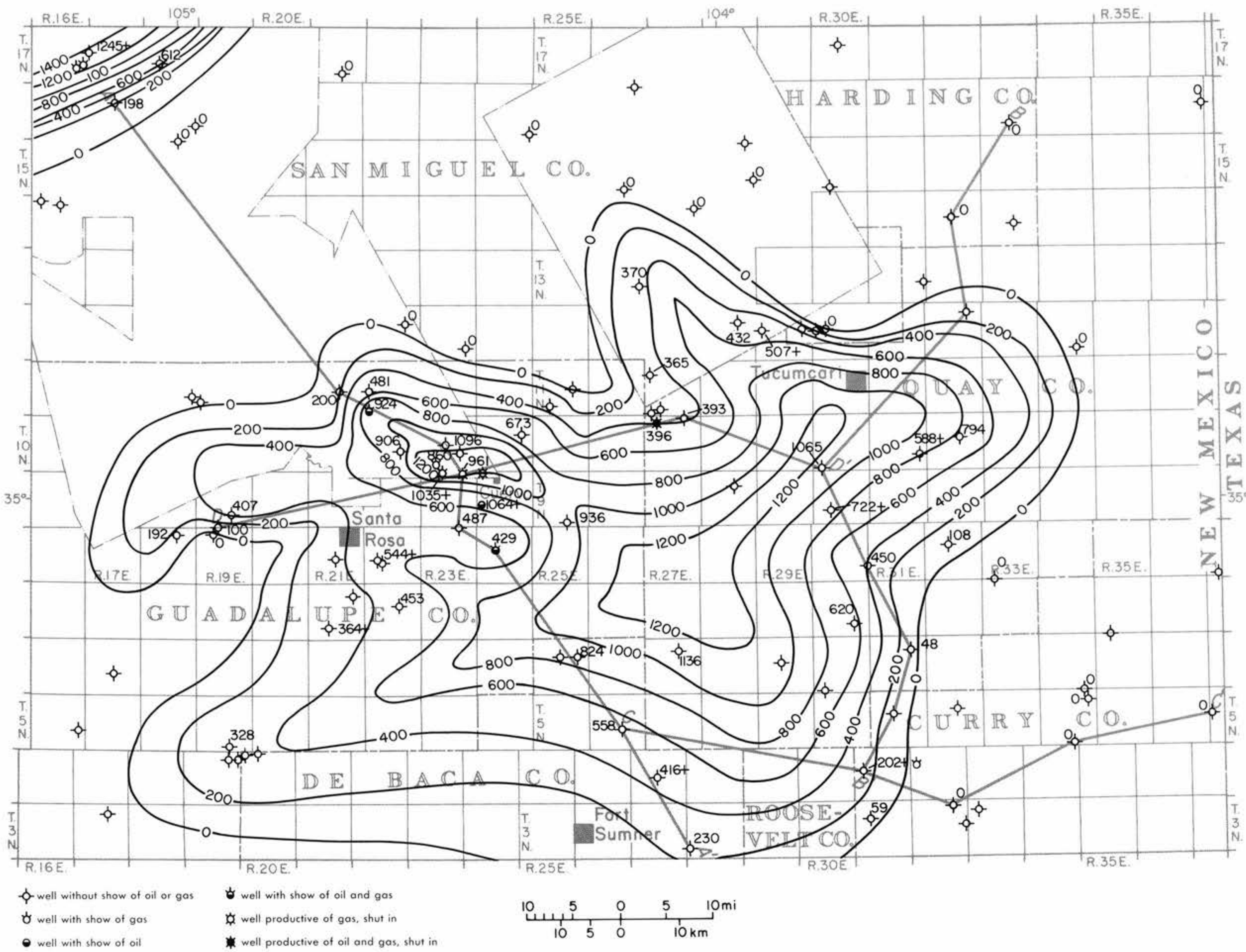


FIGURE 14A—Isopach map of Strawn and Atokan Series (Pennsylvanian). Contour interval = 200 ft.

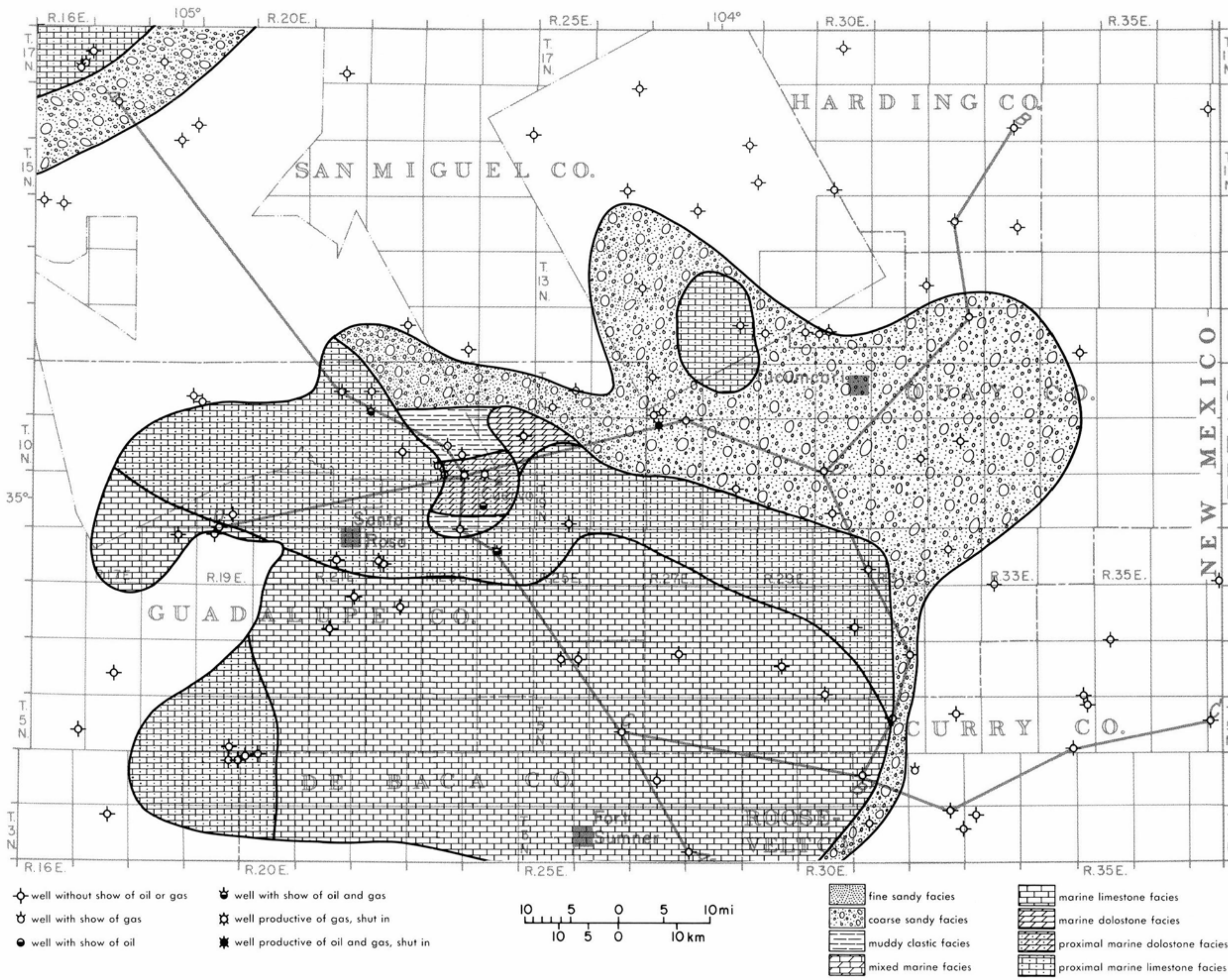


FIGURE 14B—Lithofacies map of Strawn and Atokan Series (Pennsylvanian). See Tab. 1 for description of lithofacies.

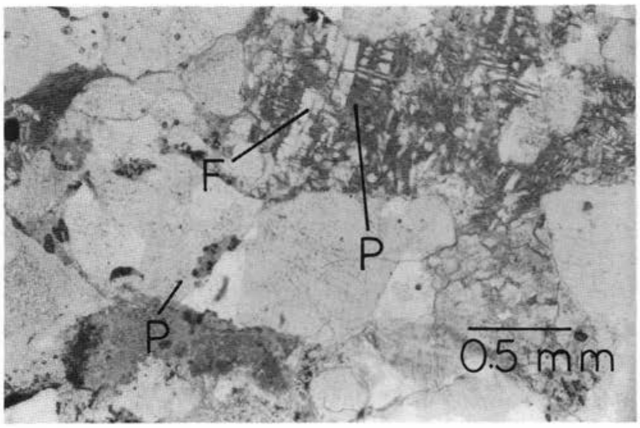


FIGURE 15—Granitic lithic arenite, Strawn Series (Pennsylvanian). Gila Exploration No. 1 Latigo Ranch D, sec. 26 T10N R23E, Guadalupe County, 6,677.6 ft. Note secondary porosity (**P**) resulting from dissolution of feldspars (**F**).

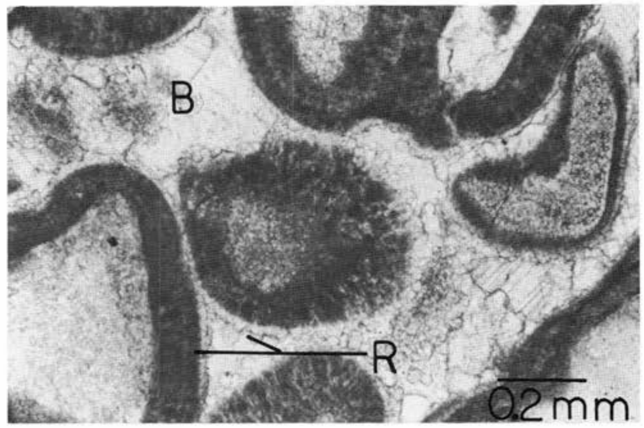


FIGURE 17—Oolitic grainstone, Strawn Series (Pennsylvanian). Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, 6,500–6,510 ft. Note rim cement (**R**) and blocky cement (**B**) of calcite.

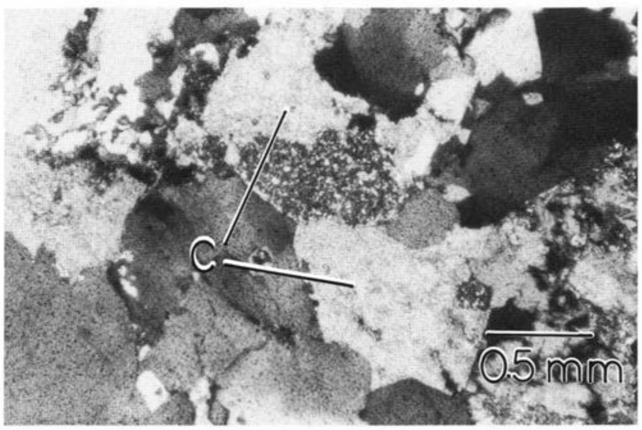


FIGURE 16—Granitic lithic arenite, Strawn Series (Pennsylvanian). Gila Exploration No. 1 Latigo Ranch D, sec. 26 T10N R23E, Guadalupe County, 7,142 ft. Note calcite (**C**) filling secondary pores formed by dissolution of feldspars.

low-marine sandstones and mudstones. Some mudstones may be alluvial or deltaic in origin, but conclusive evidence is lacking; alluvial and deltaic mudstones probably occur in Quay and San Miguel Counties where marine limestones are absent.

The *proximal marine limestone facies* lies south of the *coarse sandy facies* and is transitional between the marginal- to nonmarine *coarse sandy facies* of northern Guadalupe and northern Quay Counties and the offshore *marine limestone facies* of De Baca, southern Guadalupe, and southern Quay Counties. Sandstones and mudstones of the *proximal marine limestone facies* are similar to those of the *coarse sandy facies,* but their association with marine limestones indicates deposition in shallow- or marginal-marine (including deltaic) environments. Limestones are mostly bioclastic wackestones and packstones that variously bear brachiopod, bryozoan, fusulinid, crinoid, and ostracod faunas. A few lime mudstones and bioclastic grainstones are present. Limestones in the *proximal marine limestone facies* are nonporous and impermeable and are poor reservoirs.

The *marine limestone facies* occupies the southernmost parts of the Tucumcari Basin (Fig. 14B). It consists primarily of interbedded marine mudstones and limestones. The limestones are light-gray to black bioclastic wackestones and packstones that variously bear diverse faunas of fusulinids, crinoids, corals, brachiopods, bryozoans, phylloid algae, and ostracods. Generally, bioclasts are broken and abraded and have been either micritized or recrystallized to microspar. Porosity is generally poor, 0-5%.

Oolitic and bioclastic grainstones of the *marine limestone facies* (Fig. 17) occur in the Abercrombie and Hawkins No. **1** Nappier, sec. 22 T5N R26E, De Baca County. These limestones consist of a framework of oolites and fragments of crinoids, bryozoans, ostracods, and phylloid algae. The framework is cemented by drusy calcite; acicular rim cements are present in some samples. Porosities up to 10% were noted in drill cuttings of oolitic grainstones; the oolitic grainstones are fair to good reservoirs.

Strawn limestones are more thickly bedded in the southern part than they are in the central and northern parts of the basin (Figs. 8, 9; App. C). Drill cuttings and geophysical logs indicate some limestone beds are more than 50 ft thick in the southern part of the basin, whereas limestone beds are 5-20 ft thick in the central part of the basin and less than 10 ft thick in the northern part of the basin. Well control is insufficient to determine the geometry of individual limestone beds and it is not known whether the thicker beds in the south are biohermal or biostromal.

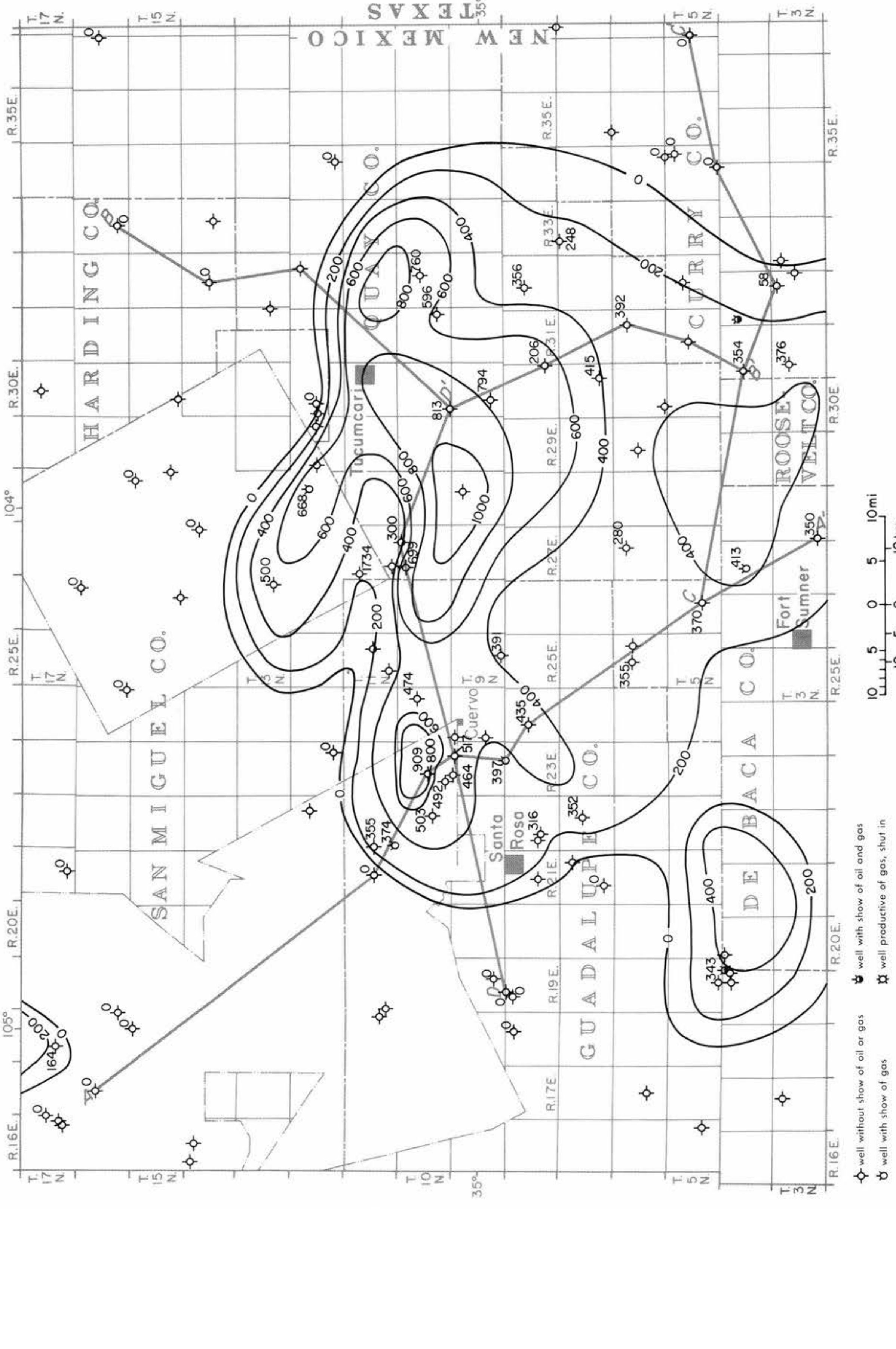
The occurrence of oolitic grainstones in the Abercrombie and Hawkins well suggests that oolite shoals and other high-energy carbonate environments are present in the southern part of the Tucumcari Basin. These carbonates may have local, well-developed porous zones that are good reservoirs.

Strawn limestones may also be good reservoirs in the northwestern and western margins of the basin. In these areas, the Strawn is overlain unconformably by younger sedimentary units; the unconformities appear to be subaerial. Freshwater solution of limestones during subaerial exposure may have created porous reservoirs (e.g. Longman, 1980). Sediments deposited above the unconformities may have sealed these reservoirs.

Sandstones also occur in the *marine limestone facies.* They are orange red in color. Most are fine grained, but a few coarse-grained sandstones are present. The sandstones are orthoquartzites and subarkoses. Generally, primary porosity has been reduced to negligible amounts by compaction, syntaxial overgrowths of quartz cement, and calcite cement. The sandstones are generally poor reservoirs; the more porous ones may be low-permeability, "tight" gas reservoirs.

Most mudstones in the *marine limestone facies* are gray. Some are red.

Lower unit of Canyon Series—The lower unit of the Canyon (Missourian) Series is 0-900 ft thick in the Tucumcari Basin (Fig. 18A) and may exceed 1,000 ft in the undrilled, deeper parts of the basin. The lower Canyon pinches out



NEW MEXICO
TEXAS
HARDING CO.
QUAY CO.
CURRY CO.
ROOSEVELT CO.
SAN MIGUEL CO.
GUADALUPE CO.
DE BACA CO.
Tucumcari
Santa Rosa
Cuervo
Fort Sumner
104°
105°
35°
R.16E.
R.17E.
R.19E.
R.20E.
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R.33E.
R.35E.
T.17N.
T.15N.
T.10N.
T.9N.
T.5N.
T.3N.
0 5 10 mi
0 5 10 km
well without show of oil or gas
well with show of gas
well with show of oil
well with show of oil and gas
well productive of gas, shut in
well productive of oil and gas, shut in

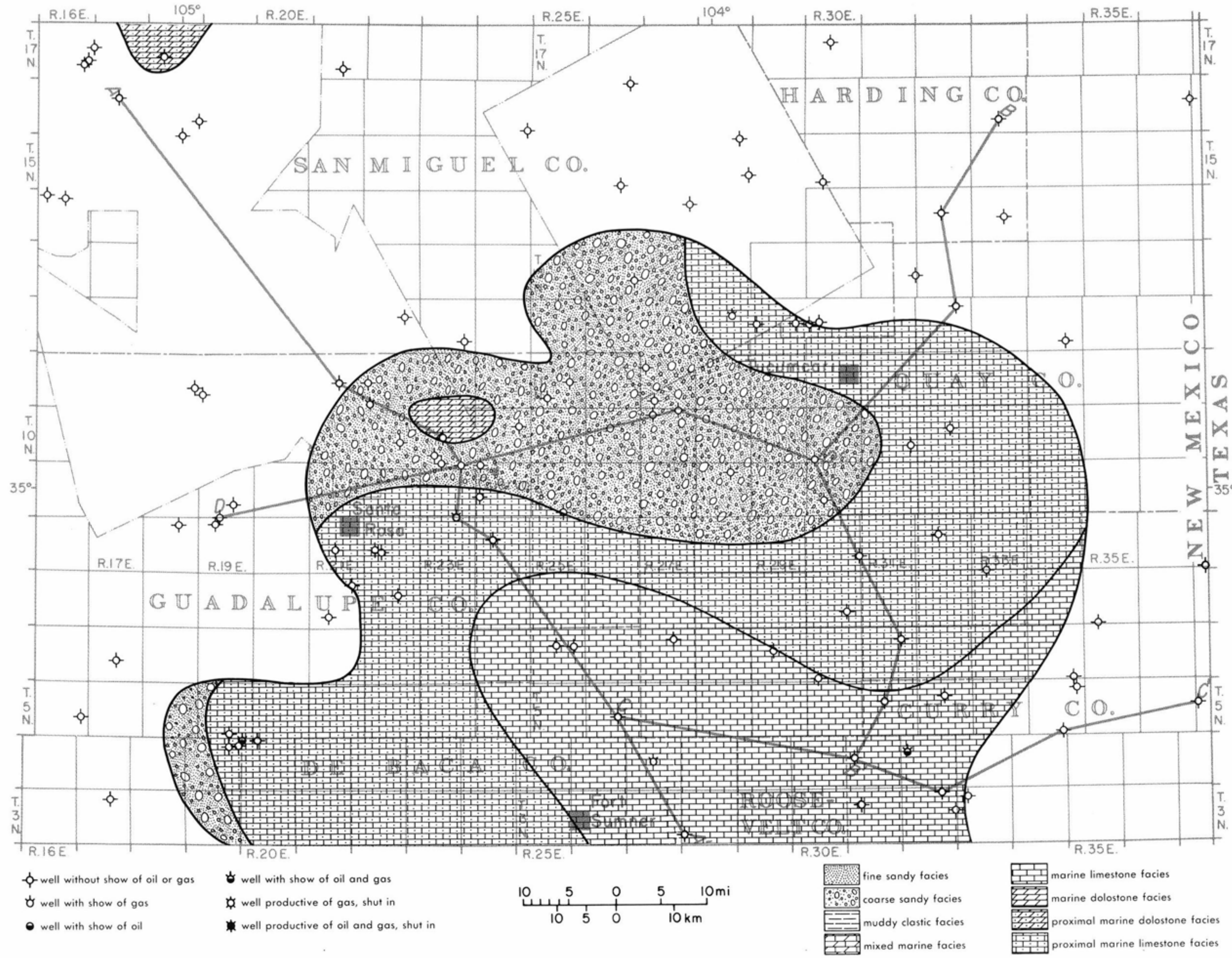


FIGURE 18B—Lithofacies map of lower unit of Canyon Series (Pennsylvanian). See Tab. 1 for description of lithofacies.

as it onlaps the Sierra Grande, Pedernal, and Frio Uplifts. In one well, the Baker and Taylor No. 1 T-4 Cattle Company, sec. 7 T11N R27E, San Miguel County, an anomalously thick section of 1,734 ft of lower Canyon was drilled; dipmeter logs indicate the thickness is caused by steeply dipping and tightly folded strata. The section may be repeated by one or more reverse faults (see discussion in structure section).

The base of the lower Canyon is the top of the prominent limestone bed that marks the top of the Strawn. The contact of the Strawn and the lower Canyon is conformable throughout most of the Tucumcari Basin.

The top of the lower Canyon is a prominent, resistive carbonate marker bed that can be correlated with resistivity logs throughout the basin (Figs. 8-11). This carbonate marker bed is a limestone in the southern part of the basin; it has been dolomitized in the northern part of the basin. The marker bed probably forms a time-parallel surface because other prominent Pennsylvanian marker beds in the Tucumcari Basin approximate time-parallel lithostratigraphic units.

Lower Canyon facies generally show a transition from *coarse sandy facies* and *proximal marine limestone facies* in the northern part of the Tucumcari Basin to *marine limestone facies* in the southern part of the basin (Fig. 18B). The presence of coarse-grained arkosic sandstones in the northern and western parts of the basin indicate the Sierra Grande and Pedernal Uplifts were emergent during early Canyon time; the Precambrian cores of these uplifts shed granitic detritus into the Tucumcari Basin. The presence of thick wedges of arkosic sands on the downthrown sides of major faults that form the basinal margins indicates these faults were active during early Canyon time.

Sandstones in the *coarse sandy facies* and *proximal marine limestone facies* were probably deposited in alluvial fans, rivers, and associated deltas that flowed into the basin from the Sierra Grande and Pedernal Uplifts. A lower Canyon conglomeratic sandstone cored in the Gila Exploration (formerly Trans-Pecos Resources) No. 1 Latigo Ranch D (Fig. 19; App. B), sec. 26 T1ON R23E, Guadalupe County, was deposited in a deltaic distributary channel that had erosionally cut into prodeltaic and delta-front muds. Most sandstones in the *proximal marine limestone facies* were probably deposited in deltas or fan deltas because they are interbedded with marine limestones and mudstones.

Sandstones in the *coarse sandy facies* are light to dark gray, fine to very coarse grained, and conglomeratic. They are composed predominantly of quartz, granitic rock fragments, and feldspars. Most feldspars have been extensively altered to clays. Visual porosity ranges from 0 to 20%. Many sandstones are friable and appear to have well-developed porosity. Primary porosity is generally negligible; in most of the sandstones it has been reduced to near zero by mechanical compaction, syntaxial overgrowths of quartz cement, and calcite cement. Quartz and calcite cements fill large primary pores, indicating that cementation occurred during a relatively early, precompactional diagenetic stage. Secondary porosity has resulted from dissolution of quartz and calcite cements (Fig. 20) and feldspars. Unlike sandstones in the *coarse sandy facies* of the Strawn Series, lower Canyon sandstones have a relatively small percentage of porosity that resulted from dissolution of feldspars.

Mudstones in the *coarse sandy facies* are red to gray in color. Many are marine. Some are dolomitic and contain dolomitized bryozoans and crinoids. Cored mudstones in the Gila Exploration No. 1 Latigo Ranch D are dark gray and contain brachiopods and crinoids; they are thinly laminated and sparsely burrowed.

The *coarse sandy facies* contains a few thin beds of marine dolostones. In the General Crude Oil Company No. 1 Simpson, sec. 21 T1ON R23E, Guadalupe County, the dolostones are dark-gray dolomudstones and dolowackestones that consist of crinoid fragments and other undetermined fauna in a dolomicritic matrix. They have no visual porosity and appear impermeable.

The *proximal marine limestone facies* consists of sandstones,

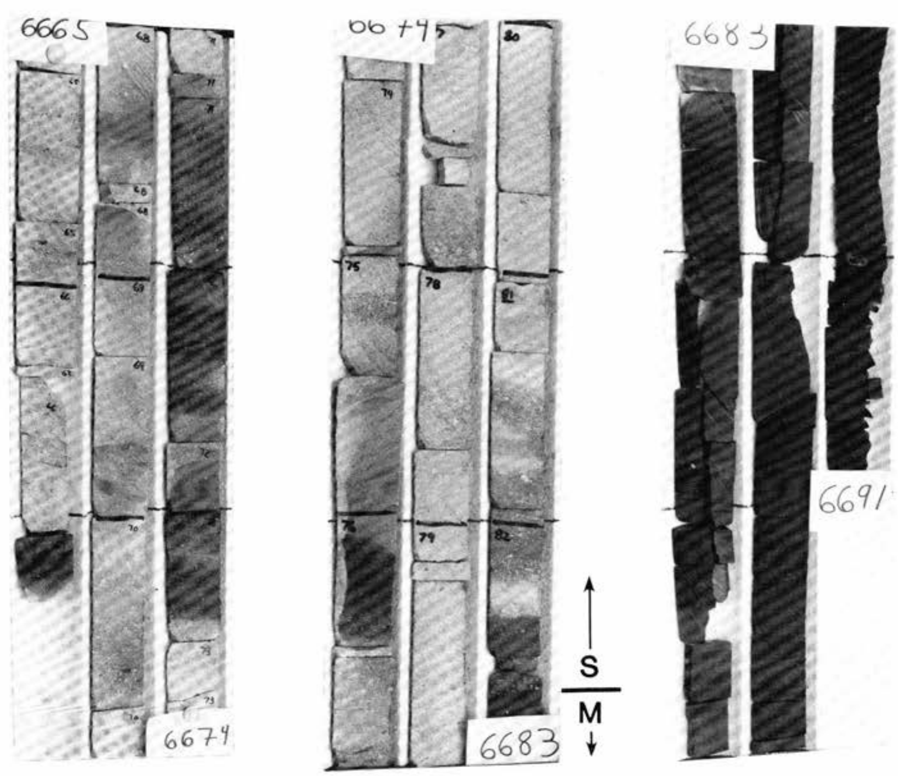


FIGURE 19—Upward-coarsening deltaic sequence, showing upward-coarsening prodeltaic and delta-front muds (**M**) erosionally overlain by distributary-channel sands (**S**), lower unit of Canyon Series (Pennsylvanian). Gila Exploration No. 1 Latigo Ranch D, sec. 26 T10N R23E, Guadalupe County, 6,665–6,691 ft (from Broadhead and King, 1985).

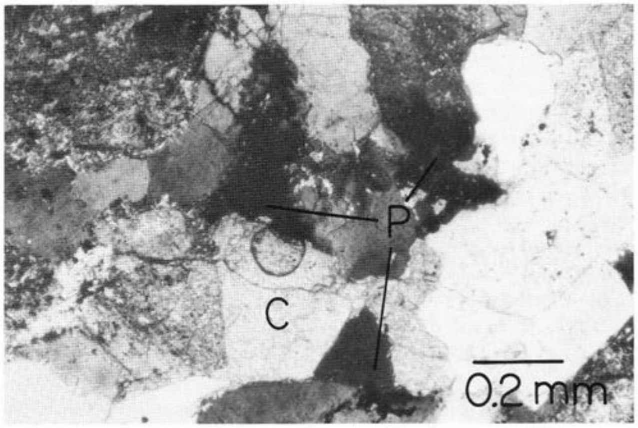


FIGURE 20—Subarkose, lower unit of Canyon Series (Pennsylvanian). Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County, 6,030–6,040 ft. Note secondary porosity (**P**) resulting from dissolution of calcite cement (**C**).

mudstones, and limestones. Sandstones in the *proximal marine limestone facies* are similar to sandstones in the *coarse sandy facies;* their stratigraphic association with marine limestones indicates deposition in marginal- or shallow-marine environments. Diagenetic controls on porosity appear similar in both facies. Mudstones are gray to red in color; many are mottled gray and red. Limestones are open-marine lime mudstones and bioclastic wackestones that variously bear brachiopod, crinoid, ostracod, and phylloid-algal faunas. The limestones are nonporous and "tight."

The *marine limestone facies* occupies the southernmost part of the Tucumcari Basin (Fig. 18B). It consists primarily of interbedded marine limestones and mudstones. Most of the limestones were deposited on a shallow, open-marine shelf. They are light- to dark-gray lime mudstones and bioclastic wackestones, packstones, and grainstones. Faunas are micritized or recrystallized fragments of brachiopods, bryozoans, gastropods, crinoids, foraminifers, and fusulinids. The gastropods are indicative of very shallow marine conditions.

Oolitic grainstones of the *marine limestone facies* (Fig. 21) are present in the Abercrombie and Hawkins No. 1 Nappier, sec. 22 T5N R26E, De Baca County, and in the Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County. These oolitic grainstones indicate high-energy shoaling conditions were present in the southern part of the Tucumcari Basin during early Canyon time.

Most limestones examined from the lower Canyon, including the oolitic grainstones, are nonporous and impermeable. However, the occurrence of high-energy marine carbonates indicates carbonate buildups, and possibly porous limestone reservoirs, may be present in the lower Canyon in the southern part of the Tucumcari Basin.

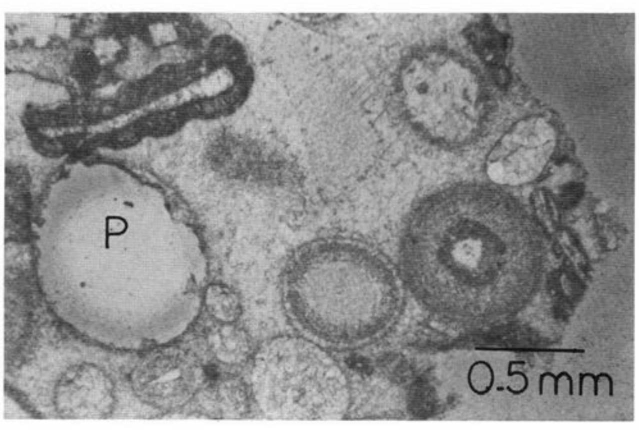


FIGURE 21—Oolitic grainstone, lower unit of Canyon Series (Pennsylvanian). Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,850–6,860 ft. Note oomoldic porosity (**P**).

Lower Canyon limestones are more thickly bedded in the southern part of the basin than they are in the central and northern parts of the basin (Figs. 8, 9; App. C). Drill cuttings and geophysical logs indicate some limestone beds are more than 50 ft thick in the southern part of the basin, whereas limestone beds are 5-30 ft thick in the central and northern parts of the basin. Well control is insufficient to determine the geometry of individual limestone beds. It is not known whether the thicker beds in the south are biohermal or biostromal.

Mudstones in the *marine limestone facies* are red and gray. Many are calcareous and bear a sparse marine fauna.

Upper unit of Canyon Series—The upper unit of the Canyon (Missourian) Series is 0-800 ft thick in the Tucumcari Basin (Fig. 22A). The upper Canyon is thickest in structurally low parts of the western half of the basin. It is absent from the Sierra Grande and Pedernal Uplifts where it is represented by an unconformity. The upper Canyon thins gradually to the east and pinches out as it onlaps the Frio Uplift. It thins gradually to the south as it onlaps the northwest shelf of the Permian Basin. The eastward and southward thinning may represent both depositional thinning and erosional truncation, but was probably caused mostly by erosional truncation; detailed lithologic correlations indicate that as much as 500 ft of upper Canyon section is missing from the eastern and southern parts of the Tucumcari Basin (Figs. 8-11).

The base of the upper Canyon is the prominent, resistive carbonate marker bed at the top of the lower unit of the Canyon Series (Figs. 8-11). The contact of the lower and upper Canyon is conformable throughout the Tucumcari Basin.

The top of the upper Canyon is a prominent unconformity throughout the Tucumcari Basin. As discussed previously, fusulinid fauna of Cisco (Virgilian) age is absent in the Tucumcari Basin; strata that bear Wolfcampian fusulinids rest on strata that bear Canyon fusulinids. Lithostratigraphic correlations (Figs. 8-11) indicate the upper Canyon has been eroded from the margins of the Tucumcari Basin and that the contact between upper Canyon and Wolfcampian strata is unconformable.

Upper Canyon facies generally grade from *coarse sandy facies, proximal marine limestone facies,* and *proximal marine dolostone fades* in the northern part of the Tucumcari Basin to *marine limestone facies* in the southern part of the basin (Fig. 22B). This general fades trend indicates the Sierra Grande Uplift was emergent and shed coarse-grained arkosic sands into the Tucumcari Basin during late Canyon time. Major faults that form the basin were also active during this time. An outlier of *proximal marine limestone facies* is preserved in a graben on the Sierra Grande Uplift in T13N R26E, San Miguel County (Figs. 3, 22B); *coarse sandy facies* and *proximal marine limestone facies* of the upper Canyon have apparently been eroded from portions of the Sierra Grande Uplift.

Upper Canyon sandstones in the northern part of the basin are fine to very coarse grained and conglomeratic. They consist predominantly of quartz, granitic rock fragments, and feldspars. Feldspars generally exhibit partial alteration to clays. Drill cuttings reveal that most of the sandstones are friable and are porous reservoirs.

Sandstones in the northern part of the basin were probably deposited in alluvial fans, rivers, deltas, and shallow-marine environments. Most of the sandstones in the *proximal marine limestone facies* and the *proximal marine dolostone facies* were probably deposited in deltaic and shallow-ma-

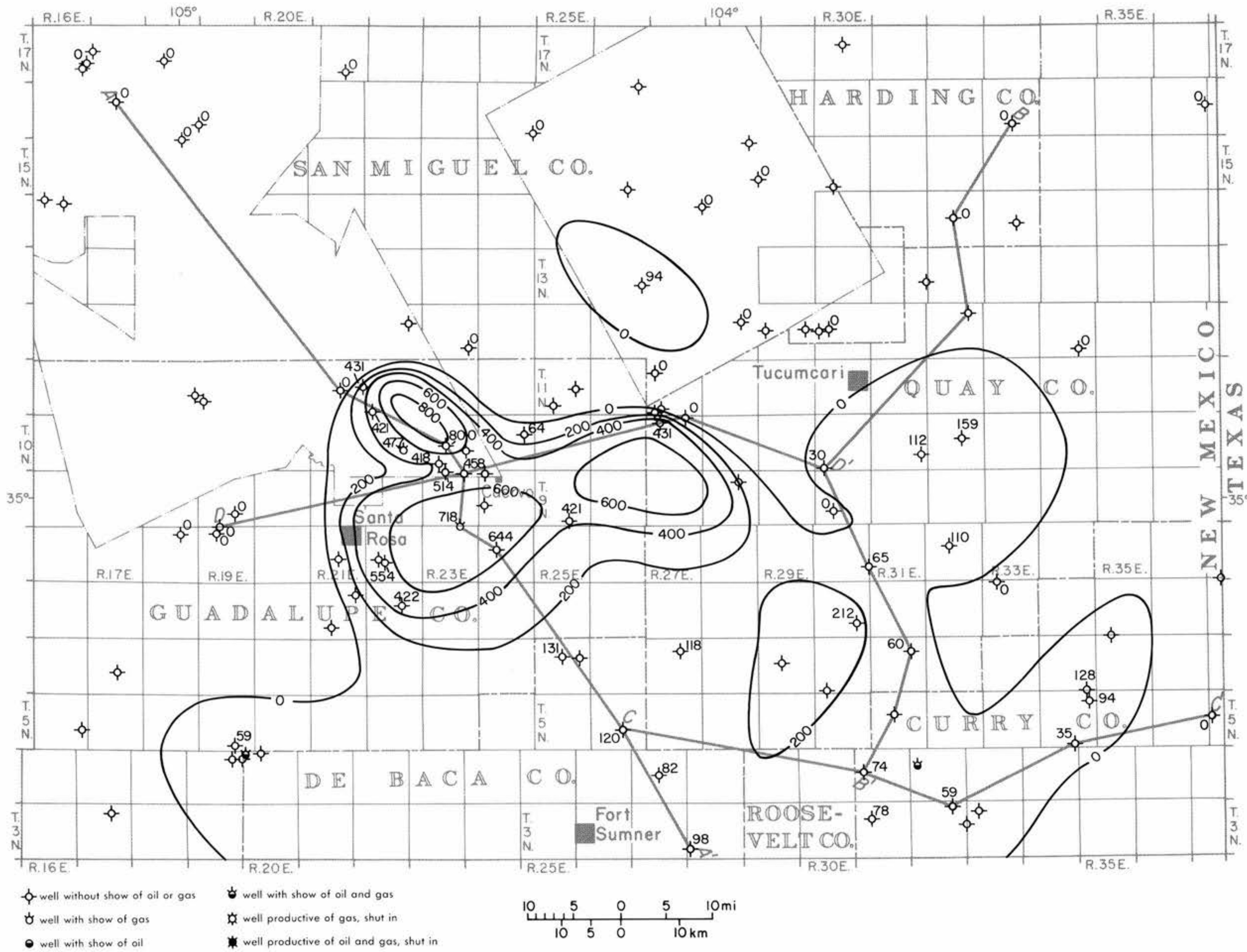


FIGURE 22A—Isopach map of upper unit of Canyon Series (Pennsylvanian). Contour interval = 200 ft.

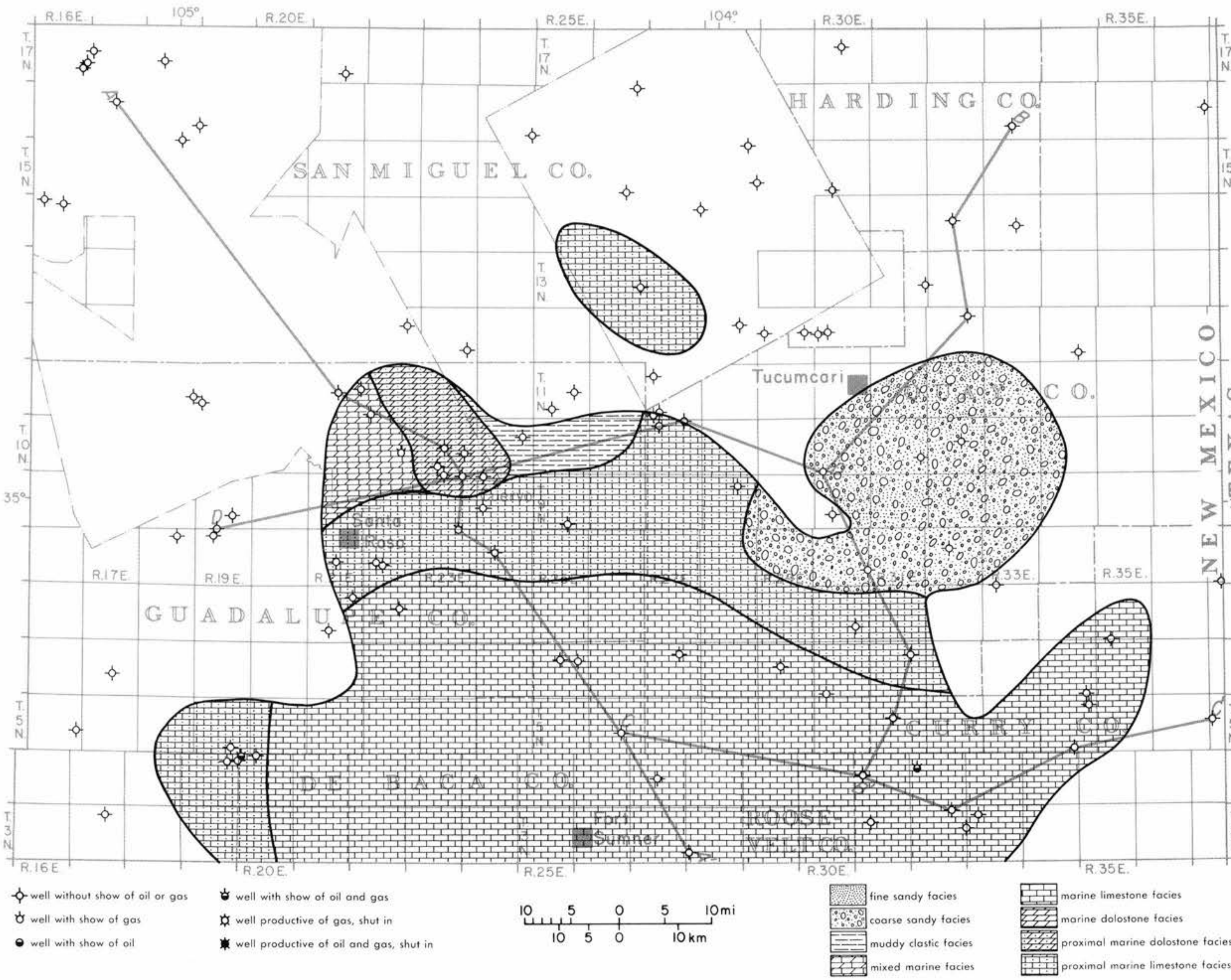


FIGURE 22B—Lithofacies map of upper unit of Canyon Series (Pennsylvanian). See Tab. 1 for description of lithofacies.

FIGURE 23—Bioclastic–oolitic packstone, upper unit of Canyon Series (Pennsylvanian). Husky Oil Company and General Crude Oil Company No. 1 Hanchett State, sec. 16 T8N R24E, Guadalupe County, 5,980–5,990 ft.

rine environments because they are interbedded with marine carbonates. Cores of upper Canyon sandstones were not available for environmental analyses.

Limestones in the *proximal marine limestone facies* are bioclastic wackestones, packstones (Fig. 23), and grainstones. They are medium to olive gray. Clasts are oolites and fragments of bryozoans, crinoids, fusulinids, gastropods, and algae. Visual porosity ranges from 0 to 5%. The textures and fauna of the limestones indicate deposition in shallow-marine waters. The grainstones were probably deposited in high-energy shoaling conditions. The presence of these high-energy carbonates indicates porous reservoirs may be present in the northern part of the Tucumcari Basin.

Dolostones in the *proximal marine dolostone facies* (Fig. 22B) are dolopackstones and dolowackestones. Porosity is low and was formed by minor dissolution of dolomite and sparsely distributed microfractures.

Siliciclastic mudstones occur in all upper Canyon facies in the northern part of the Tucumari Basin. They are medium to dark gray or grayish red to dark reddish brown.

The *marine limestone facies* constitutes the upper Canyon section in the southern part of the Tucumcari Basin and on the Frio Uplift (Fig. 22B). It consists primarily of interbedded marine mudstones and limestones. In the southern part of the basin, the limestones were mostly deposited in fairly low energy environments. They are light- to olive-gray lime mudstones and bioclastic wackestones. Fauna consists mostly of crinoids, bryozoans, foraminifers, brachiopods, and fusulinids. The limestones are generally nonporous and are poor reservoirs. It is possible, however, that porous zones may be present in carbonates in the uppermost part of the upper Canyon. These carbonates may have been subjected to freshwater dissolution during formation of the Cisco (Virgilian) unconformity, and porous reservoirs may have formed (see Longman, 1980). Hueco (Wolfcampian) sediments that were deposited upon the upper Canyon carbonates may have sealed these reservoirs.

Cisco Series—The Cisco (Virgilian) Series is not present in the Tucumcari Basin. Fusulinids of Cisco age were not found in any of the drill cuttings examined. Furthermore, a nonmarine section, which would be devoid of autochthonous fusulinids, does not lie between sections bearing Canyon fusulinids and sections bearing Wolfcampian fusulinids. Therefore, the authors believe that an unconformity lies between upper Canyon and Wolfcampian strata in the Tucumcari Basin. This conclusion is supported by previously discussed lithostratigraphic correlations that indicate upper Canyon strata are erosionally truncated in the basin. Rose (1986a) also indicated that the Cisco is not present on the Frio Uplift, or on any of the uplifts surrounding the Palo Duro Basin of the Texas panhandle. The Cisco is present in the center of the Palo Duro Basin as a starved-basin facies of dark shales and thin limestones (Rose, 1986a).

Permian

Lower unit of Hueco Formation—The lower unit of the Hueco Formation (Wolfcampian) is 0-1,400 ft thick in the Tucumcari Basin (Figs. 8-11, 24A). The lower Hueco pinches out as it onlaps the Sierra Grande and Pedernal Uplifts. It thins over the Frio Uplift. Three major thick areas are present in northern Guadalupe and southern San Miguel Counties on the south flank of the Sierra Grande Uplift. A fourth major thick area is in southeastern Guadalupe County, where more than 1,400 ft of lower Hueco occurs. The lower Hueco extends farther to the north and west than Pennsylvanian sediments. In the central and southern parts of the basin, the lower Hueco rests unconformably on the Canyon. To the north and west, the lower Hueco stratigraphically overlaps the Canyon and rests unconformably on the Strawn and Precambrian of the Sierra Grande and Pedernal Uplifts. The lower Hueco thickens rapidly into the westernmost Palo Duro Basin, indicating rapid subsidence of the western Palo Duro Basin during early Hueco time.

The base of the lower Hueco was picked to coincide with the base of the Wolfcampian Series as determined by fusulinid biostratigraphy. The approximate base of the Hueco is lithostratigraphically defined with geophysical logs. For mapping purposes, the top of the highest Canyon limestone (Figs. 8-11) is chosen as the Hueco base. In some wells, a few feet of Canyon shale may be present above the limestone marker.

A resistive carbonate marker bed that can be correlated with geophysical logs throughout the Tucumcari Basin (Figs. 8-11) is selected as the top of the lower Hueco. In most wells the marker bed is a limestone, but in some wells it is a dolostone.

Lower Hueco facies generally show a transition from *coarse sandy facies* in the northern part of the Tucumcari Basin to *marine limestone facies* in the southern part of the basin (Fig. 24B). The *mixed marine facies* covers the Frio Uplift and the New Mexico part of the Palo Duro Basin. The presence of coarse-grained arkosic sandstones in the northern part of the basin and on the south flank of the Sierra Grande Uplift indicates the Sierra Grande Uplift was rejuvenated during early Hueco time after being quiescent during Cisco time. The Precambrian core of the Sierra Grande Uplift and reworked Strawn and Canyon sediments were the sources of lower Hueco clastic deposits. Although the northern part of the Pedernal Uplift was apparently active during the early Wolfcampian (Kottlowski and Stewart, 1970), coarse-grained clastic sandstones are not known to exist along the east flank of the Pedernal Uplift in Guadalupe County. Their absence indicates the western edge of the lower Hueco in the Tucumcari Basin is erosional. It appears that the westernmost lower Hueco is unconformably overlain by upper Hueco and Abo sediments.

Lower Hueco sandstones are marginal- to nonmarine in origin. Sandstones in the *coarse sandy facies, proximal marine limestone facies,* and *proximal marine dolostone facies* were probably deposited in alluvial fans, rivers, and associated deltas that flowed into the Tucumcari Basin from the Sierra Grande and Pedernal Uplifts. Sandstones in the *proximal marine limestone facies* and *proximal marine dolostone facies* are interbedded with marine limestones and mudstones and were probably deposited in deltas or fan deltas.

Sandstones in the *coarse sandy facies* of the lower Hueco are fine to very coarse grained and conglomeratic. They are composed mostly of quartz, granitic rock fragments, and

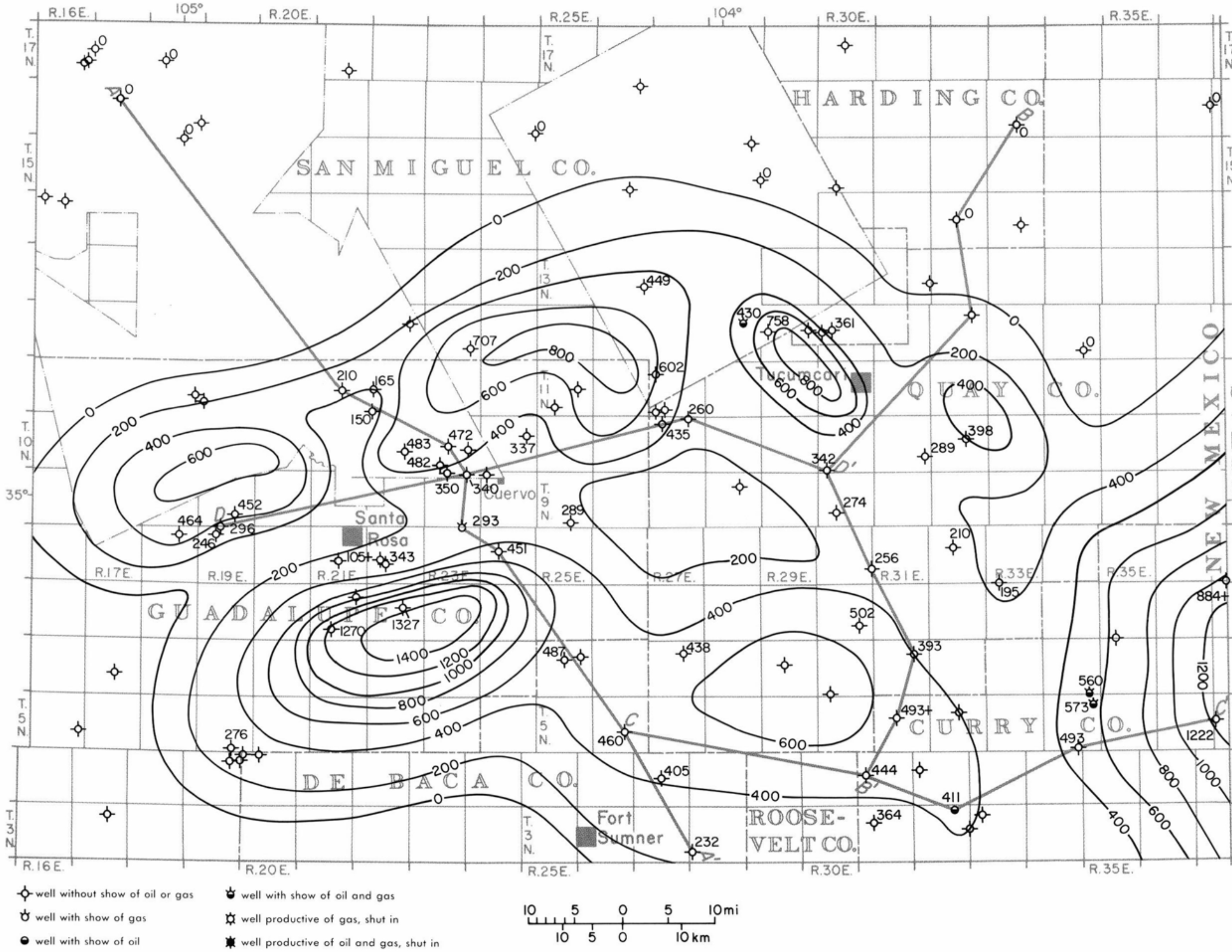


FIGURE 24A—Isopach map of lower unit of Hueco Formation (Permian). Contour interval = 200 ft.

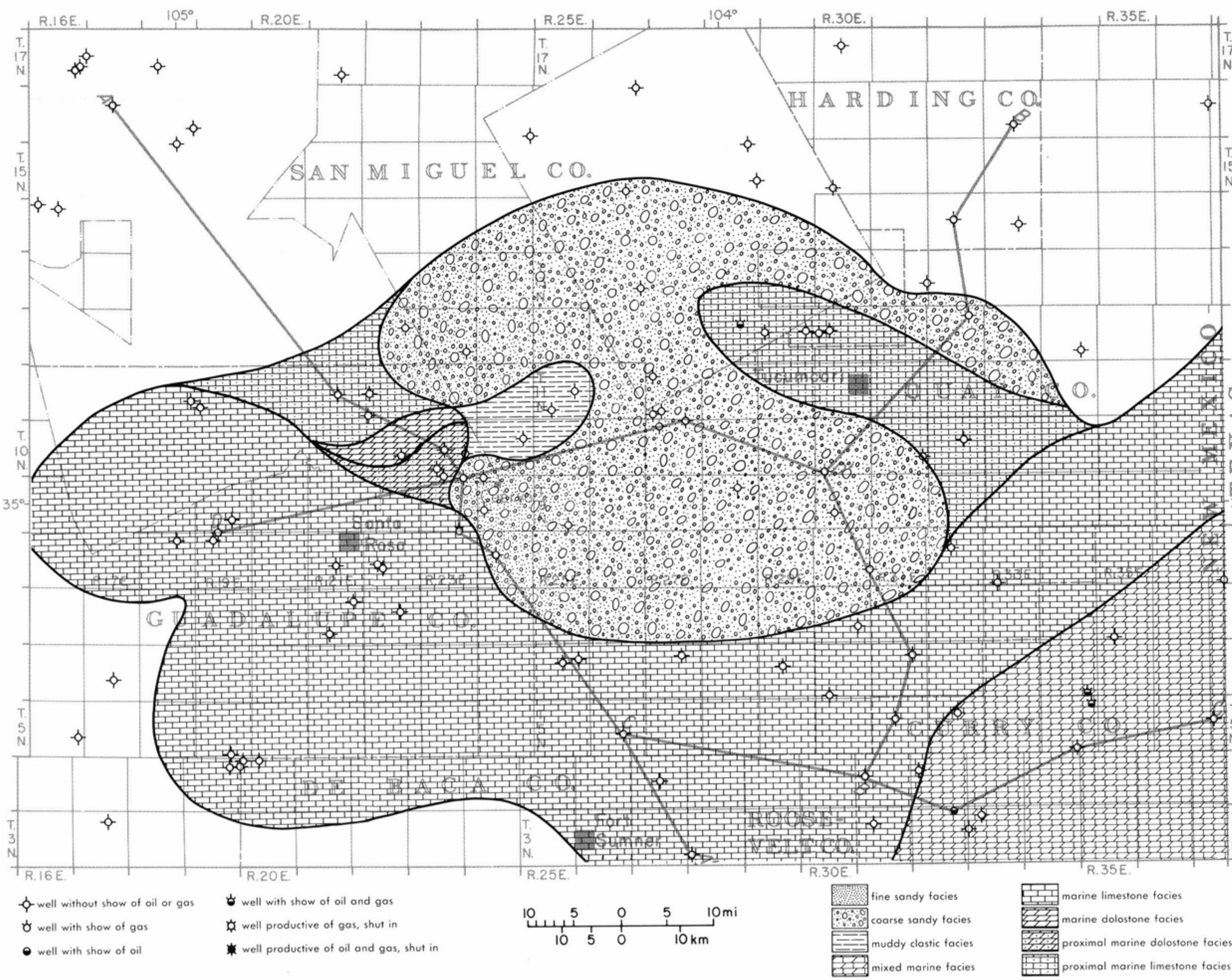


FIGURE 24B—Lithofacies map of lower unit of Hueco Formation (Permian). See Tab. 1 for description of lithofacies.

feldspars. Most feldspars appear fresh and unaltered. Lower Hueco sandstones are generally friable and porous; they are good reservoirs. Some lower Hueco sandstones are tightly cemented by calcite and are poor reservoirs. Porosity generally appears to be primary, but there may be some secondary porosity that resulted from dissolution of cements.

Mudstones in the *coarse sandy facies* are red to gray in color. Red mudstones predominate in the upper part of the section and gray mudstones predominate in the lower part of the section.

A few thin-bedded limestones are present in the *coarse sandy facies* in the Husky Oil Company and General Crude Oil Company No. 1 Hanchett State, sec. 16 T8N R24E, Guadalupe County. They are lime mudstones and bioclastic packstones. Fauna consists of fusulinids, bryozoans, and brachiopods. The limestones have no visual porosity and are poor reservoirs.

A few thin-bedded dolostones are present in the Stanolind No. 1 J. W. Fuller, sec. 25 T8N R30E, Quay County, and in the Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County. They are light-olive gray and microcrystalline. The dolostones have no visual porosity and are poor reservoirs.

The *marine limestone facies* occupies the southern and central parts of the Tucumcari Basin (Fig. 24B). It consists primarily of interbedded marine mudstones and limestones. Most limestones are bioclastic wackestones and packstones, but some are lime mudstones. They appear to have been deposited on a shallow-marine shelf. Faunas are generally micritized or recrystallized fragments of crinoids, bryozoans, brachiopods, foraminifers, fusulinids, and gastropods. The limestones are poor reservoirs. Most have no visual porosity.

Limestone beds are 5-30 ft thick and the percentage of limestone decreases toward the sources of clastic sediment supply in the north. Bed thickness does not vary areally within the basin. The Tucumcari Basin, unlike the Palo Duro Basin, does not appear to have had a pronounced carbonate shelf-margin, slope, and basin system (Handford and Dutton, 1980; Crevello et al., 1985). However, the presence of a thick carbonate section in the bottom half of the lower Hueco in the Cities Service No. 1 Widner, sec. 17 T4N R31E, Curry County (Fig. 10), which is not present in other wells in the basin, is suggestive of reefing.

The *mixed marine facies* covers the Frio Uplift and the New Mexico part of the Palo Duro Basin. Data from wells drilled into the *mixed marine facies* reveal a marked areal variation in lithology. In the Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, the lower Hueco is 411 ft thick and consists of approximately 70 ft of interbedded limestones and mudstones that are overlain by approximately 160 ft of interbedded dolostones and mudstones that, in turn, are overlain gradationally by approximately 180 ft of interbedded limestones, mudstones, and minor, orange-red very fine grained sandstones. In the Texas Gulf Producing Company No. 1 Garrett, sec. 34 T5N R34E, Curry County, the lower Hueco is 493 ft thick and consists of approximately 200 ft of interbedded dolostones, mud-stones, and minor limestones that are overlain by approximately 150 ft of interbedded dolostones and mudstones that, in turn, are overlain by approximately 150 ft of interbedded limestones and mudstones. In the Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, the lower Hueco is 1,222 ft thick and consists of approximately 900 ft of interbedded limestones, mudstones, and minor dolostones that are overlain by approximately 160 ft of interbedded dolostones and mudstones that, in turn, are overlain by approximately 170 ft of interbedded limestones and mudstones. In the Humble Oil and Refining Company No. 1 Northcutt, sec. 32 T8N R37E, Curry County, the lower Hueco is more than 884 ft thick; the exact thickness is not known because the well reached total depth in the lower Hueco. The part of the lower Hueco penetrated by the well consists of approximately 320 ft of interbedded limestones, mudstones, and minor fine-grained sandstones that are overlain by approximately 340 ft of interbedded limestones, dolostones, mudstones, and minor fine-grained sandstones that, in turn, are overlain by approximately 220 ft of interbedded shales, coarse-grained arkosic sandstones, and minor limestones.

The *mixed marine facies* is thus comprised of three units. The lower unit is 200-900 ft thick and generally consists of interbedded limestones, mudstones, and minor dolostones and fine-grained sandstones. The middle unit is 150-340 ft thick and generally consists of interbedded dolostones, mudstones, and minor limestones. This unit may roughly correlate with the prolific oil reservoirs of "white dolomite" on the Amarillo Arch, Texas panhandle. The upper unit is 150-220 ft thick and consists of interbedded limestones, mudstones, and, in the Humble Oil and Refining Company No. 1 Northcutt, minor coarse-grained arkosic sandstones.

Limestones in the *mixed marine facies* are light-, olive-, and dark-gray lime mudstones and bioclastic wackestones, packstones, and grainstones. The mudstones, wackestones, and packstones appear to have been deposited in shallow-marine conditions. The grainstones may have been deposited in high-energy shoaling environments. The limestones variously bear crinoid, brachiopod, bryozoan, coral, and gastropod faunas; phylloid algae are present in some limestones. Faunal diversity in individual samples is generally high, indicating deposition in open-marine waters of normal salinity. Bioclasts have generally been partially micritized or recrystallized to microspar. The limestones are generally poor, "tight" reservoirs with no visual porosity. However, a few of the limestones have well-developed vuggy porosity.

Dolostones in the *mixed marine facies* are light to olive gray. Textures range from microcrystalline and dense to macro-crystalline and sucrosic. The dense microcrystalline dolostones are poor reservoirs and generally have only trace amounts of porosity. The sucrosic macrocrystalline dolostones are good to excellent reservoirs that have intercrystal porosities ranging from 10 to 20% (Fig. 25).

Limestone and dolostone beds in the *mixed marine facies* are 5-50 ft thick; most carbonate beds are 20-30 ft thick. They are separated by mudstone beds 5-20 ft thick. Well control is insufficient to determine the geometry of individual limestone and dolostone beds; it is not known whether the thickest beds are biohermal or biostromal.

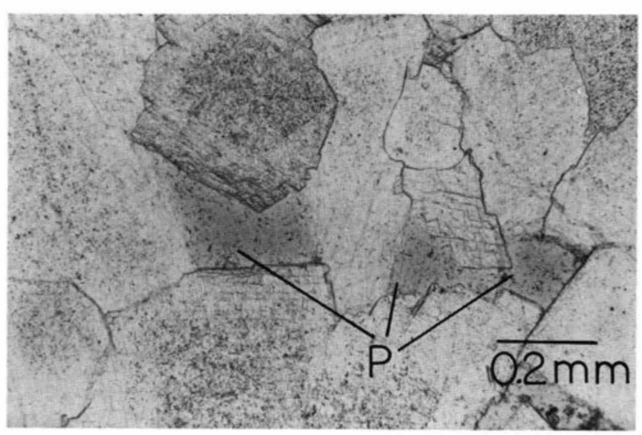


FIGURE 25—Dolostone, lower unit of Hueco Formation (Permian). Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 6,620–6,630 ft. Note intercrystal porosity (**P**).

The lower Hueco consists of considerably less siliciclastic mudstones and sandstones on the Frio Uplift than in the Tucumcari Basin. The relative paucity of clastic sediments on the uplift indicates it probably was a positive area that received relatively few fine-grained clastic sediments during early Hueco time. Carbonate petrology and bed thicknesses do not indicate a carbonate bank developed on the uplift. If a carbonate bank was not present, then it is probable that a carbonate shelf margin did not form on the west flank of the Frio Uplift. However, a carbonate shelf margin apparently existed on the east flank of the uplift and separated the uplift from the Palo Duro Basin (Rose, 1986a; Dutton et al., 1982; Handford and Dutton, 1980).

Upper unit of Hueco Formation—The upper unit of the Hueco Formation (Wolfcampian) is 310-520 ft thick in the Tucumcari Basin (Fig. 26A). Slightly thicker areas of the upper Hueco coincide with structurally low areas of the basin (Fig. 3). The upper Hueco thins on the flanks of the Sierra Grande, Pedernal, and Frio Uplifts, indicating that these uplifts were topographically positive areas during late Hueco time.

The top of the resistive carbonate marker bed at the top of the lower Hueco is chosen as the base of the upper Hueco (Figs. 8-11). The contact between the lower and upper units of the Hueco is conformable.

A resistive carbonate marker bed that can be correlated with geophysical logs throughout the Tucumcari Basin is chosen as the top of the upper Hueco. This marker bed is absent on the south flank of the Sierra Grande Uplift. Because of its absence, the upper Hueco cannot be correlated north into San Miguel or northern Quay Counties (Fig. 26A), where it grades into the lower part of the Abo Formation (Figs. 8, 9). The top of the upper Hueco can be correlated south into Chaves County (Broadhead, 1984b).

Upper Hueco facies generally range between *coarse sandy facies* in the northern part of the Tucumcari Basin, *proximal marine limestone facies* in the central and western parts of the basin, and *marine limestone facies* in the southern part of the basin and on the Frio Uplift (Fig. 26B). The *mixed marine facies* was deposited in the New Mexico part of the Palo Duro Basin. The *muddy clastic facies* covers large areas in the northwestern part of the Tucumcari Basin. The presence of coarse-grained arkosic sandstones in the northern part of the basin and the northward transition from upper Hueco marine sediments to lower Abo, nonmarine, coarse-grained sediments indicate the Sierra Grande Uplift was tectonically active and emergent during late Hueco time. The Precambrian granitic core of the Sierra Grande Uplift was the source of the coarse-grained arkosic sandstones and mudstones. The isopach and lithofacies maps (Figs. 26A, B) subtly reflect features of the Frio Uplift; the Frio Uplift appears to have been tectonically subdued and largely buried by the end of Hueco time.

The Pedernal Uplift also appears to have been emergent during late Hueco time. Coarse-grained arkosic sandstones are present in the *proximal marine limestone facies* in western Guadalupe County (Fig. 26B). The Precambrian of the Pedernal highland consists of large terranes of quartzites, schists, and metavolcanic rocks, as well as granitic rocks (Bauer and Williams, 1985; Gonzalez and Woodward, 1972). The relative paucity of granitic rocks may explain why coarse-grained arkosic rocks are not as well developed along the east flank of the Pedernal Uplift as they are along the south flank of the Sierra Grande Uplift.

Sandstones in the *coarse sandy facies* and *proximal marine limestone facies* were deposited in alluvial fans, braided streams, and associated deltas that flowed into the Tucumcari Basin from the Sierra Grande and Pedernal Uplifts. A core of the *coarse sandy facies* from the Amoco Production Company No. 1 State GM (App. B), sec. 16 T6N R29E, Quay County, recovered planar-laminated and crossbedded, arkosic, conglomeratic sandstones that appear to have been deposited by a braided stream. Their interbedding with dolostones may indicate deposition in a fan delta. Sandstones in the *proximal marine limestone facies* are interbedded with marine limestones and probably represent deposition in deltas or fan deltas.

Sandstones in the *coarse sandy facies* and *proximal marine limestone facies* of the upper Hueco are fine to very coarse grained and conglomeratic. They consist mostly of quartz, feldspars, and granitic rock fragments. Most feldspars appear fresh and unaltered. Upper Hueco sandstones in the *coarse sandy facies* and *proximal marine limestone facies* are generally friable and porous; they are good reservoirs. Pores in some sandstones are filled with red mud; these sandstones are poor reservoirs.

Mudstones in the *coarse sandy facies* are red to gray in color. Most are red.

The *marine limestone facies* occupies the Frio Uplift in the southern part of the Tucumcari Basin (Fig. 26B). It consists primarily of interbedded marine limestones, mudstones, and minor fine-grained sandstones. Most of the limestones were deposited on a shallow-marine shelf. They are light-to dark-gray lime mudstones and bioclastic wackestones, packstones, and grainstones. The limestones variously bear faunas of fusulinids, foraminifers, bryozoans, crinoids, brachiopods, gastropods, ostracods, and sponges; some bioclasts are encrusted by algae. Most bioclasts are micritized or recrystallized fragments. The bioclastic grainstones are cemented by drusy microspar. The limestones are "tight," poor reservoirs with no visual porosity.

Mudstones in the *marine limestone facies* are red to gray in color. Most are red. The gray mudstones are generally calcareous; some bear fragments of marine fauna and are marine in origin.

Sandstones in the *marine limestone facies* are orange and fine to very fine grained. Some have a mud matrix and others are cemented by calcite. They are generally poor reservoirs with only trace amounts of visual porosity. The more porous sandstones may be of some interest as low-permeability gas reservoirs.

The *mixed marine facies* in the Palo Duro Basin consists of interbedded dolostones, marine limestones, and siliciclastic mudstones. The dolostones are light gray and finely crystalline. Most appear impermeable and nonporous, but well control is sparse and this facies is poorly known.

Abo Formation—The Abo Formation (Wolfcampian) is 0-2,400 ft thick in the Tucumcari Basin (Fig. 27A). Maximum thickness is attained in two northeast-trending clastic wedges. One wedge is in northeastern Guadalupe County and southeastern San Miguel County. The other wedge lies to the southeast and cuts through central Quay County. The Abo thins to the southeast as it onlaps the Frio Uplift. Southeast of the Frio Uplift, it thickens slightly as it descends into the Palo Duro Basin. The Abo thins northward over the crest of the Sierra Grande Uplift and Bravo Dome and is absent from the highest parts of the Sierra Grande Uplift.

The Abo rests conformably on the resistive carbonate marker bed that marks the top of the upper Hueco Formation in the Tucumcari Basin and on the Frio Uplift (Figs. 8-11). This marker bed is absent on the Sierra Grande Uplift in San Miguel and northern Quay Counties. In these areas, the Abo rests unconformably on the lower Hueco, the Strawn, or the Precambrian, and the lower 300-400 ft of Abo are laterally equivalent to the upper unit of the Hueco Formation. The Abo is generally correlative with the Wichita Group and Red Cave Formation of the Texas panhandle (Handford and Fredericks, 1980).

The top of the Abo corresponds to a prominent gamma-ray log marker in the Tucumcari Basin and on the northwest

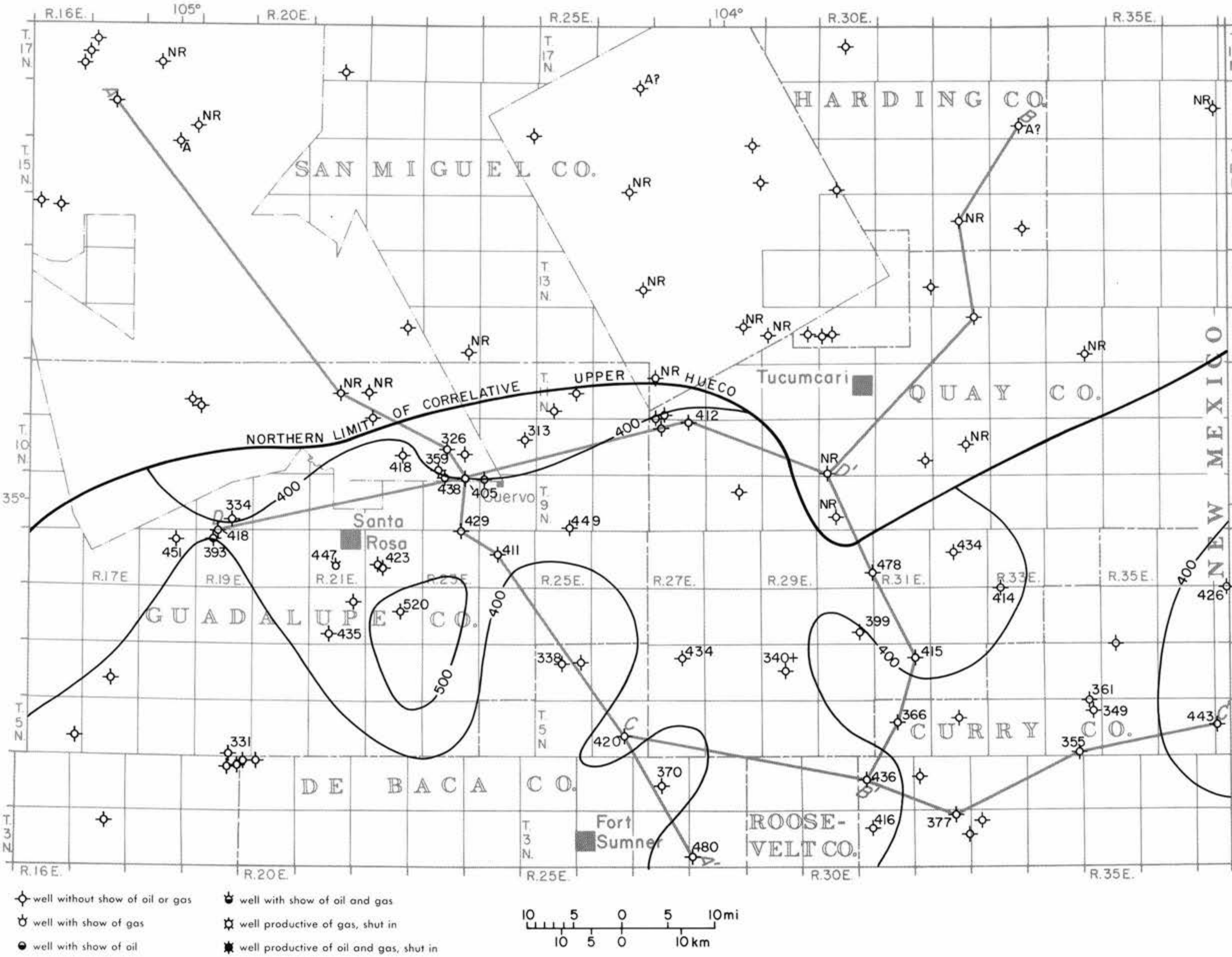


FIGURE 26A—Isopach map of upper unit of Hueco Formation (Permian). **NR**, not recognizable as a separate unit; **A**, absent. Contour interval = 100 ft.

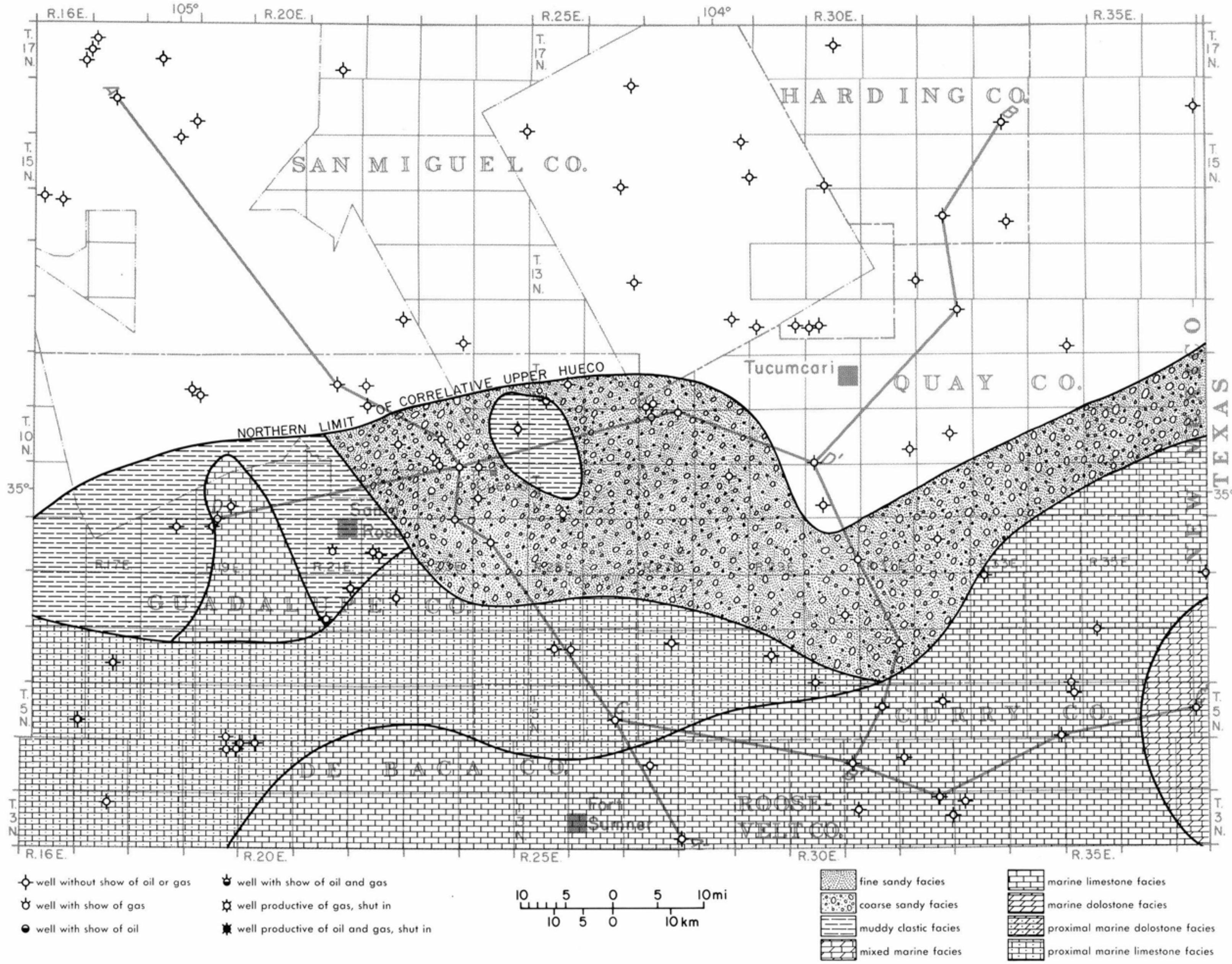


FIGURE 26B—Lithofacies map of upper unit of Hueco Formation (Permian). See Tab. 1 for description of lithofacies.

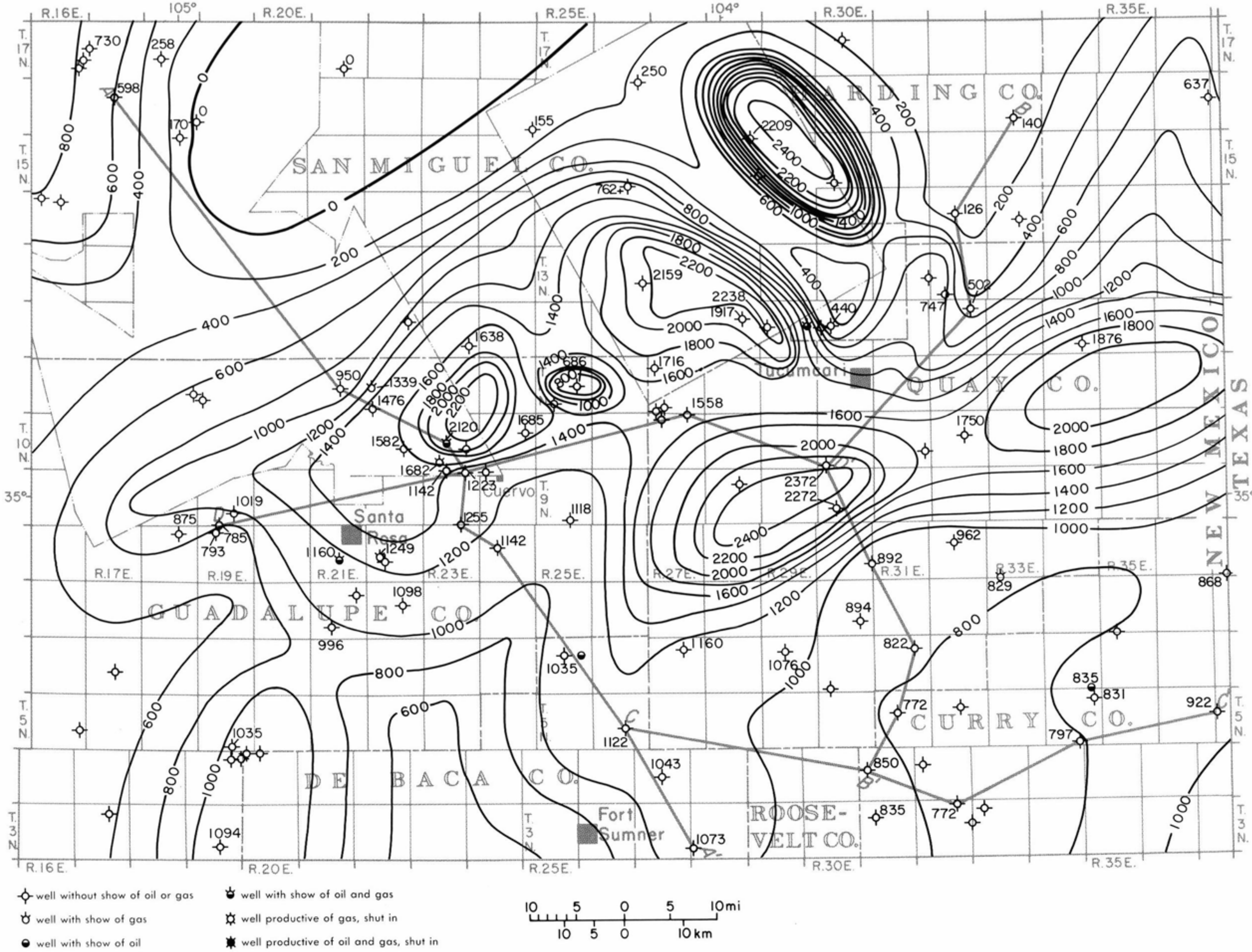


FIGURE 27A—Isopach map of Abo Formation (Permian). Contour interval = 200 ft.

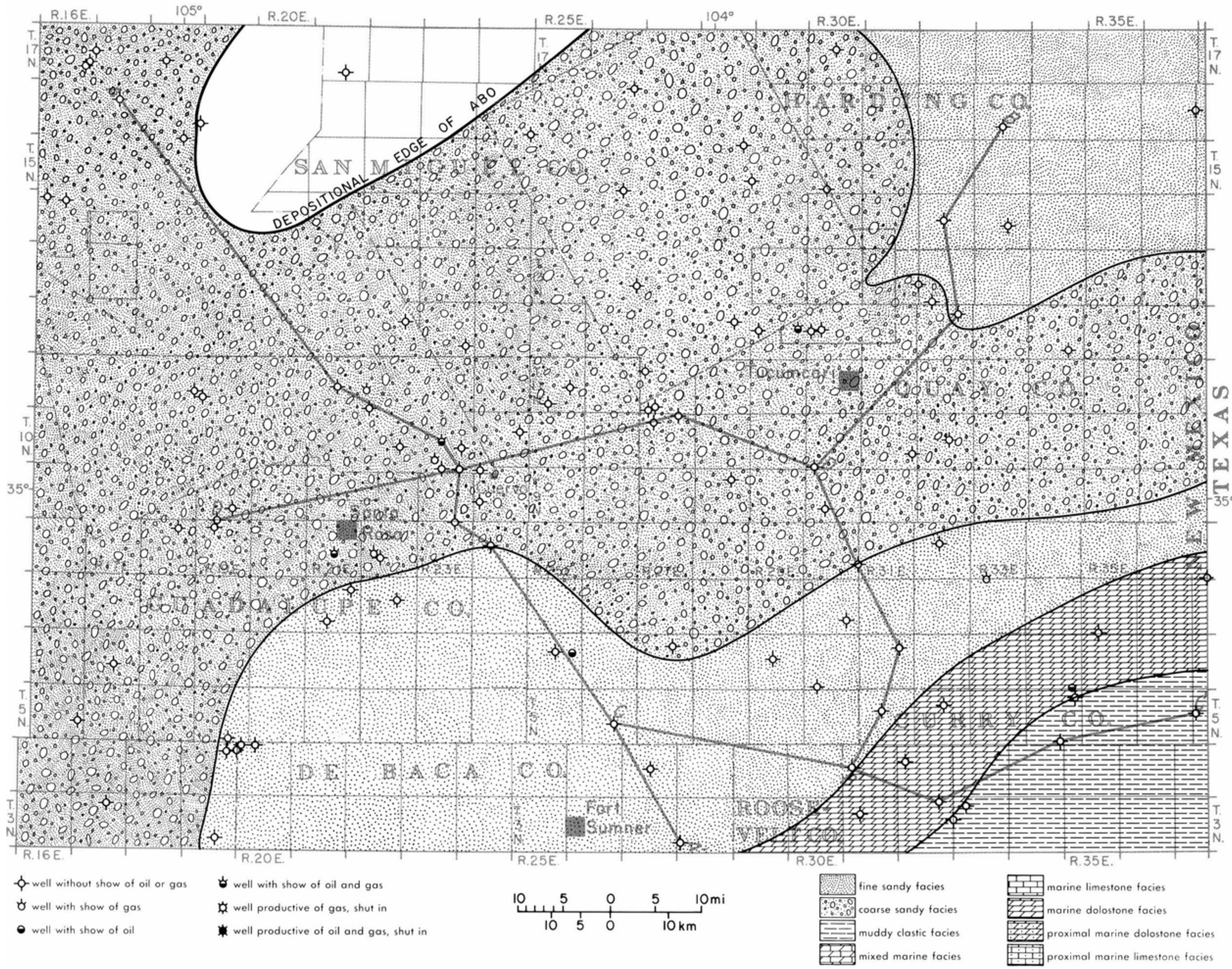


FIGURE 27B—Lithofacies map of Abo Formation (Permian). See Tab. 1 for description of lithofacies.

shelf of the Permian Basin (Figs. 8-11). The contact between the Abo and the Yeso Formation (Leonardian) separates the siliciclastic, nonmarine red beds of the Abo Formation from the marine evaporites of the lower Clear Fork zone of the Yeso Formation. The lower Clear Fork is not present on the Sierra Grande and Pedernal Uplifts. On these uplifts, the Abo is overlain by the Tubb sand zone of the Yeso Formation.

Abo fades generally show a transition from *coarse sandy facies* on the Sierra Grande Uplift and in the northern part of the Tucumcari Basin to *fine sandy facies* in the southern part of the basin (Fig. 27B). The *fine sandy facies* constitutes the upper 100-200 ft of Abo in the northern part of the basin and on the Sierra Grande Uplift, but in these areas the Abo is comprised mainly of the *coarse sandy facies.* The Abo grades southeastward into *marine dolostone facies* and *muddy clastic facies* on the Frio Uplift and in the Palo Duro Basin. The thick wedges of coarse-grained arkosic sandstones in Guadalupe, San Miguel, and Quay Counties (Fig. 27A) indicate the Sierra Grande and Pedernal areas underwent considerable uplift and shed vast amounts of granitic detritus to the south and east during Abo time. The isopach and lithofades maps show a subtle relationship between the structures of the Tucumcari Basin and the Frio Uplift, indicating that the basin and the uplift were buried by the end of Abo time and that the Frio Uplift had no pronounced effect on sedimentation.

Sandstones in the *coarse sandy facies* of the Abo were probably deposited in alluvial fans and by braided streams. Conglomeratic sandstones in the Amoco Production Company No. 1 State GM (App. B), sec. 16 T6N R29E, Quay County, are planar laminated and crossbedded; they have sharp, generally erosional contacts with interbedded mudstones. These sedimentary structures are commonly formed by braided streams (Cant, 1982) or streams in alluvial fans (Nilsen, 1982). The abundance of conglomeratic sandstones and the relative paucity of mudstones in the *coarse sandy facies* also suggest braided-stream deposition. Possibly the best evidence for alluvial-fan deposition is located in the thick wedges of the *coarse sandy facies* on the south flank of the Sierra Grande Uplift and west and south flanks of the Bravo Dome; there, the Abo unconformably lies on Precambrian basement.

Sandstones in the *coarse sandy facies* are reddish brown to reddish orange. Most are medium to very coarse grained and conglomeratic; some are fine to very fine grained. Generally, Abo sandstones are arkosic; the coarser grained sandstones contain abundant fragments of granitic rocks. The fine-grained sandstones are relatively nonporous and impermeable; they are similar to the sandstones of the *fine sandy facies.* The coarser grained sandstones have visual porosities ranging from a trace amount to 20%. The porosity is variously occluded by clay matrix or calcite, dolomite, and anhydrite cements. The more porous sandstones are permeable reservoirs of good to excellent quality. Porosity generally appears to be primary. Some porosity is secondary and was formed by dissolution of cements.

Mudstones in the *coarse sandy facies* are reddish brown to reddish orange. Stratigraphic association with alluvial sandstones indicates a nonmarine origin.

Sandstones in the *fine sandy facies* are reddish brown to reddish orange and fine to very fine grained. They are arkosic. Many have a matrix of red clay and finely divided hematite or are cemented by calcite or anhydrite. They are generally impermeable and have no visual porosity. Although they are poor oil reservoirs, the sandstones in the *fine sandy facies* may be low-permeability gas reservoirs, particularly where they are fractured; they are similar to the low-permeability gas reservoirs in the Pecos Slope Abo gas pools of north—central and northwestern Chaves County, New Mexico (Broadhead, 1984b).

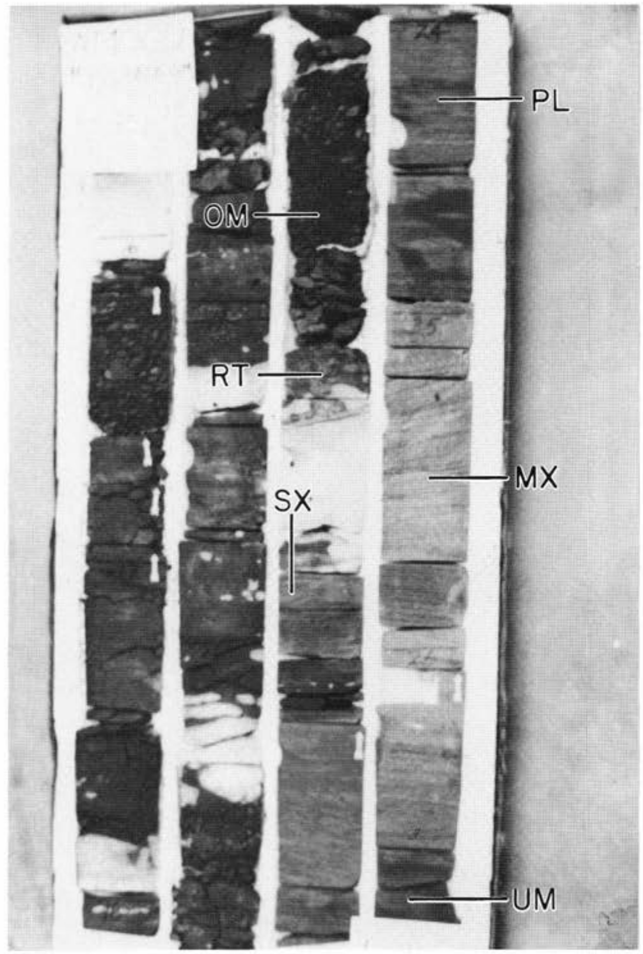


FIGURE 28—Upward-fining point-bar sequence in sandstone bed, Abo Formation (Permian). Medium-scale crossbeds (**MX**) at base, planar laminae and a few small ripples (**PL**) in middle of bed, ripples and small-scale cross-laminae (**SX**) in upper part of bed, and upward gradation into overlying mudstone (**OM**). Note root traces (**RT**), sharp contact with underlying mudstone (**UM**), and diagenetic color mottling. Amoco Production Company No. 1 State GM, sec. 16 T6N R29E, Quay County, 5,315–5,327 ft (from Broadhead, 1984b).

Sandstones in the *fine sandy facies* of the Abo are mostly alluvial in origin. In the upper part of the Amoco Production Company No. 1 State GM well, sandstones are planar- and cross-laminated and crossbedded. Beds thicker than 5 ft generally exhibit a vertical sequence of sedimentary structures with crossbeds near the base that grade upward into planar laminations that, in turn, grade upward into small-scale cross-laminations (Fig. 28). In many of the sandstones, the planar- and cross-laminations randomly alternate with each other in vertical sequence. The upper 1-2 ft of individual sandstone beds are structureless, except for desiccation cracks and root traces. The sandstones grade into overlying mudstones; basal contacts are sharp and erosional. Gravel-size intraformational clasts of sandstone and mudstone form thin layers in the lower parts of beds. Convoluted lamination and soft-sediment faults are common. The vertical sequence of sedimentary structures and the upward-fining grain size suggest that sandstones thicker than 5 ft were deposited as fluvial point bars or fluvial levees by meandering streams (see Reineck and Singh, 1975; LeBlanc, 1972; Cant, 1982).

Sandstone beds thinner than 5 ft generally contain planar- and cross-laminations, root traces, and some desiccation cracks; they generally have gradational upper and lower contacts with interbedded mudstones. The sedimentary structures and bedding contacts indicate that these thinner beds originated as crevasse-splay, natural-levee, and other overbank deposits in a meandering fluvial system (see Reineck and Singh, 1975; Cant, 1982).

Some sandstones in the lower part of the *fine sandy facies* in De Baca, southern Guadalupe, and southern Quay Counties are shallow-marine deposits. Most beds are less than 3 ft thick, although a few are as thick as 10 ft. Contacts with interbedded marine mudstones are gradational. The sandstones are planar laminated, crossbedded, or homogenously bioturbated. Unlike other sandstones in the *fine sandy facies,* they do not have root traces or desiccation cracks. Most of these sandstones are calcareous.

Mudstones in the *fine sandy facies* are predominantly reddish brown, but a few light- to dark-gray mudstones are present. Most are calcareous and nonfossiliferous. Their intercalation with alluvial sandstones indicates a nonmarine origin. Some mudstones in the lower part of the *fine sandy facies* in De Baca, southern Guadalupe, and southern Quay Counties appear to represent shallow-marine deposition. They have been burrowed and contain fragments of recrystallized invertebrate fossils and calcareous algae. They are interbedded with shallow-marine sandstones and have gradational bedding contacts with these sandstones.

The *fine sandy facies* represents distal alluvial-plain deposition in the Abo. The presence of 100-200 ft of *fine sandy facies* in the uppermost part of the Abo on the Sierra Grande Uplift indicates the uplift was tectonically quiescent and mostly buried by the end of Abo time; only a few remnant monadnocks of Precambrian basement poked upward through the blanket of fine-grained alluvial sands and muds of the Abo.

The *marine dolostone facies* lies southeast of the *fine sandy facies* (Fig. 27B). To some extent, it is interbedded with the *fine sandy facies.* The *marine dolostone* facies consists of interbedded dolostones, red mudstones, and fine-grained sandstones. Dolostones are brownish gray to gray and finely crystalline. Some are algal and oolitic. Some of the dolostones have as much as 10% intercrystal and vuggy porosity and are good reservoirs (Fig. 29). Sandstones in the *marine dolostone facies* are reddish brown and fine to very fine grained. Visual porosity is limited to trace amounts. These sandstones are poor oil reservoirs but may make good low-permeability gas reservoirs, particularly in the vicinity of structural zones where they may be fractured.

In the Humble Oil and Refining Company No. 1 Northcutt, sec. 32 T8N R37E, Curry County, the Abo contains a considerable amount of bedded salts and anhydrites. The evaporites may have been deposited in coastal sabkhas similar to those that form parts of the Red Cave Formation (Abo equivalent) in the Texas panhandle (see Handford and Fredericks, 1980).

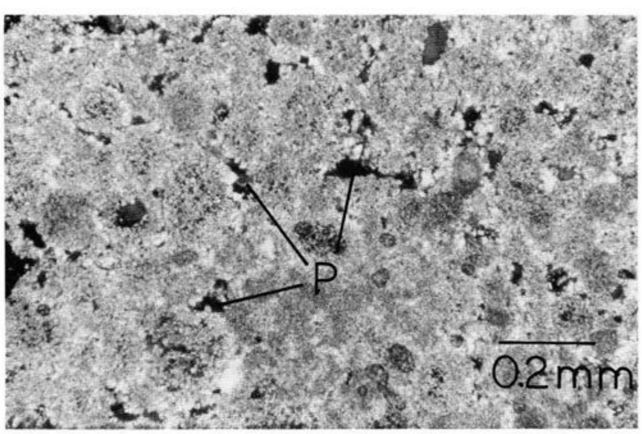


FIGURE 29—Dolostone, Abo Formation (Permian). Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County, 5,900–5,910 ft. Note peloidal texture and interpeloidal porosity (**P**). Crossed nicols.

The *muddy clastic facies* constitutes the Abo in southeastern Curry County (Fig. 27B). The *muddy clastic facies* consists predominantly of red mudstones but has minor, thin-bedded fine-grained sandstones, red finely crystalline dolostones, and green mudstones. In the Union Producing Company No. 1 Jones, sec. 18 T5N R37E, Curry County, the Abo is 922 ft thick; dense finely crystalline dolostones dominate the lower 200 ft. Good reservoirs are not present in the *muddy clastic facies.*

Yeso Formation—The Yeso Formation (Leonardian) is 4002,000 ft thick in the Tucumcari Basin (Foster et al., 1972). It is thickest in Curry County and thins over the Sierra Grande and Pedernal Uplifts and the Bravo Dome. In the Tucumcari Basin, the Yeso Formation consists of complexly interbedded, orange fine-grained sandstones, mudstones, dolostones, anhydrites, and salts. The basal part of the Yeso can be divided into two mappable units in the subsurface of northeastern and east-central New Mexico (Figs. 8-11): the lower Clear Fork and the Tubb sand zones. Both units have been mapped as formations in the Texas panhandle (Rose, 1986a). The lower Clear Fork zone is a shallow-marine deposit that consists of orange fine-grained sandstones, orange-red siliciclastic mudstones, dolostones, anhydrites, and minor salts. The lower Clear Fork pinches out as it onlaps the Sierra Grande and Pedernal Uplifts and the Bravo Dome and is stratigraphically overlapped by the Tubb sand. The Tubb sand consists primarily of orange-red fine-grained sandstones and minor, orange mudstones. The Tubb sand is generally thought to be either a nonmarine or coastal deposit.

The contact between the Abo Formation and the lower Clear Fork zone is sharp in the Tucumcari Basin. The sharpness of the contact and the abrupt transition from Abo fluvial sediments to Yeso shallow-marine sediments indicate the Abo-Yeso contact is disconformable. The period of time represented by the Abo-Yeso disconformity is unknown, but probably short. The contact may be conformable in Curry County where the Abo appears to have a shallow-marine origin.

The nature of the Abo-Yeso contact is unknown on the Sierra Grande and Pedernal Uplifts and the Bravo Dome where the lower Clear Fork is absent and the Tubb sand rests on the Abo. On these uplifted areas, the Tubb sand and the Abo are indistinguishable in drill cuttings but the contact between the two units is readily apparent on gamma-ray logs (Figs. 8, 11). The Abo is absent from the highest parts of the Sierra Grande Uplift where the Tubb sand rests unconformably on Precambrian granite.

Yeso sandstones and dolostones may be fair reservoirs. Tubb sandstones are major reservoirs for carbon dioxide gas on the Bravo Dome in southeastern Union and northeastern Harding Counties (Johnson, 1983; Broadhead, in press). The large amounts of anhydrites and salts that occur as individual beds and as pore-filling material in the sandstones and dolostones undoubtedly restrict permeability.

The fine-grained nature of Yeso sands and the absence of thick clastic wedges within the Yeso indicate the Tucumcari Basin and surrounding uplifts were tectonically inactive during the Leonardian. The absence of the lower Clear Fork on the uplifts and the stratigraphic thinning of the Yeso over the uplifts indicate topographic relief of the Sierra Grande and Pedernal Uplifts and the Bravo Dome was subdued during Yeso time.

San Andres Formation—The San Andres Formation (Leonardian) is 400-1,200 ft thick in the Tucumcari Basin (Foster et al., 1972). It is thickest in Curry County and thins over the Sierra Grande and Pedernal Uplifts and the Bravo Dome. In the Tucumcari Basin, the San Andres consists primarily of anhydrites, dolostones, limestones, and salts. The basal

Glorieta Sandstone Member attains a maximum thickness of 300 ft in the northwestern part of the basin and thins to the south and east; it is absent east of R31E (Dobrovolny et al., 1946). The Glorieta consists of permeable, fine- to medium-grained, quartzose sandstones. It is a good reservoir.

Many of the San Andres dolostones are porous and are favorable reservoirs (Pitt and Scott, 1981). Pitt and Scott have shown that porous reservoir zones in the Tucumcari Basin area pinch out to the northwest. Favorable reservoirs may also be present in the upper part of the San Andres where leaching of soluble beds has led to the formation of a permeable karst terrane. In the vicinity of Santa Rosa, cavernous limestones are present and collapse of overlying Triassic strata into solution cavities has formed numerous sinkholes.

Artesia Group—The Artesia Group (Guadalupian) is 130920 ft thick in the Tucumcari Basin (Broadhead, 1984a). It is thickest in Quay and Curry Counties and in northeastern De Baca County. It thins northward and westward as it onlaps the Sierra Grande and Pedernal Uplifts and the Bravo Dome. The regional thinning is partly depositional and partly caused by erosional truncation.

In the subsurface, the Artesia Group has been subdivided into three stratigraphic units (Fig. 2): the Grayburg-Queen unit (comprising the undivided Grayburg and Queen Formations), the Seven Rivers Formation, and the Yates-Tansill unit (comprising the undivided Yates and Tansill Formations). The Seven Rivers Formation is of limited interest as a reservoir unit because it is composed chiefly of interbedded anhydrites and red mudstones. The Grayburg-Queen and Yates-Tansill units consist primarily of red mudstones and fine-grained silty sandstones. The fine grain size of the sandstones limits their reservoir quality.

Triassic (Dockum Group)

Santa Rosa Sandstone—The Santa Rosa Sandstone is 70-350 ft thick in the Tucumcari Basin (Broadhead, 1984a). In the subsurface, it is divisible into three units: a lower sandstone unit, a middle mudstone unit, and an upper sandstone unit. The Santa Rosa Sandstone was deposited by braided streams that flowed southeastward into a large Triassic lake centered in western Texas and eastern New Mexico (McGowen et al., 1979; McKallip, 1984; Broadhead, 1984a). The Santa Rosa attains maximum thickness in broad, southeast-trending paleovalleys that were eroded into the underlying Artesia Group (Broadhead, 1984a).

Generally, the Santa Rosa Sandstone is a good reservoir in the Tucumcari Basin. It is porous, permeable, and widespread. Porosity is primary and attains maximum values of 36%.

Chinle Formation—The Chinle Formation consists of lacustrine and alluvial red-bed mudstones and sandstones. It is 700-1,300 ft thick in the Tucumcari Basin (Kelley, 1972a). The few sandstones within it are lenticular and generally of limited areal extent. One sandstone unit, the Cuervo Sandstone Member, is 10-200 ft thick and is present throughout most of the basin. Generally thinner and less permeable, the Cuervo Sandstone Member is not as good a reservoir as the Santa Rosa Sandstone.

Post-Triassic

Erosional remnants of Jurassic, Cretaceous, Tertiary, and Quaternary stratigraphic units are present throughout northeastern'and east-central New Mexico. Sandstones in these units are generally porous and permeable and are fair to good reservoirs. Where they are present they either crop out or are buried to shallow depths. They are probably flushed with fresh water throughout most of the Tucumcari Basin.

Outliers of Tertiary and Quaternary sands and gravels occur- throughout the Tucumcari Basin. They are assigned to the Ogallala Formation and the Pecos Valley sediments of Kelley (1972a).

Tertiary igneous intrusive rocks occur on the Sierra Grande Uplift and in the northern part of the Tucumcari Basin. They are isolated, relatively small dikes and sills of basaltic composition (Budding, 1980; McKallip, 1984; Wanek, 1962; Stormer, 1972). The Tertiary dikes appear to have intruded along deep-seated basement faults. Most of the deep-seated faults, however, do not appear to be associated with igneous activity.

A complex of diabase dikes occurs in the lower part of the Strawn Series in the Yates Petroleum Corporation No. 1 T-4 Cattle Company, sec. 5 T1ON R27E, Quay County. The basaltic composition of the dikes suggests they are Tertiary in age. They do not appear to have caused any significant metamorphism of the country rock. They probably intruded along one of the large faults that form the northern edge of the Tucumcari Basin.

Petroleum geology

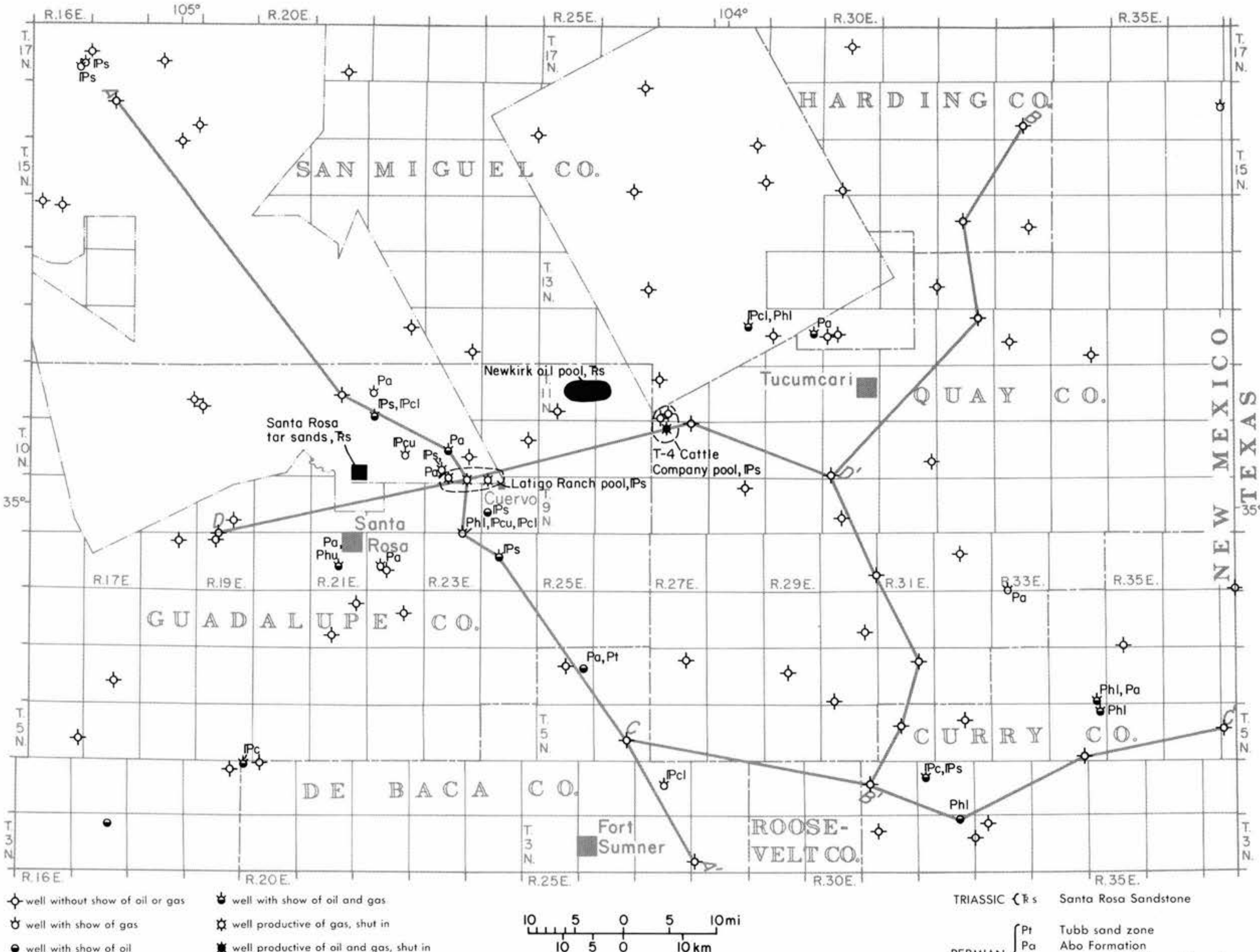
Petroleum occurrences

Oil and gas have been encountered in Pennsylvanian, Permian, and Triassic strata in the Tucumcari Basin and on adjoining uplifts (Fig. 30). Although this report concentrates on the petroleum geology of Pennsylvanian and Lower Permian units, major oil occurrences in the Triassic are discussed because they are germane to the consideration of petroleum potential in the lower part of the section.

Two pools of oil and gas have been discovered in the Strawn Series (Fig. 30; Tabs. 2, 3): the Latigo Ranch and the T-4 Cattle Company pools. Both pools are presently shut in. The Latigo Ranch pool was discovered in 1982 during drilling operations of the Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County. The Latigo Ranch A was completed through perforations from 6,658 to 6,764 ft. After acidization, the well flowed gas at a rate of 275 MCFGPD; the well reportedly flowed as much as 3,000 MCFGPD during difficult completion operations, but this can not be confirmed. Two other wells, the Trans-Pecos Resources No. 2 Latigo Ranch B, sec. 6 T9N R24E, Guadalupe County, and the Trans-Pecos Resources No. 1 Latigo Ranch C, sec. 4 T9N R23E, Guadalupe County, were also completed in the Strawn and flowed nominal volumes of gas. The Gila Exploration No. 1 Latigo Ranch D, sec. 26 T1ON R23E, Guadalupe County, acidized and fractured the Strawn through perforations from 7,395 to 7,414 ft but reportedly did not recover hydrocarbons. Reservoir rocks at the Latigo Ranch pool are arkosic sandstones of Strawn age. Both primary and secondary porosities are present; the secondary porosity resulted from dissolution of feldspars and carbonate cement.

The T-4 Cattle Company pool (Tab. 3) was discovered in 1983 during drilling of the Yates Petroleum Corporation No. 1 T-4 Cattle Company, sec. 5 T1ON R27E, Quay County. The T-4 Cattle Company well was completed in the Strawn through perforations from 7,004 to 7,120 ft. Initial potential was 1,100 MCFGPD and 48 BOPD; oil gravity was 40° API. Yates Petroleum Corporation drilled two offset wells that were tested and proved dry. Reservoir rocks at the T-4 Cattle Company pool, like those at the Latigo Ranch pool, are arkosic sandstones. The T-4 Cattle Company pool was apparently shut in because (1) there is no gas pipeline in the area, (2) there are limited reserves in only a single well, and (3) gas prices were relatively low at the time the well was completed.

Several wells have encountered shows of oil and gas in Pennsylvanian and Permian units (Fig. 30; Tab. 4). Shows



TRIASSIC	₸s	Santa Rosa Sandstone
PERMIAN	Pt	Tubb sand zone
	Pa	Abo Formation
	Phu	upper unit of Hueco Formation
	Phl	lower unit of Hueco Formation
PENNSYLVANIAN	IPc	Canyon Series
	IPcu	upper unit of Canyon Series
	IPcl	lower unit of Canyon Series
	IPs	Strawn Series

FIGURE 30—Known oil and gas occurrences in Pennsylvanian and Lower Permian strata and major oil occurrences in Triassic strata.

TABLE 2—Oil and gas occurrences in wells drilled in the Latigo Ranch pool (see Fig. 30 for location). **MCFGPD**, thousand ft³ gas per day.

Operator, well number, and lease	Location (section–township–range, county)	Completion date (mo/yr)	Total depth (ft)	Description of production tests and producing intervals
Trans-Pecos Resources No. 1 Latigo Ranch A	2–9N–23E, Guadalupe	7/82	7,202	Perforated casing from 6,658–6,764 ft (Strawn), acidized, flowed gas at rate of 275 MCFGPD. Shut in.
Trans-Pecos Resources No. 2 Latigo Ranch B	6–9N–24E, Guadalupe	9/83	7,241	Perforated casing from 6,742–6,883 ft (Strawn), acidized and fractured, flowed gas at rate of 16 MCFGPD. Shut in.
Trans-Pecos Resources No. 1 Latigo Ranch C	4–9N–23E, Guadalupe	2/83	7,407	Perforated casing from 6,746–6,819 ft (Strawn), fractured, flowed gas at rate of 16.5 MCFGPD. Shut in.
Gila Exploration (formerly Trans-Pecos Resources) No. 1 Latigo Ranch D	26–10N–23E, Guadalupe	2/84	7,836	Perforated casing from 7,395–7,414 ft (Strawn), acidized and fractured; no reported hydrocarbons. Well listed as temporarily abandoned.

in the Strawn are found in coarse-grained arkosic sandstones in the northern part of the Tucumcari Basin. Shows in the Canyon occur throughout the basin. Shows in the Hueco occur in arkosic sandstones in the northern part of the basin and in lower Hueco porous dolostones on the Frio Uplift. Shows in the Abo are found in fine- to coarse-grained arkosic sandstones.

Two major oil accumulations are known to exist in the Santa Rosa Sandstone (Triassic): the Santa Rosa tar sands and the Newkirk oil pool (Fig. 30). They are discussed because evidence presented in this report indicates that Pennsylvanian strata probably contain the source rocks that generated the oil.

The Santa Rosa tar sands are a surface exposure of oil-impregnated sandstones in T1ON R21E, Guadalupe County. The geology of the Santa Rosa tar sands was first reported by Gorman and Robeck (1946) and later by McDowell (1972) and Budding (1979, 1980). The oil has a gravity of 5.3° API, which classifies it as an asphalt, and a napthene content of approximately 98% (Budding, 1979, 1980). The low oil gravity and the high napthene content are best explained by biodegradation; bacterial degradation typically removes paraffins and enriches the relative proportion of other components, such as napthenes. The sandstone has a porosity of 10-13% and an average permeability of 100-200 millidarcies (Budding, 1980). The Santa Rosa tar sands contain an estimated 90.9 million bbls of oil in place (Budding, 1979, 1980), but the subsurface areal extent of oil-impregnated sandstones has not been determined.

The Santa Rosa tar sands were mined between 1930 and 1939 by the New Mexico Construction Company. The oil-impregnated sandstones were used for road surfacing in New Mexico, Colorado, Oklahoma, and Texas. Total production was 153,000 tons (Gorman and Robeck, 1946).

Interest in the Santa Rosa deposit was revived during the late 1970s. Plans were made by Solv-Ex Corporation to mine the tar sands and to recover oil from them with a solvent extraction process. These plans were abandoned in 1983 because of unfavorable economics and the encroachment of Santa Rosa Lake on the tar-sand outcrops.

The Newkirk oil pool, located in T11N R25-26E, Guadalupe County, was discovered by Humble Oil and Refining Company in the early 1960s. Although the Humble Oil and Refining Company drilled several cores of oil-impregnated sandstones, oil was not produced at that time. In 1981, Public Lands Exploration Company (later called Corona Oil Company and subsequently called Rio Petro Ltd.) initiated two pilot steam-flood projects, the O'Connell Ranch and the T-4 Ranch pilots, to recover heavy oil from the Santa Rosa Sandstone.

Geology of the Newkirk oil pool has been discussed by Martin (1983) and McKallip (1984, 1985). The primary trapping mechanism is the large east-trending Newkirk anticline, which is visible at the surface. The anticline was formed

TABLE 3—Oil and gas occurrences in wells drilled in the T–4 Cattle Company pool (see Fig. 30 for location). **MCFGPD**, thousand ft³ gas per day; **BOPD**, bbls oil per day.

Operator, well number, and lease	Location (section–township–range, county)	Completion date (mo/yr)	Total depth (ft)	Description of production tests and producing intervals
Yates Petroleum Corporation No. 1 T–4 Cattle Company	5–10N–27E, Quay	3/83	7,235	Perforated casing from 7,004–7,120 ft (Strawn), initial potential flowing 1,100 MCFGPD + 48 BOPD; oil gravity 40° API. Shut in.
Yates Petroleum Corporation No. 2 T–4 Cattle Company	32–11N–27E, Quay	5/84	7,033	Perforated casing from 4,902–4,937 ft (Abo), swabbed with no show. Perforated casing from 5,145–5,330 ft, no show. Perforated casing from 5,548–5,552 ft, no show. Perforated casing from 5,660–5,667 ft, swabbed with no show.
Yates Petroleum Corporation No. 3 T–4 Cattle Company	31–11N–27E, Quay	6/84	4,973	Perforated casing from 4,208–4,249 ft, no show. Perforated casing from 4,265–4,275 ft, swabbed with no show.

TABLE 4—Petroleum exploration wells that have tested Pennsylvanian and Lower Permian reservoirs. **DST**, drill-stem test; **MCFGPD**, thousand ft^3 gas per day; **BWPD**, bbls water per day; **BW**, bbls water; **IP**, initial potential; **IPF**, initial potential flowing.

Operator, well number, and lease	Location (section–township–range, county)	Description of show or test
Shell Oil Company No. 1 Stephenson	2–3N–32E, Curry	DST 6,488–6,509 ft (lower (Hueco), recovered 780 ft mud-cut sulfur water + 540 ft slight oil-cut sulfur water; DST 6,508–6,546 ft (lower Hueco), recovered 360 ft mud + 360 ft mud-cut salt water + 1,440 ft very slight oil-cut sulfur water + 540 ft salt water.
Consolidated Gas & Equipment Company No. 2 Cash Ramey	13–3N–32E, Curry	DST 6,420–6,495 ft (Hueco), recovered 10 ft mud; DST 6,649–6,695 ft (Canyon), recovered 10 ft mud.
Matador Oil Company No. 2 Salado State	6–4N–20E, De Baca	Gas show at 3,772 ft (Canyon); oil and gas show at 3,850 ft (Canyon).
J. D. Sandefer III No. 1 Good State	21–4N–27E, De Baca	DST 6,454–6,481 ft (lower Canyon), recovered 402 ft very slight gas-cut mud + 91 ft salty drilling mud; DST 6,580–6,636 ft (Strawn), recovered 540 ft drilling fluid + 627 ft salt water.
Gulf Oil Corporation No. 1 G. L. Jensen et al.	18–4N–32E, Curry	DST 6,364–6,440 ft (Canyon), weak blow, recovered 100 ft mud; DST 6,400–6,435 ft (Canyon), weak blow, recovered 300 ft water with trace of oil-cut mud + 896 ft water; DST 6,440–6,480 ft (Canyon), weak to good blow, recovered 372 ft drilling fluid + 665 ft formation water; DST 6,448–6,530 ft (Canyon), recovered 150 ft gas-cut drilling mud; DST 6,485–6,511 ft (Canyon), good blow, recovered 465 ft mud + 985 ft slight oil-cut water; DST 6,547–6,640 ft (Canyon or Strawn), weak to fair blow, recovered 200 ft mud-cut formation water + 1,700 ft formation water; DST 6,655–6,750 ft (Strawn), weak blow, recovered 10 ft mud.
Marathon Oil Company No. 1 State 16	16–5N–31E, Curry	DST 6,258–6,300 ft (lower Hueco), recovered 434 ft mud + 615 ft salt water.
J. V. Atkinson No. 1 Evelyn G. Brown	1–5N–34E, Curry	DST 6,552–6,612 ft (lower Hueco), recovered 60 ft gas- and slight oil-cut mud + 3,863 ft very slight oil-cut salt water; DST 6,875–7,048 ft (upper Canyon–lower Hueco), recovered 992 ft mud + 930 ft salt water-cut mud + 2,942 ft salt water.
Union Producing Company No. 1 Jones	18–5N–37E, Curry	DST 8,071–8,098 ft (lower Hueco), recovered 5,929 ft salt water + 5 ft mud.
United Western Mineral Company No. 1 Joe Killough	11–6N–25E, De Baca	Oil show from 3,508–3,543 ft (Abo–Tubb sand).
Exxon Corporation No. 1 Evelyn G. Brown	35–6N–34E, Curry	Perforated casing from 5,528–5,538 ft (Abo), swabbed 2½ bbls oil + 59 bbls formation water in 8 hours; DST 6,569–6,679 ft (lower Hueco), recovered 500 ft oil- and gas-cut mud + 360 ft oil- and gas-cut water + 647 ft oil- and gas-cut salty water.
Alta Energy Corporation No. 1 Walker	21–8N–21E, Guadalupe	Perforated casing from 2,514–2,609 ft (Abo), swabbed water with slight show of gas; Perforated casing from 2,840–2,846 ft (Abo), swabbed water with slight show of oil; Perforated casing from 3,226–3,291 ft and 3,451–3,456 ft (upper Hueco–Abo), swabbed water with slight show of gas.
O. H. Berry No. 1–X Tucumcari FNB	20–8N–22E, Guadalupe	Perforated casing from 2,796–3,020 ft (Abo), produced 88 MCFGPD + 120 BWPD, subsequently plugged and abandoned without commercial production.
General Crude Oil Company No. 1–1 State	2–8N–23E, Guadalupe	DST 4,395–4,407 ft (Abo), recovered 33 ft mud-cut water; DST 4,812–4,834 ft (upper Hueco), recovered 40 ft drilling mud; DST 5,805–5,834 ft (upper Canyon), recovered 30 ft drilling mud; DST 5,189–6,222 ft (lower Canyon–upper Canyon–lower Hueco), recovered 1,650 ft slight gas-cut water + mud-cut water.
Husky Oil Company & General Crude Oil Company No. 1 Hanchett State	16–8N–24E, Guadalupe	DST 5,409–5,426 ft (lower Hueco), recovered 95 ft slight salt water-cut mud; DST 6,772–6,798 ft (Strawn), gas to surface in 5 minutes, salt water with trace of oil to surface in 17 minutes.
Exxon Corporation No. 1 Dennis	32–8N–33E, Quay	Perforated casing from 5,053–5,153 ft (Abo), swabbed 12 bbls gas-cut drilling fluid + 60 bbls water in 9 hours.

TABLE 4 (continued)

Operator, well number, and lease	Location (section–township–range, county)	Description of show or test
CO_2-in-Action (also known as Baker & Taylor) No. 1 J. L. Hicks	19–9N–24E, Guadalupe	Oil show in core of Strawn.
Amoco Production Company No. 1 Baker	29–9N–30E, Quay	DST 5,094–5,323 ft (Abo), recovered 225 ft salt water + 1,115 ft salty mud; DST 8,056–8,166 ft (Strawn), recovered 3,534 ft salt water.
General Crude Oil Company No. 1 R. L. Spires	22–10N–22E, Guadalupe	DST 5,494–5,503 ft (upper Canyon), weak blow died in 8 minutes, recovered 30 ft mud.
General Crude Oil Company No. 1 Simpson	21–10N–23E, Guadalupe	DST 3,820–3,886 ft (Abo), recovered 10 ft slight oil- and gas-cut mud.
General Crude Oil Company No. 2–X Simpson	32–10N–23E, Guadalupe	DST 3,966–4,012 ft (Abo), recovered 10 ft very slight gas-cut mud; DST 4,262–4,280 ft (Abo), recovered 200 ft mud; DST 5,948–6,038 ft (upper Canyon), recovered 35 ft mud; DST 7,276–7,316 ft (Strawn), recovered 30 ft very slight gas-cut mud.
Yates Petroleum Corporation No. 1 T–4 Filly's Tooth	12–10N–27E, Quay	DST 6,760–6,820 ft (Pennsylvanian), weak blow, recovered 710 ft mud; Perforated casing from 7,265–7,271 ft (Pennsylvanian), acidized, fractured, swabbed with no show.
Sunray Mid-Continent Oil Company No. 1 Briscoe	31–10N–30E, Quay	DST 5,376–5,530 ft (Abo), recovered 1,088 ft mud.
Shell Oil Company No. 2 North Pueblo	25–10N–31E, Quay	DST 7,105–7,145 ft (lower Canyon), recovered 350 ft mud + 350 ft water-cut mud + 400 ft mud-cut water.
Cities Service No. 1 Driggers	22–11N–21E, Guadalupe	DST 2,224–2,316 ft (Abo), recovered 15 ft mud; DST 2,461–2,485 ft (Abo), recovered 30 ft mud; DST 4,374–4,435 ft (Precambrian), recovered 120 ft mud.
McClellan Oil Corporation No. 3 Burner Fee	19–11N–22E, Guadalupe	DST 4,351–4,430 ft (lower Canyon), no blow; DST 4,407–4,486 ft (lower Canyon), no blow; DST 4,706–4,785 ft (Strawn), weak blow; DST 4,782–4,861 ft (Strawn), recovered 627 ft mud-cut water; DST 5,034–5,113 ft (Strawn), recovered 100 ft mud-cut water; Perforated casing from 2,616–2,622 ft (Abo), acidized, IPF 2 MCFGPD + 24 BW; Perforated casing from 3,008–3,012 ft (Abo), acidized, swabbed slight mud-cut water.
McClellan Oil Corporation No. 2 Burner Fee	31–11N–22E, Guadalupe	Perforated casing from 4,558–4,635 ft (lower Canyon), acidized, IP 4 MCFGPD + 84 BW; Perforated casing from 5,260–5,268 ft (Strawn), swabbed 300 bbls slight oil- and gas-cut load water, swabbed 54 bbls fluid with continuous gas flare; Perforated casing from 5,393–5,396 ft (Strawn), acidized, swabbed slight gas-cut load water; Perforated casing from 5,477–5,482 ft (Strawn), acidized, fractured, no reported show; Perforated casing from 5,528–5,530 ft (Strawn), acidized, swabbed load water; Perforated casing from 5,573–5,576 ft (Strawn), acidized, swabbed load water.
Baker & Taylor No. 1 T–4 Cattle Company	7–11N–27E, San Miguel	Perforated casing from 6,342–6,356 ft (lower Canyon), swabbed water; Perforated casing from 6,363–6,371 ft (lower Canyon), no show; Perforated casing from 6,421–6,432 ft (lower Canyon), acidized, no show; Perforated casing from 6,834–6,841 ft (lower Canyon), acidized, no show; Perforated casing from 6,998–7,003 ft (lower Canyon), acidized, no show.
Miami Petroleum Company No. 1 Hoover Ranch	14–12N–28E, San Miguel	DST 5,524–5,547 ft (lower Hueco), recovered 960 ft gas in drill pipe + 120 ft slight gas-cut mud + 90 ft gas-cut muddy salt water with trace of oil; DST 6,257–6,267 ft (lower Canyon), recovered 35 ft gas in drill pipe + 55 ft gas-cut mud + 90 ft slight gas-cut salty mud + 180 ft muddy salt water.
Puretex Oil No. 1 Frank Chappell, Jr.	13–12N–29E, San Miguel	DST 3,633–3,664 ft (Abo), gas to surface in 2 minutes at 500 MCFGPD, recovered 90 ft gas-cut mud; DST 4,844–4,932 ft (Abo), recovered 2,600 ft gas + 10 ft oil + 180 ft oil-cut mud.

TABLE 4 (continued)

Operator, well number, and lease	Location (section–township–range, county)	Description of show or test
Miami Petroleum Company No. 2 Hoover Ranch	18–12N–29E, San Miguel	DST 6,475–6,505 ft (lower Hueco), recovered 98 ft salty mud.
National Petroleum Company No. 1 Reeve–Chappell	18–12N–30E, San Miguel	DST 3,496–3,630 ft (Abo), recovered 5 ft mud; DST 4,548–4,570 ft (Abo), recovered 210 ft muddy salt water.
Onshore Exploration No. 1 Bahr Megan	20–12N–33E, Quay	DST 3,478–3,518 ft, recovered 386 ft salt water; DST 3,558–3,696 ft, recovered 1,442 ft salt water; DST 3,980–4,064 ft, recovered 1,910 ft salt water.
Canyon Resources No. 1 Harvey/US	25–13N–31E, Quay	DST 3,110–3,245 ft (Abo), recovered 372 ft mud + 666 ft water; DST 3,284–3,348 ft (Abo), recovered 830 ft mud-cut salt water.
Continental Oil Company No. 1 Leatherwood–Reed	15–16N–17E, San Miguel	DST 2,944–3,008 ft (Abo), recovered 110 ft mud.
Aladdin Petroleum Corporation No. 1 Waggoner Estate, Tract 2	2–16N–26E, San Miguel	DST 2,092–2,114 ft (Abo–Tubb), recovered 35 ft mud; DST 2,224–2,300 ft (Abo), recovered 50 ft mud.
Monument Energy Corporation No. 2 Sedberry	25–17N–16E, San Miguel	DST 4,620–4,718 ft (Strawn), recovered 450 ft slight gas-cut mud + 370 ft water.
D. W. St. Clair No. 1 Sedberry	25–17N–16E, San Miguel	DST 4,671–4,781 ft (Abo), recovered 130 ft drilling fluid.
John D. Hancock Exploration Company, Ltd. No. 1 Sedberry	25–17N–16E, San Miguel	DST 4,649–4,791 ft (Strawn), gas to surface in 6 minutes, flowed 100 MCFGPD, recovered 450 ft heavy gas-cut mud; DST 4,950–4,987 ft (Strawn), weak blow—died in 5 minutes, recovered 10 ft mud.
Continental Oil Company No. 1 Shoemaker–Reed	28–17N–18E, San Miguel	DST 3,458–3,510 ft (lower Canyon), recovered 15 ft mud; DST 3,508–3,550 ft (lower Canyon), recovered 25 ft mud; DST 4,039–4,097 ft (Strawn), recovered 30 ft mud.

by the structural drape of the Triassic over a basement-seated horst block (McKallip, 1984, 1985). The horst block is a late Paleozoic structure that was reactivated during Laramide deformation (see structure section). Lateral facies changes of the reservoir to mudstones also limit and define the oil pool (Martin, 1983; McKallip, 1984, 1985). Depth to oil-saturated sands ranges from 400 to 800 ft. Average porosity of the reservoir sands is 20.8% and average permeability is 218 millidarcies (Martin, 1983). The Newkirk pool contains an estimated 62 million bbls of oil in place (McKallip, 1985). As of December 31, 1985, the steam-flood pilots had produced a total of 455 bbls of oil from the Newkirk pool (New Mexico Oil and Gas Engineering Committee, 1985).

Source rocks and migration

Dow (1979) defined a petroleum source rock as an organically rich sedimentary rock (or sedimentary rock unit) that has generated and expelled petroleum in sufficient quantity to form commercial accumulations. Identification and analysis of source rocks are essential to evaluating the petroleum potential of a basin. Unless one is willing to postulate inorganic sources for major petroleum accumulations, then source rocks *must* be present within a basin in order for petroleum accumulations to be present. However, source rocks may exist that either have not been identified or have not been drilled.

Are petroleum source rocks present within the Tucumcari Basin? The major oil accumulations in the Santa Rosa Sandstone (Santa Rosa tar sands and Newkirk oil pool) indicate oil source rocks are present within the basin. They have been matured to the stage of oil generation.

It is unlikely that sediments of the Dockum Group (Triassic) were sources for the Santa Rosa oil. The Dockum Group consists of red beds that probably owe their color to oxidation during diagenesis (Turner, 1980). Oxidation destroys most organic matter that might generate petroleum. Also, Budding (1979) used the Carbon Preference Index and pristane-to-phytane ratios to show that oil in the Santa Rosa tar sands was derived from a marine source. As previously discussed, the Santa Rosa Sandstone and the Chinle Formation of the Dockum Group are nonmarine in origin.

Possible source rocks for the oil that accumulated in the Santa Rosa Sandstone are dark-gray mudstones and micritic limestones in the San Andres Formation (Permian), lower unit of the Hueco Formation (Permian), and Canyon and Strawn Series (Pennsylvanian). Published (GeoChem Laboratories, Inc., and Chevron USA, Inc., 1987; GeoChem Laboratories, Inc., and Core Laboratories, Inc., 1987; Chevron USA, Inc., 1987; Bayliss and Schwarzer, 1987a, b, c) and unpublished geochemical data indicate the San Andres and Hueco Formations and the Canyon and Strawn Series are the stratigraphic units in the Tucumcari Basin that contain strata with sufficient organic carbon to be petroleum source rocks. Budding (1979, 1980) used carbon-isotope measurements of Santa Rosa oil and published carbon-isotope data of oil produced from stratigraphic units in the Permian Basin of southeastern New Mexico to determine that the source rocks are in either the San Andres Formation or the Pennsylvanian section. San Andres limestones have long been considered a possible source for the oil in the

Santa Rosa tar sands (Gorman and Robeck, 1946). Gorman and Robeck postulated that oil migrated into the Santa Rosa Sandstone through sinkholes and other solution conduits in the San Andres Formation.

McKallip (1984) used unpublished vitrinite-reflectance measurements to infer that the Santa Rosa oil has a Mississippian or Pennsylvanian source; the vitrinite-reflectance measurements indicated the San Andres Formation is thermally immature in the area around the Newkirk oil pool. McKallip then used a burial-history curve of the Santa Rosa area to infer that local Pennsylvanian strata reached the oil-generation stage of thermal maturity during the Jurassic and that oil migration may have begun in the Jurassic.

McKallip (1984) hypothesized that the oil migrated vertically from the Pennsylvanian source rocks through fractures. He also implied that the oil deposits at the Santa Rosa tar sands and the Newkirk oil pool are associated with local, relatively small, basic igneous dikes and sills. It is likely that the igneous rocks intruded along the same deep-seated faults through which the oil migrated; the association of intrusives with oil accumulations is the result of the magma and the oil using the same faults as migration paths, but at different times. It is also probable that some faults acted as migration paths for oil, but not for magma.

The method of Lopatin (Lopatin, 1971; Waples, 1980) was used to identify possible petroleum source rocks and to calculate the time of oil maturation in the Tucumcari Basin. Briefly, Lopatin's method considers that "both time and temperature are important factors in the process of oil generation and in the subsequent cracking of oil to methane" (Waples, 1980: p. 916). The thermal maturity of organic matter in a source rock is dependent on the kinetics of oil-generating chemical reactions and the extent to which the reactants have gone to completion. The volume of petroleum products derived from a source rock are proportional to the elapsed time since deposition of the source rock. Temperature, however, is a more important parameter in controlling the generation of petroleum. For each 10°C rise in temperature, the rate of petroleum-generating reactions approximately doubles, so that reaction rates are fairly slow near the surface and increase rapidly with increasing depth. Therefore, a source rock buried to a shallow depth will require a much longer time to reach the stage of oil generation than a deeply buried source rock. The geothermal gradient then becomes a variable to consider when calculating the maturation level of a source rock; one must not only know the present geothermal gradient, one must also deduce paleogeothermal gradients.

Waples' (1980) application of Lopatin's method allows one to calculate the maturation history of a source rock if a burial history of that source rock has been reconstructed. The maturation level of a source rock is presented as the Time-Temperature Index (TTI). Values of TTI can be calculated for various stages along the burial-history curves of a source rock. Timing of seven important stages of oil generation and preservation can be determined from TTI values: (1) onset of oil generation, (2) peak oil generation, (3) end of oil generation, (4) maturation limit for occurrence of oil with a gravity less than 40° API, (5) maturation limit for occurrence of oil with a gravity less than 50° API, (6) maturation limit for preservation of wet gas, and (7) maximum known thermal maturation limit for preservation of dry gas.

TTI values can also be used to predict values of vitrinite reflectance (R,) that might be found in a source rock. One may then compare predicted values of R_o with measured values of R, in order to ascertain the validity of the TTI values and the variables (primarily assumed values for the burial-history curve and the geothermal gradients) used in the TTI calculations. Readers are referred to Waples (1980) for a detailed discussion on how to calculate TTI.

Burial-history curves and TTI values were calculated for strata from three wells in the Tucumcari Basin (Figs. 3133): Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2

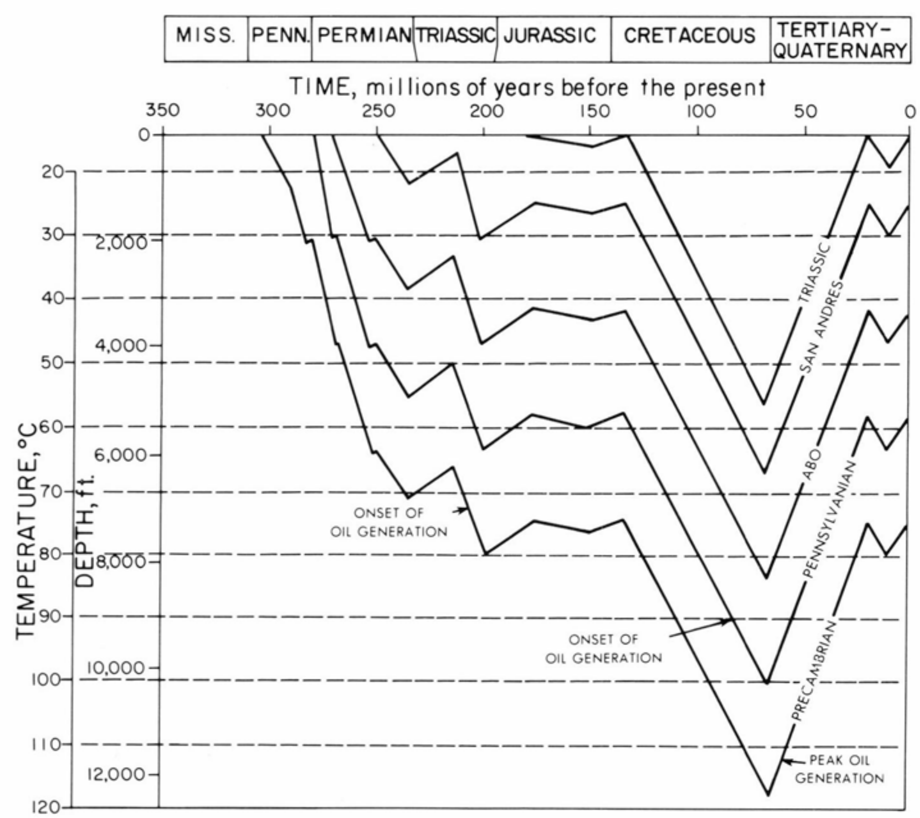


FIGURE 31—Burial-history curve, subsurface temperature grid, and important stages of oil generation and maturation calculated by Lopatin's method. Trans-Pecos Resources No. 1 Latigo Ranch A, sec. 2 T9N R23E, Guadalupe County.

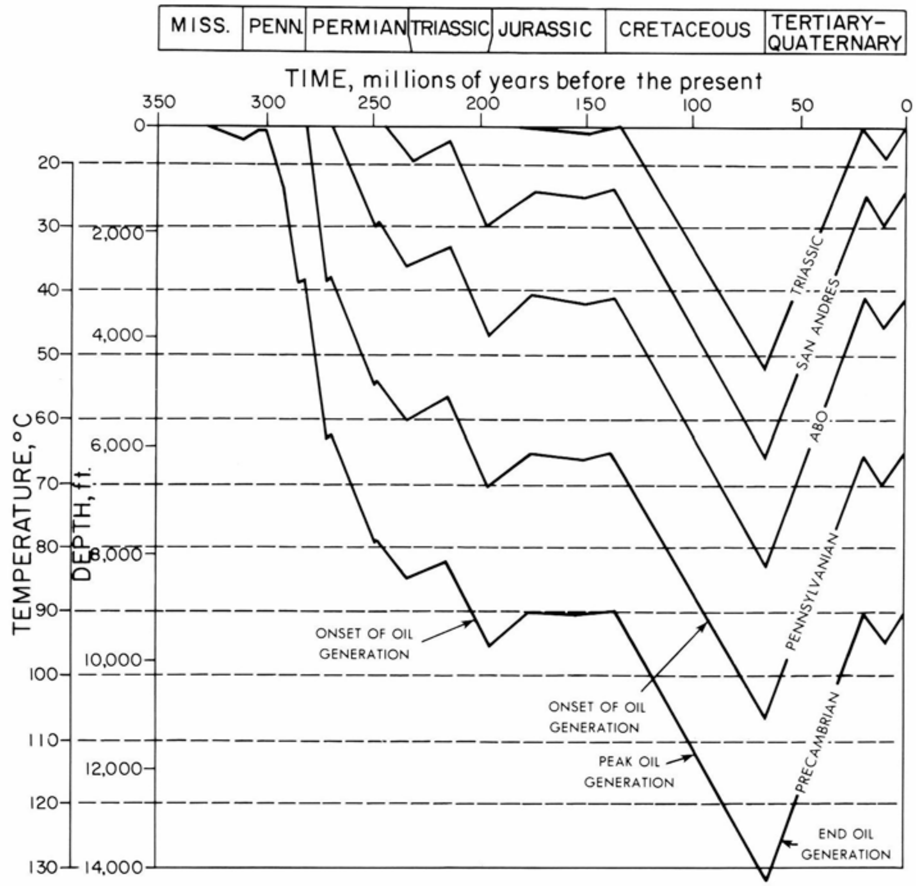


FIGURE 32—Burial-history curve, subsurface temperature grid, and important stages of oil generation and maturation calculated by Lopatin's method. General Crude Oil Company No. 1 Simpson, sec. 21 T10N R23E, Guadalupe County.

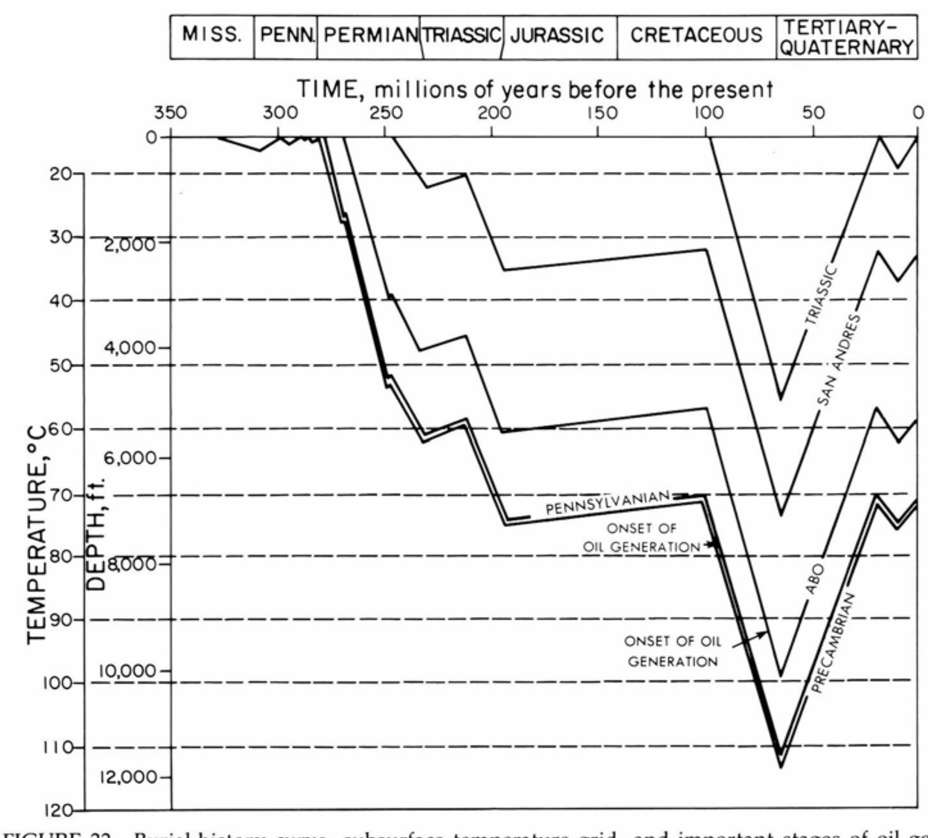


FIGURE 33—Burial-history curve, subsurface temperature grid, and important stages of oil generation and maturation calculated by Lopatin's method. Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County.

T9N R23E, Guadalupe County; General Crude Oil Company No. 1 Simpson, sec. 21 T1ON R23E, Guadalupe County; and Shell Oil Company No. 1 Stephenson, sec. 2 T3N R32E, Curry County. The three wells were selected because they are located in geographically and tectonically diverse parts of the Tucumcari Basin and encompass upper Paleozoic strata that have a wide range of maximum burial depths.

Values of TTI were calculated for the base and top of the Pennsylvanian and the tops of the Abo and San Andres Formations. TTI values for the Pennsylvanian, lower Hueco, and San Andres are significant because these are the only units in the Tucumcari Basin that contain large amounts of dark, organic-rich siliciclastic mudstones and finely crystalline limestones that have enough organic matter to be considered as possible source rocks. TTI values were not calculated for the lower Hueco because the burial history of the lower Hueco is similar to the burial history of the upper part of the Pennsylvanian.

Several different geothermal gradients were tried when making the calculations. A gradient of 1.5°F/100 ft was used for final calculations because the value yielded predicted R_o values that are close to published and unpublished R, values. This value is somewhat less than the average geothermal gradient of 2°F/100 ft reported by Levorsen (1967).

Calculated times for the important stages of oil generation and preservation were plotted on the burial-history curves for the Pennsylvanian, Abo, and San Andres sections (Figs. 31-33). According to the plots, the San Andres has not matured to the stage of oil generation in any of the three wells. Therefore, it seems unlikely that the San Andres Formation was the source of oil that accumulated in the Santa Rosa Sandstone. In all three wells, however, the entire Pennsylvanian section and the lower part of the Permian section have matured to the stage of oil generation. The lower part of the Pennsylvanian section has matured to the stage of peak oil generation in the Latigo Ranch and Simpson wells. The preservation limits of 40°-API oil have not been exceeded in any of the wells; however, oil ceased to be generated in the General Crude Oil Company No. 1 Simpson approximately 60 million years ago.

It appears that the Santa Rosa oil had a Pennsylvanian or lower Hueco (Wolfcampian) source, and not a San Andres (Leonardian) source. As discussed previously, the oil probably migrated vertically through deep-seated faults into the Santa Rosa Sandstone. Similarly, Ramondetta (1982) concluded that oil accumulated in San Andres reservoir rocks of the northern Midland Basin of west Texas had migrated vertically into the San Andres from a Wolfcampian source. Oil and gas in Strawn sandstones at the Latigo Ranch and T-4 Cattle Company pools probably originated in Strawn mudstones. Pennsylvanian and Wolfcampian strata in the Tucumcari Basin consist partly of organic-rich, marginal-marine to marine siliciclastic mudstones and micritic limestones that contain marine kerogen suitable for oil generation (GeoChem Laboratories, Inc., and Chevron USA, Inc., 1987; GeoChem Laboratories, Inc., and Core Laboratories, Inc., 1987; Chevron USA, Inc., 1987; Bayliss and Schwarzer, 1987a, b, c).

Reservoirs

A detailed discussion of Pennsylvanian and Lower Permian reservoir rocks in the Tucumcari Basin appears in the section on stratigraphy and reservoir geology. Reservoir rocks will only be summarized here.

Sandstones that may be good reservoirs are present mostly in the northern part of the Tucumcari Basin and on the south flank of the Sierra Grande Uplift. The sandstones are arkosic; many bear abundant fragments of granitic basement rocks. They were deposited in alluvial, marginal- and shallow-marine environments. The sandstone reservoirs are intercalated with and sealed by siliciclastic mudstones.

Well-developed, porous reservoirs are present in sandstones of Strawn through Abo age (Fig. 34). Porosity in Strawn sandstones is mostly secondary and has formed by dissolution of feldspars and calcite and quartz cements. Primary porosity is dominant in Abo and upper Hueco sandstones and decreases with depth to only a few percent in the lower part of the Pennsylvanian section. Porosity in Canyon sandstones is mostly secondary and has formed by dissolution of calcite, dolomite, and quartz cements and by dissolution of feldspars.

Limestones are present mostly in the central and southern parts of the Tucumcari Basin. Most of the limestones are nonporous and "tight." High-energy grainstones are present, especially in the southern part of the basin and on the flanks of the Frio Uplift. These high-energy limestones may contain local, porous zones. Secondary porosity that resulted from dissolution may be present in significant amounts.

Dolostones are present mostly in the lower Hueco on the Frio Uplift. They also occur in the Abo in northwestern Curry County. Many dolostones are good, porous reservoirs. Shows of live oil have been encountered in Hueco dolostones.

Traps

Potential undiscovered traps in the Tucumcari Basin may be present where faults, folds, sand lenses, reefs, and pinch-

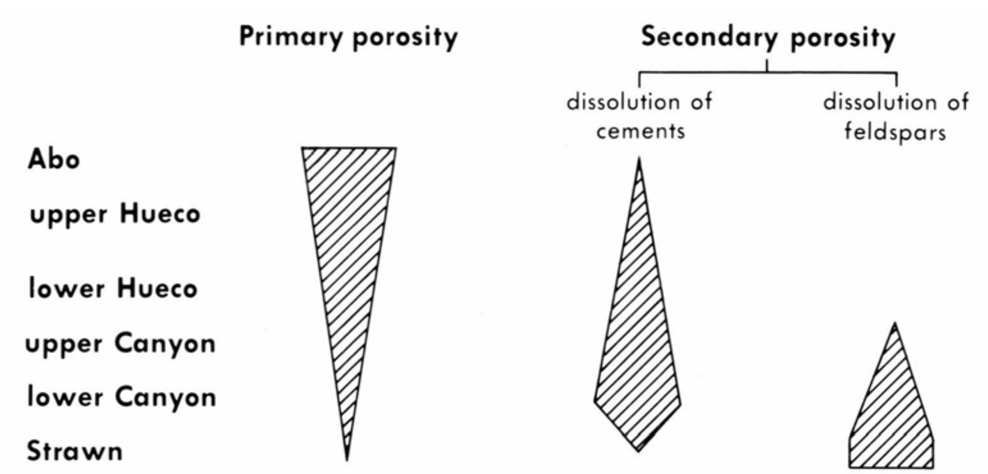


FIGURE 34—Variation in types of sandstone porosity as a function of burial depth, Pennsylvanian and Lower Permian section of Tucumcari Basin.

outs occur. The complex structures in the northern part of the basin indicate undiscovered traps in Pennsylvanian and Lower Permian reservoirs may mostly be structurally controlled. Fault traps are primary exploration targets in the northern and western parts of the basin but significant anticlinal traps may also have formed. Additional drilling will probably indicate traps in alluvial, marginal- and shallow-marine sandstones have both structural and stratigraphic aspects. Traps may primarily be stratigraphically controlled in the less deformed southern and eastern parts of the basin and on the Frio Uplift, although structural traps may also be present, especially in the vicinity of faults. Truncation traps underneath the unconformity at the top of the Pennsylvanian may be present on the flanks of structures throughout the basin. Because major tectonism ceased by late Wolfcampian time, stratigraphic units of Leonardian and younger age are relatively undeformed. Therefore, traps in post-Wolfcampian units may largely be stratigraphic.

The Lopatin analyses (Figs. 31-33) indicate most petroleum in the Tucumcari Basin was generated during the Late Cretaceous and Tertiary. This timing of oil generation coincides with maximum burial of upper Paleozoic strata. Oil generation began during the Jurassic in the deeper, northern parts of the basin (Trans-Pecos Resources No. 1 Latigo Ranch A and General Crude Oil Company No. 1 Simpson). Because most structures in the basin are Pennsylvanian and Wolfcampian in age and were present prior to oil generation and migration, they were available to trap hydrocarbons generated during the Mesozoic. Enhancement of these structures, and formation of new structures, ensued during Laramide (Late Cretaceous—early Tertiary) deformation. Oil generated during the Late Cretaceous and Tertiary may be trapped by Laramide structures. Folding of Triassic reservoirs on the Newkirk anticline probably occurred during Laramide deformation; therefore, the Santa Rosa oil was trapped at Newkirk during the Late Cretaceous or Tertiary. Although a large amount of petroleum generated in upper Paleozoic strata migrated vertically into shallower units (especially the Triassic), a significant amount of petroleum probably migrated laterally into reservoir rocks that are coeval with the source rocks.

Conclusions

(1) The Tucumcari Basin initially formed during Strawn (Middle Pennsylvanian) time. The basin is bounded to the north by the late Paleozoic Sierra Grande Uplift and Bravo Dome and to the west by the late Paleozoic Pedernal Uplift. The late Paleozoic Frio Uplift separates the Tucumcari Basin from the Palo Duro Basin of the Texas panhandle. The Tucumcari Basin merges gradationally southward into the northwest shelf of the Permian Basin and the Roosevelt Dome. Depth to Precambrian ranges from less than 2,000 ft on the Sierra Grande Uplift to more than 9,000 ft near the towns of Cuervo and Tucumcari.

(2) The Tucumcari Basin is structurally asymmetric. High-angle faults form the northern, western, and eastern borders of the basin. The southern part of the basin is not intensely faulted and strata dip gently northward into the basin center.

(3) Late Paleozoic facies reflect the structural asymmetry of the basin. Large volumes of coarse-grained arkosic sands were deposited in the faulted northern part of the basin where marginal- and nonmarine depositional environments prevailed. Shallow-marine carbonates and muds were deposited in the tectonically quiescent southern part of the basin. The Frio Uplift was covered by shallow-marine carbonates and muds by the close of Wolfcampian (Early Permian) time.

(4) Many of the coarse-grained arkosic sandstones in the northern part of the basin are porous, permeable reservoirs. Primary porosity and secondary porosity, which resulted from dissolution of feldspars and cements, exist. Sandstones that are good reservoirs are lenticular and are sealed by intercalated siliciclastic mudstones. High-energy oolitic and bioclastic limestones of Strawn (Desmoinesian) through Wolfcampian age may be local, porous reservoirs in the southern part of the Tucumcari Basin. Porous Wolfcampian dolostones are good reservoirs on the Frio Uplift.

(5) Source rocks of oil and gas are present in marine facies of Pennsylvanian and Lower Permian strata. Hydrocarbons generated by these source rocks migrated laterally into Pennsylvanian and Lower Permian reservoirs and vertically through faults into Triassic reservoirs. Hydrocarbons were generated mostly during the Late Cretaceous and Tertiary.

(6) Stratigraphic and structural traps are present in Pennsylvanian and Wolfcampian strata. Most structural traps were formed prior to the generation of hydrocarbons.

(7) Uneconomic and marginally economic hydrocarbons have been discovered in Triassic and Pennsylvanian rocks in the Tucumcari Basin. The discoveries in the Newkirk oil pool, the Santa Rosa tar sands, and the T-4 Cattle Company and Latigo Ranch pools indicate commercial occurrences may be present within the basin.

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APPENDIX A—Petroleum exploration wells used in study. Total depth and depth to Lower Permian, Pennsylvanian, Mississippian, and Precambrian units, and the elevation of the units with respect to sea level, are given (in ft) for each well. **A**, unit not present; **NR**, not recognizable as a separate unit.

Operator, well number, and lease	Location (section–township–range, county)	Total depth (ft)	Tubb sand	Abo	upper unit of Hueco	lower unit of Hueco	upper unit of Canyon	lower unit of Canyon	Strawn and Atokan	Arroyo Peñasco	Precambrian
Yates Petroleum Corporation No. 1 Duoro AAX Federal	27–3N–19E, Guadalupe	4,660	2,400/ +3,058	2,570/ +2,888	3,664/ +1,794						4,530/ +928
Pure Oil Company No. 1 Pure	31–3N–28E, De Baca	6,469	3,670/ +466	3,977/ +159	5,050/ −914	5,530/ −1,394	5,762/ −1,626	5,860/ −1,724	6,210/ −2,074	A	6,440/ −2,305
Cities Service No. 1 Swink A	8–3N–31E, Curry	7,346	4,635/ −79	5,075/ −519	5,910/ −1,354	6,326/ −1,770	6,690/ −2,134	6,768/ −2,212	7,144/ −2,588	A	7,203/ −2,647
Shell Oil Company No. 1 Stephenson	2–3N–32E, Curry	7,012	4,727/ −158	5,223/ −654	5,995/ −1,426	6,372/ −1,803	6,783/ −2,214	6,842/ −2,273	A	A	6,900/ −2,331
J. D. Sandefer III No. 1 Good State	21–4N–27E, De Baca	7,000	3,799/ +693	4,197/ +295	5,240/ −748	5,610/ −1,118	6,015/ −1,523	6,097/ −1,605	6,510/ −2,018		
Cities Service No. 1 Widner	17–4N–31E, Curry	7,348	4,538/ +19	4,992/ −435	5,842/ −1,285	6,278/ −1,721	6,722/ −2,165	6,796/ −2,239	7,150/ −2,593		
Cummins & Walker No. 1 Salado Dome Federal Unit	34–5N–19E, Guadalupe	4,760	2,107/ +3,129	2,328/ +2,908	3,363/ +1,873	3,694/ +1,542	3,970/ +1,266	4,029/ +1,207	4,372/ +864	A	4,700/ +536
Abercrombie & Hawkins No. 1 Nappier	22–5N–26E, De Baca	7,149	3,690/ +829	3,998/ +521	5,120/ −601	5,540/ −1,021	6,000/ −1,481	6,120/ −1,601	6,490/ −1,971	7,048/ −2,529	7,115/ −2,596
Marathon Oil Company No. 1 State 16	16–5N–31E, Curry	6,575	4,495/ +141	4,932/ −296	5,704/ −1,086	6,070/ −1,434					
J. V. Atkinson No. 1 Evelyn G. Brown	1–5N–34E, Curry	7,048	4,695/ −273	5,173/ −751	6,004/ −1,582	6,353/ −1,931	6,926/ −2,504	A	A	A	7,020/ −2,598
Texas Gulf Producing Company No. 1 Garrett	34–5N–34E, Curry	7,538	4,931/ −351	5,460/ −880	6,257/ −1,677	6,612/ −2,032	7,105/ −2,525	A	A	A	7,140/ −2,560
Union Producing Company No. 1 Jones	18–5N–37E, Curry	8,180	4,959/ −720	5,540/ −1,301	6,462/ −2,223	6,905/ −2,666	A	A	A	A	8,127/ −3,888
Cibola Energy, Inc. No. 1 Mesa Leon Unit	22–6N–17E, Guadalupe	4,920	1,932/ +3,770	2,050/ +3,652							
Armor Oil Company No. 1 Federal	9–6N–25E, De Baca	7,065	3,490/ +1,144	3,840/ +794	4,875/ −241	5,213/ −579	5,700/ −1,066	5,839/ −1,197	6,186/ −1,552	7,010/ −2,376	
HCW Exploration No. 1 Blackburn	10–6N–27E, Quay	8,585	4,524/ +540	4,750/ +314	5,910/ −846	6,344/ −1,280	6,782/ −1,718	6,900/ −1,836	7,180/ −2,116	8,316/ −3,252	8,526/ −3,462
Amoco Production Company No. 1 State GM	16–6N–29E, Quay	6,400	4,620/ +237	4,988/ −131	6,064/ −1,207						
CO_2-in-Action No. 1 Stewart	11–6N–31E, Quay	7,397	4,442/ +227	4,870/ −201	5,692/ −1,023	6,107/ −1,438	6,500/ −1,831	6,560/ −1,891	6,952/ −2,283	A	7,000/ −2,331
Exxon Corporation No. 1 Evelyn G. Brown	35–6N–34E, Curry	7,067	4,700/ −266	5,146/ −712	5,981/ −1,547	6,342/ −1,908	6,902/ −2,468	A	A	A	7,030/ −2,596
Hunt Oil Company No. 1 Puerto Creek Federal	28–7N–21E, Guadalupe	5,639	2,483/ +2,585	2,574/ +2,494	3,570/ +1,498	4,005/ +1,063	A	A	5,275/ −207		
Baker & Taylor No. 1 Dale Smith	15–7N–22E, Guadalupe	6,299	2,590/ +2,153	2,682/ +2,061	3,780/ +963	4,300/ +443	4,748/ −5	5,170/ −427	5,522/ −779	5,975/ −1,232	
Gulf Oil Corporation No. 1 Caton	26–7N–30E, Quay	8,490	4,806/ +72	5,180/ −302	6,074/ −1,196	6,473/ −1,595	6,975/ −2,097	7,187/ −2,309	7,602/ −2,724	8,222/ −3,344	8,335/ −3,457
Sunray Oil Corporation No. 1 NM Federal	3–8N–18E, Guadalupe	4,653	1,880/ +3,645	1,940/ +3,585	2,815/ +2,710	3,266/ +2,259	A	A	3,730/ +1,795	3,922/ +1,603	4,132/ +1,393
Sunray Mid-Continent Oil Company No. 1 R. Padilla	4–8N–19E, Guadalupe	3,800	1,831/ +3,534	1,913/ +3,452	2,698/ +2,667	3,116/ +2,249	A	A	3,412/ +1,953	3,512 +1,853	3,639/ +1,726
Sunray Oil Corporation No. 1A NM Federal	5–8N–19E, Guadalupe	3,728	1,848/ +3,583	1,920/ +3,511	2,713/ +2,718	3,106/ +2,325	A	A	A	3,352/ +2,079	3,516/ +1,915
Alta Energy Corporation No. 1 Walker	21–8N–21E, Guadalupe	4,000		2,288/ +2,360	3,448/ +1,236	3,895/ +789					
Bert Thompson No. 1 Tucumcari FNB	20–8N–22E, Guadalupe	6,032	2,471/ +2,341	2,603/ +2,209	3,852/ +960	4,275/ +537	4,618/ +194	5,172/ −360	5,488/ −676		
General Crude Oil Company No. 1-1 State	2–8N–23E, Guadalupe	7,103	3,158/ +1,849	3,293/ +1,714	4,548/ +459	4,977/ +30	5,270/ −263	5,988/ −981	6,385/ −1,378	6,872/ −1,865	6,994/ −1,987
Husky Oil Company & General Crude Oil Company No. 1 Hanchett State	16–8N–24E, Guadalupe	7,244	3,400/ +1,627	3,497/ +1,530	4,639/ +388	5,050/ −23	5,504/ −474	6,145/ −1,118	6,580/ −1,553	A	7,009/ −1,982
Stanolind No. 1 J. W. Fuller	25–8N–30E, Quay	6,747	4,046/ +413	4,383/ +76	5,275/ −816	5,753/ −1,294	6,009/ −1,550	6,074/ −1,615	6,280/ −1,821	A	6,730/ −2,271
CO_2-in-Action No. 1 Diplodocus State	16–8N–32E, Quay	7,022	4,262/ +68	4,334/ −4	5,296/ −966	5,730/ −1,400	5,940/ −1,610	6,050/ −1,720	6,406/ −2,076	A	6,514/ −2,184
Exxon Corporation No. 1 Dennis	32–8N–33E, Quay	6,750	4,719/ +17	4,814/ −78	5,643/ −907	6,057/ −1,321	A	6,252/ −1,516	A	A	6,500/ −1,764

APPENDIX A (continued)

Operator, well number, and lease	Location (section–township–range, county)	Total depth (ft)	Tubb sand	Abo	upper unit of Hueco	lower unit of Hueco	upper unit of Canyon	lower unit of Canyon	Strawn and Atokan	Arroyo Peñasco	Precambrian
Humble Oil & Refining Company No. 1 Northcutt	32–8N–37E, Curry	7,520	4,860/ −383	5,342/ −865	6,210/ −1,733	6,636/ −2,159					
A. G. Hill Company No. 1 Federal A	27–9N–19E, Guadalupe	4,932	2,170/ +3,388	2,243/ +3,315	3,262/ +2,296	3,596/ +1,962	A	A	4,048/ +1,510	4,455/ +1,103	4,563/ +995
Trans-Pecos Resources No. 1 Latigo Ranch A	2–9N–23E, Guadalupe	7,202	3,118/ +1,769	3,232/ +1,655	4,455/ +432	4,860/ +27	5,200/ −313	5,658/ −771	6,175/ −1,288	A	7,136/ −2,249
Trans-Pecos Resources No. 1 Latigo Ranch C	4–9N–23E, Guadalupe	7,407	3,165/ +1,829	3,250/ +1,744	4,392/ +602	4,830/ +164	5,180/ −186	5,694/ −700	6,158/ −1,164		
Trans-Pecos Resources No. 2 Latigo Ranch B	6–9N–24E, Guadalupe	7,241							6,185/ −1,372	A	7,111/ −2,298
CO_2-in-Action (also known as Baker & Taylor) No. 1 J. L. Hicks	19–9N–24E, Guadalupe	7,275	3,252/ +1,686	3,364/ +1,574	4,630/ +308	5,052/ −114	5,360/ −422	5,832/ −894	6,210/ −1,272		
Baker & Taylor No. 1 Reilly Minerals	34–9N–25E, Guadalupe	7,825	3,898/ +1,251	4,062/ +1,087	5,180/ −31	5,629/ −480	5,918/ −769	6,339/ −1,190	6,730/ −1,581	A	7,666/ −2,517
Amoco Production Company No. 1 Baker	29–9N–30E, Quay	8,330	3,953/ +255	4,260/ −52	NR	6,532/ −2,324	A	6,806/ −2,598	7,600/ −3,392		
General Crude Oil Company No. 1 R. L. Spires	22–10N–22E, Guadalupe	7,661	2,853/ +2,108	2,940/ +2,021	4,522/ +439	4,940/ +21	5,423/ −462	5,900/ −939	6,403/ −1,442	7,309/ −2,348	7,437/ −2,476
General Crude Oil Company No. 1 Simpson	21–10N–23E, Guadalupe	9,151	3,092/ +1,573	3,182/ +1,483	5,302/ −638	5,628/ −964	6,100/ −1,436	6,900/ −2,236	7,809/ −3,145	8,905/ −4,240	9,060/ −4,396
General Crude Oil Company No. 2–X Simpson	32–10N–23E, Guadalupe	7,621	3,040/ +1,916	3,154/ +1,802	4,837/ +119	5,196/ −240	5,678/ −722	6,096/ −1,140	6,588/ −1,632	7,448/ −2,492	7,517/ −2,561
General Crude Oil Company No. 14–1 A. S. Wilke	14–10N–24E, Guadalupe	6,980	3,130/ +1,663	3,234/ +1,559	4,920/ −127	5,233/ −440	5,570/ −777	5,634/ −841	6,108/ −1,315	6,781/ −1,988	6,832/ −2,039
Miami Petroleum Company No. 1 Hoover Ranch A	2–10N–27E, Quay	6,415	3,218/ +1,050	3,370/ +1,898	4,928/ −660	5,340/ −1,072	A	5,600/ −1,332	5,900/ −1,632	6,293/ −2,025	6,380/ −2,142
Yates Petroleum Corporation No. 1 T–4 Cattle Company	5–10N–27E, Quay	7,235	3,230/ +1,088	3,372/ +946	NR	5,117/ −799	5,552/ −1,234	5,983/ −1,665	6,682/ −2,364	A	7,078/ −2,760
Sunray Mid-Continent Oil Company No. 1 Briscoe	31–10N–30E, Quay	9,069	4,008/ +235	4,318/ −75	NR	6,690/ −2,447	7,032/ −2,789	7,062/ −2,819	7,875/ −3,632	8,940/ −4,697	
Shell Oil Company No. 2 North Pueblo	25–10N–31E, Quay	7,867	3,945/ +181	4,124/ +2	NR	6,273/ −2,147	6,562/ −2,436	6,674/ −2,548	7,270/ −3,144		
Gulf Oil Corporation No. 1 Whatley	15–10N–32E, Quay	8,484	3,976/ +36	4,174/ −162	NR	5,924/ −1,912	6,322/ −2,310	6,481/ −2,469	7,241/ −3,229	8,035/ −4,023	8,373/ −4,361
Murray Hill Oil & Gas No. 1 Stoner Unit	10–10N–34E, Quay	6,800									6,055/ −2,021
Franklin Petroleum Corporation No. 1 Anton Chico	24–11N–18E, Guadalupe	2,205									1,726/ +3,659
Cities Service No. 1 Driggers	22–11N–21E, Guadalupe	4,581	1,866/ +3,226	1,900/ +3,192	NR	2,850/ +2,242	A	A	3,060/ +2,032	A	3,260/ +1,832
McClellan Oil Corporation No. 1 Meg, Branum, Burner Fee	22–11N–21E, Guadalupe	3,219	1,890/ +3,190	1,942/ +3,138	NR	2,998/ +2,082					
McClellan Oil Corporation No. 3 Burner Fee	19–11N–22E, Guadalupe	5,411	2,229/ +2,694	2,304/ +2,619	NR	3,643/ +1,280	3,808/ +1,115	4,239/ +684	4,574/ +349	A	5,055/ −132
McClellan Oil Corporation No. 2 Burner Fee	31–11N–22E, Guadalupe	6,150	2,249/ +2,614	2,317/ +2,546	NR	3,793/ +1,070	3,943/ +920	4,364/ +499	4,738/ +125	A	5,662/ −799
Humble Oil & Refining Company No. 1 W. R. Moore, Jr.	23–11N–25E, Guadalupe	3,915	2,595/ +2,340	2,726/ +2,209	A	A	A	A	A	A	3,412/ +1,523
Baker & Taylor No. 1 T–4 Cattle Company	7–11N–27E, San Miguel	8,083	3,457/ +1,630	3,578/ +1,509	NR	5,294/ −207	A	5,896/ −809	7,630/ −2,543	A	7,995/ −2,908
Hartwell & Perry No. 1 Monsimer	26–12N–23E, San Miguel	5,035	2,327/ +2,400	2,445/ +2,282	NR	4,083/ +644	A	A	A	4,790/ −63	4,910/ −183
Miami Petroleum Company No. 1 Hoover Ranch	14–12N–28E, San Miguel	6,848	3,168/ +916	3,303/ +781	NR	5,220/ −1,136	A	5,650/ −1,566	6,318/ −2,234	A	6,750/ −2,666
Puretex Oil No. 1 Frank Chappell, Jr.	13–12N–29E, San Miguel	4,932	2,836/ +1,331	3,112/ +1,055							
Miami Petroleum Company No. 2 Hoover Ranch	18–12N–29E, San Miguel	7,075	3,290/ +829	3,574/ +545	NR	5,812/ −1,693	A	A	6,570/ −2,451		
Puretex Oil No. 2 Frank Chappell, Jr.	17–12N–30E, San Miguel	5,006	2,836/ +1,331	3,258/ +909	NR	3,698/ +469	A	A	A	4,059/ +108	4,130/ +37

APPENDIX A (continued)

Operator, well number, and lease	Location (section–township–range, county)	Total depth (ft)	Tubb sand	Abo	upper unit of Hueco	lower unit of Hueco	upper unit of Canyon	lower unit of Canyon	Strawn and Atokan	Arroyo Peñasco	Precambrian
National Oil Company No. 1 Ute Anticline	11–12N–32E, Quay	3,746	2,756/ +1,317	3,132/ +941							
G. H. Hamill No. 1 Tippins	35–12N–34E, Quay	5,615	3,230/ +835	3,730/ +335	A	A	A	A	A	A	5,606/ −1,541
Miami Petroleum Company No. 3 Hoover Ranch	25–13N–26E, San Miguel	6,670	2,860/ +1,298	2,938/ +1,220	NR	5,097/ −939	5,546/ −1,388	5,640/ −1,482	6,140/ −1,982	6,510/ −2,352	6,640/ −2,482
National Oil Company No. 1 Columbine State	32–13N–32E, Quay	3,406	2,547/ +1,423	2,659/ +1,311							
Miami Petroleum Company No. 2 Bell Ranch	12–14N–27E, San Miguel	3,202					A	A	A	A	3,145/ +1,138
Sunray Mid-Continent Oil Company No. 1 State N	16–14N–32E, Harding	2,850	2,192/ +1,734	2,590/ +1,336	A	A	A	A	A	A	2,716/ +1,210
Sam Sanders No. 1 Sanders	22–14N–33E, Harding	4,475									2,995/ +974
Phillips No. 1 Leatherwood	2–15N–18E, San Miguel	2,773	NR	2,510/ +4,483	A	A	A	A	A	A	2,680/ +4,313
Miami Petroleum Company No. 1 Bell Ranch	34–15N–26E, San Miguel	2,672	1,790/ +2,632	1,910/ +2,512							
Texas Pacific Oil Company No. 1 Trigg	2–15N–28E, San Miguel	5,786	3,151/ +1,494	3,543/ +1,102	A	A	A	A	A	A	5,752/ −1,107
Continental Oil Company No. 1 Leatherwood–Reed	15–16N–17E, San Miguel	3,911	2,409/ +4,339	2,435/ +4,313	NR	A	A	A	3,033/ +3,715	3,231/ +3,509	3,377/ +3,371
Reese & Jones No. 1 M. E. O'Connor	30–16N–19E, San Miguel	4,596	2,539/ +4,213	A	A	A	A	A	A	A	2,564/ +4,188
Aladdin Petroleum Corporation No. 1 Waggoner Estate	36–16N–24E, San Miguel	1,905	1,550/ +3,100	1,585/ +3,065	A	A	A	A	A	A	1,740/ +2,910
Aladdin Petroleum Corporation No. 1 Waggoner Estate, Tract 2	2–16N–26E, San Miguel	2,961	2,063/ +2,632	2,100/ +2,595	A	A	A	A	2,350/ +2,345	A	2,686/ +2,009
Astro–Tex Corporation No. 1X Olympic State	27–16N–33E, Harding	2,906	2,420/ +1,805	2,740/ +1,485	A	A	A	A	A	A	2,880/ +1,345
Sun Exploration & Production Company No. 1 R. C. Bell	13–16N–36E, Quay	2,870	2,023/ +2,172	2,177/ +2,018	A	A	A	A	A	A	2,814/ +1,381
John D. Hancock Exploration Company, Ltd. No. 1 Sedberry	25–17N–16E, San Miguel	5,135		3,160/ +3,425	A	A	A	A	3,890/ +2,695		
Monument Energy Corporation No. 2 Sedberry	25–17N–16E, San Miguel	4,718	3,117/ +3,469	3,153/ +3,433	A	A	A	A	3,878/ +2,708		
Continental Oil Company No. 1 Shoemaker–Reed	28–17N–18E, San Miguel	4,519	NR	3,190/ +3,613	A	A	A	3,448/ +3,355	3,612/ +3,191	4,224/ +2,579	4,360/ +2,443
Southwest Drilling No. 1 Conchas Development	34–17N–21E, San Miguel	3,512		A	A	A	A	A	A	A	2,565/ +3,958

APPENDIX B—Core descriptions of Pennsylvanian and Lower Permian strata for five wells used in study. Descriptions for each well are presented as a separate table.

Cores for each well were analyzed on a bed-by-bed basis. During analysis, however, it was found that beds could generally be grouped into units on the basis of similar thickness or lithology. Individual thick beds merit description as separate units. The lithologic descriptions in Tabs. B1–B5 were grouped according to those units. Each unit was described by the depth interval in which the unit occurs. Rock color was described using the GSA Rock Color Chart (Goddard et al., 1980).

TABLE B1—Core description, Amoco Production Company No. 1 State GK, located 1,980 ft FNL, 1,980 ft FWL, sec. 32 T1N R26E, De Baca County. Elevation 3,956 ft, ground level. Total depth 4,900 ft. Plugged and abandoned 1/12/80.

Depth interval (ft)	Description
Abo Formation (Permian)	
3,923.0–3,955.2	*Mudstones* (65%); dark reddish brown (10R3/4) when wet, pale reddish brown (10R4/4) to grayish red (10R4/2) when dry, contain 0–30% irregular to spherical, light-gray (N7) to greenish-gray (5GY6/1) color bands 0.1–0.5 ft thick; silty; beds 0.4–14.3 ft thick, bioturbated, contain desiccation cracks. Closed fractures present throughout; poorly to moderately indurated. *Sandstones* (35%); dark reddish brown (10R3/4) to very dark red (5R2/6) when wet, pale red (10R6/2) to grayish red (10R4/2) when dry, contain tr–100% irregular to spherical, greenish-gray (5G6/1) color bands 0.1–0.5 ft thick that cut across primary sedimentary structures; fine to very fine grained, conglomeratic, moderately sorted; composed of angular, coarse sand- to granule-size rip-up clasts of red mudstone and very fine grained sandstone floating in a fine to very fine sand matrix; grain size fines upward in most beds; beds 0.8–4.7 ft thick, planar laminated and small- to medium-scale cross-laminated, contain soft-sediment faults and, in upper parts of beds, desiccation cracks. Contacts with interbedded mudstones sharp; well indurated.
3,955.2–4,177.0	No core.
4,177.0–4,187.6	*Mudstones*; dark reddish brown (10R3/4) to dusky red (10R3/2) when wet, grayish red (10R4/2) to dusky red (10R3/2) when dry; silty, contain a trace of subangular to rounded, granule- to pebble-size clasts of greenish-gray and red mudstones and very fine grained sandstone. Sharp base; poorly indurated.
4,187.6–4,193.0	*Sandstones*; dark reddish brown (10R3/4) when wet and dry, contain 10% irregular, greenish-gray (5G6/1), calcareous color bands 0.1–0.3 ft thick; very fine grained, well sorted, contain a trace of angular, coarse sand- to granule-size red mudstone flakes; wavy bedded, planar laminated and small- to medium-scale cross-laminated; some lamination convoluted. Sharp base; well indurated.
4,193.0–4,196.6	*Mudstones*; dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to dark reddish brown (10R3/4) when dry; silty, contain a trace of subangular to subrounded, coarse sand- to granule-size clasts of greenish-gray and red mudstone and very fine grained sandstone floating in a mud matrix; fossils (tr%): calcareous, sand-size fragments of fusulinids, brachiopods, and ostracods; poorly indurated.
4,196.6–4,497.4	No core.
Hueco Formation (Permian)	
4,497.4–4,511.5	*Limestones* (65%); olive gray (5Y4/1) when wet, medium gray (N5) when dry; microcrystalline (20–60%); fossils (40–80%): sand-size fragments of ostracods, gastropods, and brachiopods; intraclasts (10–40%): rounded to subangular microcrystalline limestone; intraclastic–bioclastic packstones and wackestones; beds 0.2–3.2 ft thick. Contacts with interbedded mudstones gradational; well indurated. *Mudstones* (35%); dark gray (N3) to grayish black (N2) when wet, medium gray (N5) to medium dark gray (N4) when dry; argillaceous; calcareous; fossils (tr%): brachiopod fragments; intraclasts (tr%): angular to rounded, granule- to cobble-size fragments of fossiliferous limestone; thinly to very thinly fissile; poorly indurated.
4,511.5–4,535.9	*Limestones* (95%); grayish black (N2) when wet, medium dark gray (N4) when dry; microcrystalline (80%); fossils (20%): disarticulated crinoid columnals, echinoid spines, brachiopods, bryozoans, ostracods, and calcareous algae; crinoidal wackestones; locally intraclastic: composed of 90% angular, granule- to cobble-size limestone intraclasts; contain abundant syneresis cracks filled with gray siliciclastic mudstone; beds 5.7–10.5 ft thick. Contacts with interbedded mudstones gradational; well indurated. *Mudstones* (5%); grayish black (N2) to olive black (5Y2/1) when wet, medium dark gray (N4) to dark gray (N3) when dry; argillaceous; calcareous; fossils (tr%): sand-size, recrystallized; beds 0.3–0.6 ft thick; thinly fissile; poorly indurated.
4,535.9–4,559.0	*Limestones* (50%); grayish black (N2) to olive gray (5Y4/1) when wet, medium gray (N5) to medium dark gray (N4) when dry; microcrystalline (70–90%); fossils, peloids, siliciclastic mudstone clasts (10–30%): fossils are partially to completely recrystallized fusulinids, brachiopods, disarticulated crinoid columnals, and foraminifers; mudstone clasts are sand- to granule-size; crinoidal and brachiopodal wackestones; beds 0.3–4.8 ft thick, planar laminated, contain high-angle desiccation cracks; most contacts with interbedded mudstones gradational, some sharp; well indurated. *Mudstones* (50%); medium dark gray (N4) to grayish black (N2) when wet, medium gray (N5) to dark gray (N3) when dry; argillaceous, calcareous; fossils (tr%): crinoid fragments; beds 0.3–3.0 ft thick; thinly fissile to nonfissile; poorly indurated.
4,559.0–4,565.4	*Limestones*; dark gray (N3) when wet, medium dark gray (N4) when dry; microcrystalline (100%); lime mudstone, grades downward to intraclastic packstone; gradational base; well indurated.
4,565.4–4,571.4	*Mudstones*; dark reddish brown (10R3/4) when wet, grayish red (5R4/2) when dry; argillaceous; calcareous; intraclasts (40%): rounded to angular, coarse sand- to cobble-size clasts of fossiliferous microcrystalline limestone, decrease in abundance toward center of bed, medium dark gray (N4) to greenish gray (5GY6/1) when wet, medium gray (N5) when dry. Contacts with overlying and underlying beds gradational; poorly to moderately indurated.
4,571.4–4,580.9	*Limestones*; olive gray (5Y4/1) when wet, olive gray (5Y5/1) when dry; microcrystalline (100%); fossils (tr%): brachiopod fragments, disarticulated crinoid columnals; lime mudstones; lightly burrowed: vertical to horizontal, tubular to irregularly shaped burrows 1–5 mm in diameter filled with red siliciclastic mudstone; vertical burrows contain spreite; syneresis polygons present, separated by dark-gray siliciclastic mudstone; gradational base; well indurated.
4,580.9–4,591.0	*Limestones* (70%); thinly laminated grayish black (N2) and olive gray (5Y4/1) when wet, dark gray (N3) when dry; microcrystalline (100%); fossils (tr%): fusulinids; lime mudstone; beds 0.8–3.1 ft thick, contain vertical to horizontal syneresis cracks throughout; limestones intraclastic near contacts with interbedded mudstones; contacts gradational; well indurated. *Mudstones* (30%); dark gray (N3) to grayish black (N2) when wet, medium dark gray (N4) to dark gray (N3) when dry; argillaceous; calcareous; fossils (tr%): sand-size fragments; burrows: horizontal, tubular burrows 15–30 mm in diameter filled with microcrystalline calcite; beds 0.4–1.0 ft thick; thinly fissile to nonfissile; poorly indurated.
4,591.0–4,601.6	*Mudstones*; olive black (5Y2/1) when wet, medium dark gray (N4) when dry; argillaceous; calcareous; gradational base; thinly fissile to nonfissile; poorly indurated.
4,601.6–4,655.0	*Limestones* (80%); dark gray (N3) to grayish black (N2) when wet, medium gray (N5) when dry; microcrystalline (80–100%); fossils (tr–20%): brachiopod fragments and disarticulated crinoid columnals; lime mudstones and brachiopod wackestones, grade to intraclastic packstones near contacts with interbedded siliciclastic mudstones; beds 0.2–6.1 ft thick, planar to ripple laminated. Contacts with interbedded mudstones gradational; well indurated. *Mudstones* (20%); brownish black (5YR2/1) when wet and dry; argillaceous; calcareous; beds 0.1–0.9 ft thick; poorly indurated.
4,655.0–4,669.0	No core.

TABLE B1 (continued)

Depth interval (ft)	Description
4,669.0–4,736.4	*Limestones*; brownish gray (5YR4/1) when wet, brownish gray (5YR5/1) when dry, mottled with dark reddish brown (10R3/4) siliciclastic mudstone. Intraclastic packstone: angular, sand- to cobble-size intraclasts of lime mudstone and crinoidal–brachiopodal wackestone separated by siliciclastic mudstone; gradational base; moderately indurated.
4,736.4–4,748.5	*Limestones*; grayish black (N2) when wet, dark gray (N4) when dry; microcrystalline (70–100%); fossils (tr–30%): brachiopods, disarticulated crinoid columnals; lime mudstones and bioclastic wackestones; wavy to ripple laminated, syneresis cracks abundant; well indurated. *Mudstones* (tr%); dark gray (N4) to grayish black (N2) when wet, medium dark gray (N4) to dark gray (N3) when dry; argillaceous; calcareous; beds less than 0.1 ft thick, wavy; poorly indurated.
4,748.5–4,760.0	*Mudstones* (85%); grayish black (N2) when wet, medium dark gray (N4) when dry; argillaceous, calcareous; fossils (tr%): brachiopod fragments; intraclasts (tr%): rounded, sand- to pebble-size lime mudstone; beds 1.6–5.6 ft thick. Contacts with interbedded limestone sharp to gradational; poorly indurated. *Limestones* (15%); grayish black (N2) when wet, medium dark gray (N4) when dry; microcrystalline (30–100%); fossils (tr–70%): brachiopods, disarticulated crinoid columnals; lime mudstones and bioclastic wackestones and packstones; beds 0.5–1.3 ft thick; well indurated.
4,760.0–4,762.2	*Mudstones*; dark reddish brown (10R3/4) when wet, grayish red (5R4/2) when dry; argillaceous; calcareous; intraclasts (30%): angular, coarse sand- to granule-size clasts of fossiliferous microcrystalline limestone, medium dark gray (N4) to greenish gray (5GY6/1) when wet, medium gray (N5) when dry; poorly to moderately indurated.
4,762.2–4,771.5	No core.
4,771.5–4,794.0	*Limestones* (70%); grayish black (N2) when wet, medium dark gray (N4) when dry; microcrystalline (30–100%); fossils (tr–70%): brachiopods, disarticulated crinoid columnals, calcareous algae; lime mudstones and bioclastic wackestones and packstones; beds 0.2–2.4 ft thick. Contacts with interbedded mudstones sharp to gradational; well indurated. *Mudstones* (30%); grayish black (N2) when wet, medium dark gray (N4) when dry; argillaceous; calcareous; intraclasts (tr%): rounded to subangular, sand- to cobble-size limestone; poorly indurated.

TABLE B2—Core description, Amoco Production Company No. 1 State GM, located 660 ft FNL, 660 ft FEL, sec. 16 T6N R29E, Quay County. Elevation 4,845 ft, ground level. Total depth 6,400 ft. Plugged and abandoned 9/11/79.

Depth interval (ft)	Description
Abo Formation (Permian)	
5,135.0–5,162.7	*Sandstones* (65%); moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) when wet, grayish red (10R3/2) to pale reddish brown (10R5/4) when dry, contain 10% irregular, greenish-gray (5GY6/1) to very light gray (N8) color bands as thick as 7 cm that cut across primary sedimentary structures; fine to very fine grained, well sorted, anhydritic; arkosic arenite; contain sparse molds of chickenwire anhydrite; beds 1.4–6.8 ft thick, generally conglomeratic near base and fine upward into fine to very fine sand and then grade upward into overlying mudstones; conglomerate composed of angular to subrounded, coarse sand- to granule-size clasts of very fine grained sandstone and red mudstone floating in a fine to very fine sand matrix; beds thicker than 5 ft small- to medium-scale cross-laminated and current rippled, contain some convoluted bedding, desiccation cracks, and root traces; beds thinner than 5 ft generally have gradational contacts with interbedded mudstones, contain plane-parallel laminae, cross-laminae, and root traces; well indurated. *Mudstones* (35%); dark reddish brown (10R3/4) when wet, grayish red (5R4/2) when dry, contain a trace of spherical greenish-gray (5GY6/1) blebs as large as 1 cm in diameter; silty; beds 1.0–4.6 ft thick; poorly indurated.
5,162.7–5,173.3	*Sandstones*; dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) when dry; lower 0.4 ft greenish gray (5G6/1) to yellowish gray (5Y8/1) when dry; very fine grained, well sorted; arkosic arenite; lower 0.2 ft conglomeratic, composed of angular to subrounded, coarse sand- to pebble-size clasts of greenish-gray mudstone in a fine sand matrix; trough cross-laminated throughout, desiccation cracks in upper 1 ft. Sharp base and gradational top; well indurated.
5,173.3–5,226.6	*Mudstones* (55%); dark reddish brown (10R3/4) when wet, reddish brown (10R4/4) when dry, contain a trace of spherical to irregularly shaped greenish-gray zones as thick as 1 cm; silty; beds 0.9–5.7 ft thick, contain closed chickenwire fractures, root traces, and desiccation cracks; basal contacts gradational and upper contacts sharp to gradational; poorly indurated. *Sandstones* (45%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to pale reddish brown (10R5/4) when dry, beds contain 0–20% irregular, greenish-gray (5G6/1) to light-gray (N8) color bands and blebs 0.01–0.4 ft thick; very fine grained, well sorted; arkosic arenite; beds 0.2–4.7 ft thick. Most beds thicker than 2 ft have a sharp base, are medium-scale cross-laminated in lower third of the bed, cross-laminated in the middle third, unbedded in upper third, and grade into overlying mudstone; desiccation cracks and root traces present throughout but are most prevalent in upper third of beds. Most beds thinner than 2 ft grade into overlying and underlying mudstones, are parallel laminated or small-scale cross-laminated, and contain desiccation cracks and root traces; some contain horizontal to vertical closed fractures. Moderately to well indurated.
5,226.6–5,278.6	*Sandstones* (95%); moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) when dry; beds contain tr–10% irregular, greenish-gray (5G6/1) to grayish-yellow (5Y8/4) color bands and blebs; fine to very fine grained, well sorted, locally conglomeratic and poorly to moderately sorted; arkosic arenite. Conglomerate intraformational, composed of angular to subrounded clasts of red mudstone and fine-grained sandstone floating in a fine sand matrix; beds 10.3–14.4 ft thick, grade upward from fine sands to very fine sands, grade into overlying mudstones, and have sharp basal contacts. Lower third of individual beds is medium-scale cross-laminated, the middle third is small-scale cross-laminated, and upper third is structureless except for desiccation cracks and root traces; soft-sediment faults and convoluted bedding occur throughout; cross-laminated sandstones contain anhydrite cement and a trace of visual porosity; well indurated. *Mudstones* (5%); dark reddish brown (10R3/4) when wet, reddish brown (10R4/4) when dry; silty; beds 0.8–2.0 ft thick; upper contacts sharp and lower contacts gradational; poorly to moderately indurated.
5,278.6–5,299.9	*Sandstones* (65%); dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) when dry, beds contain 0–60% greenish-gray (5G6/1) to light-gray (N8) color bands that cut across primary sedimentary structures; fine grained, well sorted; arkosic arenite; beds 0.2–6.8 ft thick, small- to medium-scale cross-laminated; some lamination convoluted; contain soft-sediment faults, desiccation cracks, root traces, and closed fractures. Contacts with interbedded mudstones gradational; well indurated. *Mudstones* (35%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to reddish brown (10R4/4) when dry; silty; beds 0.4–3.8 ft thick; poorly to moderately indurated.
5,299.9–5,347.6	*Sandstones* (85%); dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) to grayish pink (5R8/2) when dry; very fine to medium grained, moderately to well sorted, locally conglomeratic, anhydritic; arkosic arenite; conglomerate intraformational, forms layers 0.3–0.5 ft thick, composed of angular to subrounded, granule- to pebble-size clasts of red mudstone floating in a fine sand matrix; beds 1.7–16.2 ft thick, form sequences of medium-scale cross-laminated in lower part and small-scale cross-laminated or planar

TABLE B2 (continued)

Depth interval (ft)	Description
	laminated in upper part; this sequence is repeated as many as 3 times in a single bed; some lamination is convoluted. Upper parts of some beds contain desiccation cracks and root traces; lower medium-scale cross-laminated portions of beds have a trace of visual porosity; lower contacts sharp and upper contacts gradational; well to moderately indurated. *Mudstones* (15%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to reddish brown (10R4/4) when dry; silty; beds 0.6–2.6 ft thick, contain desiccation cracks and root traces; poorly to moderately indurated.
5,347.6–5,351.6	*Sandstones*; dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) to grayish pink (5R8/2) when dry; medium sand- to pebble-size, poorly sorted, arkosic conglomerate grades upward into a fine-grained, well-sorted, planar- to cross-laminated arkosic arenite; convolute lamination in upper 1 ft; gradational top and sharp base; well indurated.
5,351.6–5,410.3	*Sandstones* (65%); dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) when dry; beds contain tr–10% irregular, greenish-gray (5G6/1) color bands; fine to very fine grained, well sorted, anhydritic; arkosic arenite; beds 2.8–20.1 ft thick, small- to medium-scale cross-laminated and planar laminated; some beds have closed vertical fractures; bases sharp and tops gradational; porosity (tr%): intergranular; moderately to well indurated. *Mudstones* (35%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to reddish brown (10R4/4) when dry; beds contain 0–20% greenish-gray (5G6/1) color bands 0.1–0.4 ft thick; silty, contain thin laminae of very fine grained sandstone; beds 1.9–15.3 ft thick; poorly to moderately indurated.
5,410.3–5,455.0	No core.
5,455.0–5,466.0	*Sandstones*; dark reddish brown (10R3/4) when wet, pale reddish brown (10R5/4) when dry; bed contains 10% irregular, greenish-gray (5G6/1) color bands; very fine grained, well sorted; locally conglomeratic and poorly sorted; arkosic arenite. Conglomerate intraformational, composed of granule- to pebble-size grains of red mudstone and fine to very fine grained sandstone floating in a very fine sand matrix. Bed arranged into four fining-upward sequences that start at the base with an intraformational conglomerate that is overlain by an interval of convoluted, high-angle, large-scale cross-laminations that is overlain by a small-scale cross-laminated sandstone that is overlain by a silty, sandy mudstone; base of each sequence sharp; moderately to well indurated.
5,466.0–5,571.0	*Mudstones* (90%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) to reddish brown (10R4/4) when dry; silty to argillaceous; calcareous (10%); swells in water (10%); calcareous mudstone contains recrystallized fossil fragments. Most beds are thicker than 5 ft; poorly indurated. *Sandstones* (10%); dark reddish brown (10R3/4) when wet, grayish red (10R4/2) when dry; very fine grained, well sorted; arkosic arenite; beds less than 3 ft thick; moderately indurated.
5,571.0–5,604.0	*Mudstones* (60%); grayish brown (5R3/2) when wet, dusky red (10R3/2) when dry; silty; sparse, horizontal and vertical, branching tubular burrows 3–10 mm in diameter; beds 0.5–1.0 ft thick. Contacts with interbedded sandstones gradational; poorly to moderately indurated. *Sandstones* (40%); dark reddish brown (10R3/4) when wet, dusky red (10R3/2) when dry; very fine grained, well sorted, structureless; calcareous; arkosic arenite; sparse, horizontal and vertical, branching tubular burrows 3–10 mm in diameter; beds 0.5–1.0 ft thick, contain closed vertical fractures; moderately indurated.
5,604.0–5,607.2	*Sandstones*; dark reddish brown (10R3/4) to pinkish gray (5YR8/1) when wet, grayish pink (5R8/2) to pale purple (5P6/2) when dry; fine to coarse grained, moderately sorted, calcareous; arkosic arenite; coarser grains are angular to rounded, medium to coarse sand-size clasts of red mudstone and very fine grained sandstone; planar laminated to medium-scale cross-laminated; well indurated.
5,607.2–5,632.0	No core.
5,632.0–5,659.5	*Mudstones* (65%); dusky red (10R3/2) when wet, grayish red (10R4/2) when dry; beds mottled with 0–30% light bluish gray (5B7/1) to greenish-gray (5GY6/1) mudstone; silty; calcareous; fossils (tr%): fragments of calcareous algae; beds 0.7–14.4 ft thick, contain calcite-filled fractures less than 1 cm long. Contacts with interbedded sandstones gradational; poorly to well indurated. *Sandstones* (35%); mottled dark reddish brown (10R3/4) and greenish gray (5GY6/1) when wet, dark reddish brown (10R3/4) and greenish gray (5GY6/1) to light bluish gray (5B7/1) when dry; very fine grained, well sorted; calcareous; arkosic arenite; beds 1.2–7.9 ft thick, bioturbated, and wavy to ripple laminated; well indurated.
5,659.5–5,813.0	No core.
5,813.0–5,831.0	*Mudstones* (60%); dark reddish brown (10R3/4) when wet, grayish red (10R3/2) when dry; silty; calcareous; dolomite nodules (10%): microcrystalline, 2–7 cm in diameter; beds 2.0–8.4 ft thick. Contacts with interbedded sandstone gradational; poorly indurated. *Sandstones* (40%); dark reddish brown (10R3/4) when wet, grayish red (10R3/2) when dry; fine to very coarse grained, moderately to poorly sorted; arkosic arenite; beds 3.0–4.9 ft thick, crudely parallel laminated, contain closed vertical fractures; well indurated. *Dolostones* (tr%); light gray (N7) when dry; microcrystalline, nodular. One bed 0.1 ft thick.
5,831.0–5,849.0	No core.
5,849.0–5,853.0	*Sandstones*; dark reddish brown (10R3/4) when wet, grayish red (10R3/2) when dry; very fine grained, conglomeratic, poorly sorted; composed of coarse sand- to pebble-size clasts of microcrystalline limestone floating in a sand matrix; wavy laminated and small- to medium-scale cross-laminated.
5,835.0–5,857.0	No core.
5,857.0–5,857.6	*Mudstones*; dark reddish brown (10R3/4) when wet, grayish red (10R3/2) when dry; silty; calcareous. Sharp base; poorly indurated.
5,857.6–5,859.0	*Sandstones*; dark reddish brown (10R3/4) when wet, grayish red (10R3/2) when dry; fine to coarse grained, conglomeratic, poorly sorted; anhydritic; arkosic arenite. Sharp base.
5,859.0–5,862.0	*Mudstones*; similar to 5,857.0–5,857.6 ft.
5,862.0–5,866.0	No core.
5,866.0–5,867.0	*Mudstones*; similar to 5,857.0–5,857.6 ft.
5,867.0–5,870.3	*Conglomerates*; fine sand- to pebble-size, very poorly sorted; calcareous, arkosic. Sharp base; moderately indurated.
5,870.3–5,888.4	*Sandstones*; pale reddish brown (10R5/4) to very dusky red (10R2/2) when dry; mottled light greenish gray (5G8/1) and dark greenish gray (5G6/1) below 5,885.7 ft; fine to very fine grained, well sorted; calcareous; arkosic arenite; planar and cross-laminated throughout; medium-scale laminae in upper 1 ft have superimposed climbing current ripples; burrowed below 5,885.7 ft; well indurated.
5,888.4–5,895.0	No core.
5,895.0–5,909.0	*Sandstones*; pink to red; fine sand- to pebble-size, conglomeratic, poorly sorted, angular to subrounded, anhydritic; arkosic arenite; porosity (tr%): intergranular; low-angle cross-laminae throughout; well indurated.
5,909.0–5,934.0	No core.
5,934.0–5,962.0	*Sandstones* (90%); similar to 5,895.0–5,909.0 ft, but beds 0.3–8.8 ft thick, have sharp contacts with interbedded mudstones; moderately to well indurated. *Mudstones* (10%); red; silty; beds 0.1–1.0 ft thick; moderately indurated.
5,962.0–5,983.0	No core.

TABLE B2 (continued)

Depth interval (ft)	Description
5,983.0–5,988.6	*Mudstones*; red; silty; sand (40%): coarse to very coarse grained, angular quartz and feldspar floating in mud matrix; poorly sorted; arkosic wacke. Sharp base; poorly indurated.
5,988.6–6,016.6	*Sandstones*; grayish red (10R4/2) when wet, moderate orange pink (10R7/4) when dry; fine sand- to pebble-size, conglomeratic, poorly sorted, dolomitic, calcareous, anhydritic; arkosic arenite; pebble-size clasts are granitic rock fragments and quartz and feldspar; crude planar laminations to low-angle cross-laminations throughout; moderately to well indurated.
6,016.6–6,050.0	No core.
6,050.0–6,050.9	*Mudstones*; olive gray (5Y4/1) when wet, medium gray (N5) when dry; argillaceous; calcareous; poorly indurated.
Upper unit of Hueco Formation (Permian)	
6,050.9–6,052.0	*Limestones*; olive gray (5Y4/1) when wet, medium gray (N5) when dry. Intraclasts (60%): angular to subrounded, medium sand- to pebble-size clasts of microcrystalline limestone; microcrystalline (40%). Intraclastic packstone; gradational base; well indurated.
6,052.0–6,056.0	*Dolostones*; pale brown (5YR5/2) when wet, brownish gray (5YR4/1) when dry; microcrystalline, some ghost fabric of intraclastic limestone; porosity (tr%): vuggy; gradational base; well indurated.
6,056.0–6,064.0	*Limestones*; similar to 6,050.9–6,052.0 ft.
6,064.0–6,069.4	*Dolostones*; similar to 6,052.0–6,056.0 ft.
6,069.4–6,140.4	*Sandstones* (90%); very dusky red (10R2/2) when wet, dusky red (10R3/2) when dry; medium sand- to pebble-size, conglomeratic, poorly sorted; calcareous; arkosic arenite; beds 2.0–10.5 ft thick, planar laminated to medium-scale crossbedded. Contacts with interbedded mudstones sharp to gradational; well indurated. *Mudstones* (10%); blackish red (5R2/2) when wet, very dusky red (10R2/2) when dry; silty; beds 1.4–2.1 ft thick; poorly to well indurated.

TABLE B3—Core description, Trans-Pecos Resources No. 1 Latigo Ranch C, located 660 ft FNL, 1,980 ft FWL, sec. 4 T9N R23E, Guadalupe County. Elevation 4,982 ft, ground level. Total depth 7,407 ft in Pennsylvanian. Completed 2/23/83 through perforations from 6,746–6,756 ft, 6,769–6,776 ft, 6,783–6,788 ft, 6,792–6,802 ft, and 6,809–6,819 ft in Strawn Series (Pennsylvanian). Initial potential flowing 16.5 MCFGPD. Shut in.

Depth interval (ft)	Description
Abo Formation (Permian)	
4,033–4,039	*Sandstones*; grayish red (5R4/2) when dry, grayish red (5R3/2) when wet; well indurated; coarse to very coarse grained, conglomeratic; arkosic, not calcareous; no visual porosity; poor reservoir quality.
4,116–4,123	*Mudstones*; grayish red (10R4/2) when dry, dark reddish brown (10R3/4) when wet; consist of less than 1% greenish-gray reduction spots; not calcareous; contain 1–2% irregularly shaped dolomite nodules (cornstones).
Upper unit of Hueco Formation (Permian)	
4,427–4,428	*Sandstones*; grayish red (10R4/2) when dry, dark reddish brown (10R3/4) when wet; coarse to very coarse grained, conglomeratic; arkosic, not calcareous. Internally structureless, irregular, erosional lower contact; no visual porosity; poor reservoir quality.
4,428–4,429.8	*Mudstones*; grayish red (10R4/2) to very dusky red (10R2/2) when dry, grayish red (5R4/2) to blackish red (5R2/2) when wet; silty, sandy; micaceous, not calcareous; contain polygonal mudcracks; gradational lower contact.
4,429.8–4,433	*Sandstones*; very light gray (N8) when dry, medium light gray (N6) when wet in upper 0.5 ft; grade downward to red sandstones, grayish red (5R4/2) when dry, dark reddish brown (10R3/4) when wet; medium to very coarse grained, fine upward; arkosic; crudely crossbedded in lower part; no visual porosity; poor reservoir quality.
Strawn Series (Pennsylvanian)	
6,971–6,973.2	*Mudstones*; 90% olive gray (5Y4/1) with 10% grayish-black (N2) laminations; laminations are undulatory; contain a few thin carbonaceous wisps and streaks 1–2 mm thick; sharp lower contact.
6,973.2–6,978	*Sandstones*; light gray (N7); medium to coarse grained, moderately to well sorted; consist mostly of quartz and trace amounts of altered feldspars; contain 10–20% white clay matrix (may be authigenic alteration product of feldspars); contain nodules up to 4 cm in diameter of pyrite-cemented sandstone; trace amounts of gravel-size intraclasts of black carbonaceous mudstone; rippled and flaser bedded; soft-sediment deformation has contorted sedimentary structures in places; no visual porosity; impermeable, will not absorb water sprayed on core; poor reservoir quality. Contain discontinuous laminations of black carbonaceous mudstone mostly as clay drapes over ripples.

TABLE B4—Core description, CO_2-in-Action No. 1 J. L. Hicks, located 990 ft FNL, 990 ft FEL, sec. 19 T9N R24E, Guadalupe County. Elevation 4,926 ft, ground level. Total depth 7,274 ft in Pennsylvanian. Completed 8/28/84. Dry and abandoned. Oil show reported in cored interval.

Depth interval (ft)	Description
Strawn Series (Pennsylvanian)	
6,399–6,403.1	*Mudstones*; grayish black (N2) when dry, black (N1) when wet; contain 5% horizontal, wavy to planar and occasionally rippled, silt laminations; minor closed vertical fractures. Gradational lower contact.
6,403.1–6,406.8	*Sandstones*; dark gray (N3) when dry, grayish black (N2) when wet; fine to coarse grained, conglomeratic; arkosic, contain squashed rock fragments of black mudstone; crude, horizontal wavy lamination; no visual porosity; poor reservoir quality.
6,406.8–6,414	Unit has gradational lower contact. *Sandstones* (40%); light gray (N7) when dry, olive gray (5Y4/1) when wet; medium grained, moderately to well sorted; high-angle crossbeds and faint, horizontal wavy laminations; beds 0.3–1.4 ft thick. Fractured; tight, impermeable matrix; poor to moderate reservoir quality. *Shaly sandstones* (60%); fine to medium grained, composed of interlaminated sandstones and dark-gray mudstones; wavy laminated and cross-laminated; beds 0.4–0.7 ft thick; soft-sediment faults.
6,414–6,419.5	*Mudstones*; interlaminated grayish black (N2) and olive gray (5Y4/1); contain 5% wavy silt laminations, tr% fossils (disarticulated crinoids and brachiopods); sparsely to moderately bioturbated. Sharp, burrowed lower contact.

TABLE B4 (continued)

Depth interval (ft)	Description
6,419.5–6,422.7	*Sandstones*; medium gray (N5) when dry, medium dark gray (N4) when wet; medium to very coarse grained, conglomeratic, poorly sorted; arkosic; crude high-angle cross-stratification, possibly trough shaped. Scoured lower contact; tr% visual matrix porosity; vertical to subvertical fractures; moderate reservoir quality.
6,422.7–6,431.3	Unit has sharp, conformable lower contact. *Mudstones* (90%); grayish black (N2) when dry, laminated dark gray (N3) and olive gray (5Y4/1) when wet; sparsely bioturbated. *Sandstones* (10%); fine grained, silty; arkosic; cross-laminated, wavy and hummocky laminated; beds less than 0.2 ft thick.
6,431.3–6,432	*Sandstones*; pinkish gray (5YR8/1) when dry, olive gray (5Y4/1) when wet; medium to very coarse grained, moderately sorted; arkosic. High-angle cross-lamination. Vertical-escape burrow extends upward to top of unit; lower contact missing; tr% visual porosity; moderate reservoir quality.
6,432–6,435.9	*Mudstones*; laminated olive gray (5Y5/1) and dark greenish gray (5GY4/1) when wet; black (N1) mud chips in upper 1 ft; moderately bioturbated. Gradational lower contact.
6,435.9–6,436.4	*Sandstones*; light gray (N7) when dry, olive gray (5Y4/1) when wet; medium to very coarse grained, moderately sorted; arkosic; contain 5% dark-gray siliciclastic mudstone as horizontal laminations; no visual porosity; poor reservoir quality.

TABLE B5—Core description, Gila Exploration No. 1 Latigo Ranch D, located 660 ft FNL, 1,312 ft FEL, sec. 26 T10N R23E, Guadalupe County. Elevation 4,810 ft, ground level. Total depth 7,836 ft in Pennsylvanian. Completed 2/6/84. Perforated 7,395–7,414 ft in Strawn Series (Pennsylvanian), acidized and artificially fractured; no production established.

Depth interval (ft)	Description
Lower unit of Canyon Series (Pennsylvanian)	
6,665–6,682.7	*Sandstones*; white (N9) to medium dark gray (N4) when dry, light gray (N7) to greenish gray (5GY5/1) to dark gray (N3) when wet; fine to very coarse grained, conglomeratic, moderately sorted; arkosic, feldspars are soft and altered to clays, form ductile framework grains; contain squashed intraclasts of siliciclastic mudstone; horizontally laminated to low-angle cross-laminated; most laminations 0.1–0.5 ft thick. Erosional scoured base with a lag conglomerate; no visual porosity; poor reservoir quality.
6,682.7–6,691	*Mudstones*; dark gray (N3) when dry, grayish black (N2) when wet; grade upward into well-sorted, very fine to fine-grained sandstones, light gray (N7) when dry, greenish gray (5GY5/1) when wet. Lower muddy part not calcareous, contains brachiopods and fragments of crinoids and other shell debris. Thinly laminated and sparsely bioturbated throughout; laminations formed by alternating sand- and mud-rich layers; burrows are horizontal.
6,779–6,788	*Sandstones*; very light gray (N8) when dry, light gray (N7) when wet; very fine to very coarse grained, conglomeratic, poorly sorted; 10% of unit consists of very fine to fine-grained sandstones in beds 0.4–0.7 ft thick; contain gravel clasts of quartz, feldspar, and granite up to 2 cm in diameter; not calcareous; sedimentary structures are crude horizontal laminations and low-angle cross-laminations; some scour surfaces internal to beds; no visual porosity, but unit slowly absorbs water sprayed on surface of core; poor reservoir quality.
Strawn Series (Pennsylvanian)	
7,159–7,161.4	*Sandstones*; very light gray (N8) when dry, medium gray (N5) when wet; medium to very coarse grained, conglomeratic, poorly sorted; consist mostly of lithoclasts of granite and trace amounts of intraclasts of dark-gray siliciclastic mudstone; no visible internal structure, scoured lower contact; no visual porosity, unit slowly absorbs water sprayed on surface of core; poor reservoir quality.
7,161.4–7,169	*Sandstones* (70%); very light gray (N8) when dry, medium gray (N5) when wet; medium to very coarse grained, moderately to well sorted; arkosic; beds 0.1–0.7 ft thick; beds are structureless or have low-angle cross-laminations; contacts with interbedded mudstones are gradational, occasionally mottled; no visual porosity; poor reservoir quality. *Mudstones* (30%); dark gray (N3) when dry, grayish black (N2) when wet; beds 0.1–0.7 ft thick, contain horizontal planar and wavy laminae of silt and fine sand.
7,169–7,182.7	*Mudstones*; medium dark gray (N3) when dry, black (N1) when wet; mostly structureless but contain a few silty laminations. Abundant phylloid algae and some crinoid debris below 7,179 ft, not calcareous; mottled below 7,179 ft. Gradational lower contact.
7,182.7–7,187.6	*Limestones*; medium light gray (N6) to medium gray (N5) when dry, medium gray (N5) to grayish black (N2) when wet; argillaceous, contain thin discontinuous laminations of siliciclastic mudstone; contain abundant fragments of crinoids, brachiopods, fusulinids, and phylloid algae; gradational lower contact; no visual porosity, poor reservoir quality.
7,187.6–7,192.3	*Mudstones*; medium gray (N4 1/2) when dry, olive black (5Y2/1) when wet; not calcareous, contain trace amounts of fine to medium sand-size, calcareous fossil fragments. Gradational and mottled lower contact.
7,192.3–7,197.7	*Sandstones*; light gray (N7) to medium gray (N5) when dry, medium dark gray (N4) to olive gray (5Y4/1) when wet; very fine to coarse grained, silty, moderately to well sorted; planar laminated; laminations 0.2–0.6 ft thick, defined by alternating layers of fine sands and medium to coarse sands; slightly bioturbated. Sharp lower contact; no visual porosity, poor reservoir quality.
7,197.7–7,209	*Mudstones*; medium dark gray (N3) when dry, grayish black (N2) when wet; contain gravel-size clasts of light-gray microcrystalline limestone as large as 10 cm in diameter below 7,203 ft; contain brachiopods and sand-size fossil fragments of undetermined phyla.
7,272–7,278	*Sandstones*; medium light gray (N5) when dry, light gray (N7) to dark gray (N3) when wet; medium to very coarse grained, moderately sorted; quartzose, intergranular calcite cement; contain 10% calcareous fossil fragments (mostly crinoids, some brachiopods, bryozoans, and coralline algae); contain 0–10% sand-size clasts of dark-gray siliciclastic mudstone; upper 3 ft contain 10% thin wavy laminations of sandy limestone 1–2 cm thick; gradational lower contact; no visual porosity, sparse microfractures; poor reservoir quality.
7,278–7,284.2	*Sandstones*; light gray (N7) when dry, medium dark gray (N4) when wet; medium to very coarse grained, moderately sorted; consist of quartz, feldspar, and granite rock fragments, feldspars partially altered to clays; contains tr% calcareous fossil fragments (mostly crinoids). Faint horizontal laminations defined by fossil content. Sharp, apparently nonerosional lower contact; tr% visual porosity, uncemented horizontal to subvertical fractures; moderate reservoir quality.
7,284.2–7,287.6	*Limestones*; medium dark gray (N4) when dry, dark gray (N3) to medium dark gray (N4) when wet; bioclastic wackestones to packstones, consist of fragments of crinoids, brachiopods, foraminifers, and bryozoans in a lime-mud matrix; contain tr% fine- to medium-grained quartz sands and tr% wood fragments and other organic detritus. Irregular clay and organic-rich laminations less than 2 mm thick. Sharp lower contact; no visual porosity; poor reservoir quality.
7,287.6–7,299.3	*Sandstones*; medium dark gray (N4) when dry, dark gray (N3) to grayish black (N2) when wet; fine to very coarse grained, poorly sorted; arkosic, contain 0–20% rock fragments of gray siliciclastic mudstone, tr% fossil fragments (crinoids, brachiopods), contain intergranular calcite cement; contain sparse, wavy clay laminae 1–3 mm thick; below 7296.3 ft, consist of 10–20% horizontal to subhorizontal burrows filled with carbonate shell debris; gradational lower contact; no visual intergranular porosity; open vertical to horizontal fractures 1–2 mm wide; good reservoir quality.

TABLE B5 (continued)

Depth interval (ft)	Description
7,299.3–7,309	*Limestones* (60%); medium dark gray (N4) when dry, grayish black (N2) when wet; bioclastic packstones, contain abundant fragments of brachiopods and crinoids and lesser amount of bryozoan fragments; contain tr% quartz sands. Individual limestone beds grade downward into fossiliferous sandy limestones; beds 0.4–1.6 ft thick; 5% of limestones consist of horizontal to subhorizontal burrows filled with carbonate shell debris. Gradational contacts with interbedded mudstones; below 7,307 ft, individual limestone beds grade downward into fossiliferous fine- to medium-grained sandstones. *Mudstones* (40%); dark gray (N3) when dry, brownish black (5YR2/1) when wet; fissile; beds 0.01–2 ft thick, very finely laminated. Gradational contacts with interbedded limestones.
7,309.5–7,313.9	*Mudstones*; olive gray (5Y4/1) when dry, olive gray (5Y4/1) when wet; not calcareous; bioturbated; contain jagged, irregular branching veinlets of dark-gray mudstone (root traces?). Gradational lower contact.
7,313.9–7,316.3	*Sandstones*; pale yellowish brown (10YR6/2) when dry, brownish gray (5YR4/1) when wet; fine to medium grained, well sorted; quartzose; crude planar to wavy parallel laminations; gradational lower contact; tr% visual porosity; moderate reservoir quality.
7,316.3–7,320	*Sandstones*; dark gray (N3) when dry, dark gray (N3) to grayish black (N2) when wet; fine to very coarse grained, argillaceous, poorly sorted; consist of 10–20% clasts of medium- to dark-gray siliciclastic mudstone; contain irregular horizontal clay laminations less than 2 mm thick; no visual porosity; poor reservoir quality.

APPENDIX C—Descriptions of drill cuttings from the Pennsylvanian and Lower Permian sections of ten selected wells. Descriptions for each well are presented as a separate table. Stratigraphic data for each well appear in App. A.

Drill cuttings were described and analyzed with a binocular microscope. Cuttings of most wells were available in 10 ft intervals. It was found that descriptions could generally be grouped into lithologic units. Each unit was described by the depth interval in which the unit occurs. Rock color was described using the GSA Rock Color Chart (Goddard et al., 1980).

Many sandstones are disaggregated into individual sand grains in the drill cuttings. This disaggregation indicates relatively poor induration and is generally regarded to indicate relatively well-developed porosity. However, some nonporous sandstones may have been disaggregated into individual sand grains by the drill bit (see Graves, 1986).

TABLE C1—Drill-cuttings descriptions, Shell Oil Company No. 1 Stephenson, located 1,650 ft FSL, 1,650 ft FWL, sec. 2 T3N R32E, Curry County. Elevation 4,568 ft, ground level. Total depth 7,012 ft in Precambrian. Completed 1/22/64. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Abo Formation (Permian)	
Top of Abo Formation at 5,223 ft	
5,900–6,000	Mudstones and thinly interbedded sandstones, traces of dolostones and anhydrites. *Mudstones* (90%); pale reddish brown (10R5/4) to dusky red (10R3/2) when dry, moderate reddish orange (10R6/6) to grayish red (10R4/2) when wet; fissile, silty, generally not calcareous; some contain rectangular, "stairstep" molds of anhydrite nodules. *Mudstones* (10%); very light gray (N8) to medium dark gray (N4) when dry, medium gray (N5) to dark gray (N3) when wet; fissile, silty, micaceous; generally not calcareous. *Sandstones*; white (N9) to pale reddish brown (10R5/4) when dry, light gray (N8) to moderate reddish brown (10R4/6) when wet; very fine to medium grained, silty, arkosic, slightly calcareous, traces of clay cement; 0–tr% visual porosity. *Dolostones*; olive gray (5Y4/1) when wet; consist of spherical grains 0.1 mm in diameter that appear to be dolomitized oolites. *Anhydrites*; mostly cavings from Yeso Formation, but some appear to be diagenetic nodules in mudstones.
Top of upper unit of Hueco Formation (Permian) at 5,995 ft	
6,000–6,370	Interbedded limestones and mudstones, minor sandstones. *Limestones*; very light gray (N8) to light olive gray (5Y6/1) to brownish gray (5YR3/1) when wet; lime mudstones and bioclastic wackestones and packstones, variously contain fusulinids, brachiopods, and crinoid debris; no visual porosity. *Mudstones*; mostly red, some are gray. *Sandstones*; occur in lower 100 ft, thinly bedded; orange, fine to very fine grained; no visual porosity.
Top of lower unit of Hueco Formation (Permian) at 6,372 ft	
6,370–6,510	Interbedded limestones, mudstones, minor thinly bedded sandstones; thinly bedded salts at 6,460 ft. *Limestones*; white (N9) to olive gray (5Y4/1) to very dusky red purple (5RP2/2) when wet; lime mudstones and bioclastic wackestones; bioclasts are fusulinids, coralline algae, and brachiopods; some limestones consist of up to 30% clasts of gray siliciclastic mudstone; a few thin limestone beds consist of fragments of limestone in a matrix of red siliciclastic mudstone; no visual porosity. *Mudstones*; mostly red, some are gray. *Sandstones*; moderate reddish orange (10R6/6) to pale reddish brown (10R5/4) when dry, moderate reddish brown (10R4/6) when wet; fine to very fine grained, silty; 0–tr% visual porosity.
6,510–6,710	Interbedded dolostones and mudstones. *Dolostones*; very light gray (N8) to olive gray (5Y4/1) when wet; fine to very coarsely crystalline; finely crystalline dolostones have 0–tr% visual intercrystal porosity; coarsely crystalline dolostones have 0–20% visual intercrystal and vuggy porosity. *Mudstones*; mostly red, some are gray.
6,710–6,780	Interbedded limestones and mudstones. *Limestones*; white (N9) to light gray (N7) when dry, white (N9) to yellowish gray (5Y8/1) when wet; lime mudstones and bioclastic wackestones; 0–1% visual porosity. *Mudstones*; gray to red, calcareous, silty.
Top of upper unit of Canyon Series (Pennsylvanian) at 6,783 ft	
6,780–6,840	Interbedded limestones, dolostones, and mudstones. *Limestones*; white (N9) to light gray (N7) when dry, white (N9) to yellowish gray (5Y8/1) when wet; lime mudstones and bioclastic wackestones; bioclasts are bryozoans and foraminifers; no visual porosity. *Dolostones*; white (N9) to very light gray (N8) when wet; macrocrystalline; tr% vuggy visual porosity. *Mudstones*; gray to red; some contain chickenwire anhydrite nodules.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,842 ft	
6,840–6,900	Interbedded limestones and mudstones. *Limestones*; light gray, lime mudstones, bioclastic wackestones, oolitic grainstones; 0–tr% visual porosity. *Mudstones*; gray to red.
Top of Precambrian at 6,900 ft	
6,900–7,012	*Granite.*

TABLE C2—Drill-cuttings descriptions, Cities Service No. 1 Widner, located 660 ft FSL, 660 ft FWL, sec. 17 T4N R31E, Curry County. Elevation 4,557 ft, ground level. Total depth 7,348 ft in Strawn (Pennsylvanian). Completed 4/26/54. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Abo Formation (Permian)	
Top of Abo Formation at 4,992 ft	
5,500–5,840	Interbedded mudstones and minor anhydrites, traces of sandstones and salts. *Mudstones* (90%); pale reddish brown (10R5/4) when dry, pale reddish brown (10R5/4) when wet; slightly calcareous, anhydritic. *Mudstones* (10%); light bluish gray (5B7/1) when dry, medium dark gray (N4) when wet; silty, not calcareous. *Anhydrites*; white (N9) to very light gray (N8), micro- to macrocrystalline; some are dolomitic; nondolomitic anhydrites have 0–10% vuggy visual porosity. Some anhydrites are nodular. *Sandstones*; orange, very fine grained, silty; no visual porosity. *Salts*; occur as thin beds.

TABLE C2 (continued)

Depth interval (ft)	Description
Top of upper unit of Hueco Formation (Permian) at 5,842 ft	
5,840–6,280	Interbedded limestones, mudstones, and minor sandstones. *Limestones;* very light gray (N8) to medium gray (N5) when dry, very light gray (N8) to medium light gray (N6) to yellowish gray (5Y8/1) to bluish white (5B9/1) when wet; bioclastic wackestones and packstones; bioclasts are fusulinids, bryozoans, and foraminifers; no visual porosity. *Mudstones* (10%); medium gray (N5) to medium dark gray (N4) when dry, medium dark gray (N4) when wet; generally calcareous, fossiliferous. *Mudstones* (90%); dark reddish brown (10R3/4) when dry, reddish orange (10R5/6) when wet; silty, calcareous to noncalcareous. *Sandstones;* orange, fine to very fine grained, argillaceous, some are calcareously cemented; 0–tr% visual intergranular porosity.
Top of lower unit of Hueco Formation (Permian) at 6,278 ft	
6,280–6,720	Interbedded limestones, mudstones, and minor sandstones. *Limestones;* white (N9) to yellowish gray (5Y8/1) to medium gray (N5) when dry, white (N9) to yellowish gray (5Y8/1) to light olive gray (5Y6/1) when wet; lime mudstones and bioclastic wackestones and packstones; bioclasts are brachiopods, foraminifers, and fusulinids; some limestones contain sand-size clasts of gray siliciclastic mudstone; no visual porosity. *Mudstones;* mostly red, some are gray. *Sandstones;* orange to gray, very fine to very coarse grained, moderately to well sorted; red sandstones are argillaceous, gray sandstones have calcite cement; 0–tr% porosity in fine-grained sandstones; coarse-grained sandstones are disaggregated into individual sand grains and appear to have well-developed porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 6,722 ft	
6,720–6,800	Interbedded limestones, mudstones, and minor sandstones. *Sandstones;* fine to very coarse grained, arkosic, poorly sorted; no visual porosity.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,796 ft	
6,800–7,150	Interbedded limestones and mudstones. *Limestones;* light gray, bioclastic wackestones, packstones, and grainstones; bioclasts are crinoids, bryozoans, and foraminifers; no visual porosity. *Mudstones;* gray to red; some are fossiliferous.
Top of Strawn Series (Pennsylvanian) at 7,150 ft	
7,150–7,348	Interbedded limestones, mudstones, and minor sandstones. *Limestones;* light gray (N7) to black (N1) and mottled light gray (N7) and dark gray (N3) when wet; bioclastic wackestones and packstones; bioclasts are fusulinids, foraminifers, and crinoids; no visual porosity. *Mudstones;* gray to red. *Sandstones;* red, very fine to very coarse grained, conglomeratic, arkosic; well compacted; 0–tr% visual porosity.

TABLE C3—Drill-cuttings descriptions, Abercrombie & Hawkins No. 1 Nappier, located 1,980 ft FSL, 1,980 ft FWL, sec. 22 T5N R26E, De Baca County. Elevation 4,507 ft, ground level. Total depth 7,149 ft in Precambrian. Completed 10/4/49. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Yeso Formation (Permian)	
3,800–4,000	Interbedded mudstones, sandstones, and anhydrites. *Mudstones* (80%); pale red (10R6/2) to moderate reddish brown (10R4/6) when wet; silty, anhydritic; contain salt casts. *Mudstones* (20%); light bluish gray (5B7/1) to dark gray (N3) when wet; silty, calcareous, anhydritic. *Sandstones;* moderate reddish orange (10R6/6) to pinkish gray (5YR8/1) when wet; argillaceous, anhydrite cement; 0–tr% visual porosity. *Anhydrites;* white (N9) to olive gray (5Y5/1) when wet; microcrystalline, argillaceous, nodular.
Top of Abo Formation (Permian) at 3,998 ft	
4,000–4,650	Interbedded sandstones and mudstones, minor salts. *Sandstones;* moderate reddish orange (10R6/6) to white (N9) when wet; very fine to medium grained, moderately to well sorted, argillaceous, calcareous; 0–tr% visual porosity. *Mudstones;* moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) when wet; silty, sandy, anhydritic; contain salt casts. *Mudstones* (20%); light bluish gray (5B7/1) to medium dark gray (N4) when wet; silty, anhydritic. *Salts;* thinly bedded.
4,650–4,720	*Mudstones;* moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) when wet; silty; contain salt casts.
4,720–4,920	Interbedded mudstones and sandstones. *Mudstones* moderate reddish brown (10R4/6) when wet; silty, sandy, calcareous. *Sandstones;* moderate reddish brown (10R4/6) to very light gray (N8) when wet; fine to very fine grained, well sorted; carbonate and anhydrite cement; 0–tr% visual porosity.
4,920–5,120	Interbedded mudstones and minor sandstones. *Mudstones;* mostly red, some are gray. *Sandstones;* moderate reddish brown (10R4/6) to very light gray (N8) when wet; fine to very fine grained, anhydritic, calcareous; 0–tr% visual porosity.
Top of upper unit of Hueco Formation (Permian) at 5,120 ft	
5,120–5,540	Interbedded limestones, mudstones, and sandstones. *Limestones;* light gray (N7) to dark gray (N3) when wet; lime mudstones and bioclastic wackestones; bioclasts are brachiopods, crinoids, and fusulinids; no visual porosity. *Mudstones* (80%); moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) mottled with grayish orange pink (10R8/2) when wet; silty, calcareous, some anhydritic. *Mudstones* (20%); light gray (N7) to dark gray (N3) when wet; silty, calcareous; contain abundant wood fragments. *Sandstones;* moderate reddish brown (10R4/6) to moderate reddish orange (10R6/6) when wet; very fine to very coarse grained, conglomeratic, poorly to well sorted; anhydritic, calcite and hematite cement; 0–tr% visual intergranular porosity.
Top of lower unit of Hueco Formation (Permian) at 5,540 ft	
5,540–6,000	Interbedded limestones and mudstones, minor sandstones. *Limestones;* light gray (N7) to dark gray (N3) when dry, light gray (N7) to olive gray (5Y5/1) to brownish gray (5YR4/1) when wet; lime mudstones and bioclastic wackestones; no visual porosity.

TABLE C3 (continued)

Depth interval (ft)	Description
	Mudstones (70%); grayish red (10R4/2) to dark reddish brown (10R3/4) when dry, moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) when wet; silty, calcareous, burrowed; contain chickenwire anhydrite nodules. *Mudstones* (30%); dark gray (N3) when dry, medium gray (N5) to light olive gray (5Y6/1) when wet; silty, calcareous. *Sandstones*; red, very fine to coarse grained, conglomeratic, argillaceous, poorly to well sorted; some calcareous; consist of quartz, feldspar, and fragments of siliciclastic mudstone; 0–tr% visual intergranular porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 6,000 ft	
6,000–6,120	Interbedded limestones and mudstones, minor coal. *Limestones*; light olive gray (5Y6/1) when wet; lime mudstones and bioclastic wackestones and packstones; bioclasts are crinoids and bryozoans; no visual porosity. *Mudstones* (70%); light gray (N7) to medium dark gray (N4) when wet; silty, calcareous, pyritic. *Mudstones* (30%); moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) when wet; silty, calcareous, mottled. *Coal*; a thin bed between 6,030 and 6,040 ft.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,120 ft	
6,120–6,490	Interbedded limestones and mudstones, minor sandstones and coal. *Sandstones*; very light gray (N8) when wet; fine to coarse grained, moderately to well sorted, arkosic; calcite cement; no visual porosity. *Coal*; a thin bed between 6,290 and 6,300 ft. *Limestones*; bioclastic–pelletal wackestones and bioclastic–oolitic grainstones.
Top of Strawn Series (Pennsylvanian) at 6,490 ft	
Top of Atokan Series (Pennsylvanian) at 6,942 ft	
6,490–7,050	Interbedded limestones and mudstones, minor sandstones and coals. *Limestones*; light olive gray (5Y6/1) to brownish gray (5YR4/1) to dark gray (N3) when wet; lime mudstones, bioclastic wackestones and packstones, and oolitic grainstones; 0–5% visual porosity. *Mudstones*; mostly gray; some are red. *Sandstones*; white (N9) to very light gray (N8) when dry, very light gray (N8) when wet; fine to coarse grained, moderately to well sorted, calcite cement; 0–tr% visual intergranular porosity. *Coals*; thin beds between 6,910 and 6,930 ft, 6,950 and 6,960 ft, 6,990 and 7,000 ft, and 7,020 and 7,030 ft.
Top of Arroyo Peñasco Formation (Mississippian) at 7,048 ft	
7,050–7,110	Interbedded limestones and mudstones. *Limestones*; yellowish gray (5Y8/1) to light olive gray (5Y6/1) when wet; peloidal oolitic grainstones and packstones; tr% visual porosity.
Top of Precambrian at 7,115 ft	
7,110–7,149	*Granite*.

TABLE C4—Drill-cuttings descriptions, Texas Gulf Producing Company No. 1 Garrett, located 1,980 ft FSL, 1,980 ft FEL, sec. 34 T5N R34E, Curry County. Elevation 4,568 ft, ground level. Total depth 7,538 ft in Precambrian. Completed 12/14/62. Dry and abandoned.

Depth interval (ft)	Description
Description starts in upper unit of Hueco Formation (Permian)	
Top of upper unit of Hueco Formation at 6,257 ft	
6,500–6,610	Interbedded limestones and mudstones. *Limestones*; yellowish gray (5Y8/1) to medium dark gray (N4) to brownish gray (5YR4/1) when wet; intraclastic, bioclastic wackestones and packstones; intraclasts are dark-gray siliciclastic mudstone; bioclasts are bryozoans, crinoids, and coralline algae; no visual porosity. *Mudstones* (90%); grayish red (5R4/2) when dry, moderate reddish brown (10R4/6) when wet; silty, sandy. *Mudstones* (10%); medium gray (N5) when dry, light gray (N7) to medium gray (N5) when wet; silty, pyritic, calcareous.
Top of lower unit of Hueco Formation (Permian) at 6,612 ft	
6,610–6,770	Interbedded limestones and mudstones.
6,770–7,100	Interbedded dolostones and mudstones, minor limestones. *Dolostones*; light gray (N7) to brownish black (5YR3/1) when dry, very light gray (N8) to brownish gray (5YR5/1) when wet; compact to sucrosic microcrystalline texture; generally have ghosts of depositional bioclastic textures; 2–7% visual porosity. *Mudstones*; gray to red; gray mudstones contain fragments of crinoids. *Limestones*; light gray (N7) to medium dark gray (N4) when dry, light olive gray (5Y6/1) to brownish black (5YR2/1) to grayish black (N2) when wet; lime mudstones and bioclastic wackestones, packstones, and grainstones; no visual porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 7,105 ft	
7,100–7,140	Interbedded dolostones and mudstones, minor limestones. *Dolostones*; compact crystalline, no visual porosity. *Mudstones*; mostly red, some are gray. *Limestones*; lime mudstones and bioclastic wackestones.
Top of Precambrian at 7,140 ft	
7,140–7,300	*Granite*.

TABLE C5—Drill-cuttings descriptions, Exxon Corporation No. 1 Evelyn G. Brown, located 990 ft FSL, 990 ft FEL, sec. 35 T6N R34E, Curry County. Elevation 4,423 ft, ground level. Total depth 7,067 ft in Precambrian. Completed 11/3/74. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Abo Formation (Permian)	
Top of Abo Formation at 5,146 ft	
5,500–5,600	Interbedded mudstones and sandstones, minor anhydrites. *Mudstones*; moderate reddish brown (10R4/6) to grayish red (10R5/2) when dry; silty, sandy, micaceous. *Sandstones*; pale reddish brown (10R5/4) when dry; fine to very fine grained, argillaceous, arkosic, pyritic; tr–10% visual intergranular porosity.

TABLE C5 (continued)

Depth interval (ft)	Description
5,600–6,500	No cuttings.
Top of upper unit of Hueco Formation (Permian) at 5,981 ft	
Top of lower unit of Hueco Formation (Permian) at 6,342 ft	
6,500–6,570	Interbedded sandstones and mudstones, minor limestones. *Sandstones;* fine to very coarse grained, silty, argillaceous, arkosic; mostly disaggregated into individual sand grains, indicating well-developed porosity. *Limestones;* light olive gray (5Y6/1) when wet; bioclastic grainstones; no visual porosity.
6,570–6,700	Interbedded dolostones and mudstones. *Dolostones;* light gray (N7) when dry, very light gray (N8) when wet; microcrystalline; 0–tr% visual porosity. *Mudstones* (90%); pale reddish brown (10R5/4) to moderate reddish brown (10R4/6) when wet; silty, calcareous. *Mudstones* (10%); dark gray (N3) to grayish black (N2) when dry, light olive gray (5Y6/1) to medium dark gray (N4) when wet; silty; contain wood fragments.
6,700–6,900	Interbedded limestones and mudstones. *Limestones;* olive gray (5Y6/1) to medium dark gray (N4) when dry, yellowish gray (5YR8/1) to olive gray (5Y4/1) to brownish gray (5YR3/1) when wet; lime mudstones and bioclastic wackestones; no visual porosity. *Mudstones* (50%); dark reddish brown (10R3/4) when dry, moderate reddish brown (10R4/6) when wet; silty, calcareous. *Mudstones* (50%); dark gray (N3) to grayish black (N2) when dry, light olive gray (5Y6/1) to medium dark gray (N4) when wet; silty, calcareous; contain wood fragments.
Top of upper unit of Canyon Series (Pennsylvanian) at 6,902 ft	
6,900–7,030	Interbedded mudstones and limestones, minor sandstones. *Limestones;* light gray (N7) to olive gray (5Y4/1) when wet; bioclastic wackestones and grainstones; bioclasts are fusulinids, bryozoans, crinoids, and brachiopods. *Sandstones;* clear to light gray, fine to very coarse grained, poorly to moderately sorted; mostly disaggregated into individual sand grains, indicating well-developed porosity.
Top of Precambrian at 7,030 ft	
7,030–7,070	*Granite.* Cuttings badly caved.

TABLE C6—Drill-cuttings descriptions, Husky Oil Company & General Crude Oil Company No. 1 Hanchett State, located 2,310 ft FSL and 330 ft FWL, sec. 16 T8N R24E, Guadalupe County. Elevation 5,013 ft, ground level. Total depth 7,244 ft in Precambrian. Completed 3/29/56. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Abo Formation (Permian)	
Top of Abo Formation at 3,497 ft	
4,300–4,640	Interbedded mudstones and minor sandstones. *Mudstones;* reddish brown (10R4/4) to dusky red (10R3/2) when dry, moderate reddish brown (10R4/6) to reddish orange (10R5/6) when wet; silty, micaceous, calcareous. *Sandstones;* pale reddish brown (10R5/4) when dry, moderate reddish brown (10R4/6) when wet; very fine to very coarse grained, poorly to moderately sorted, argillaceous, micaceous, arkosic, calcareous; no visual porosity.
Top of upper unit of Hueco Formation (Permian) at 4,639 ft	
4,640–5,050	Interbedded mudstones and sandstones. *Mudstones* (90%); grayish red (5R4/2) to reddish brown (10R4/4) when dry, grayish red (10R4/2) to moderate reddish brown (10R4/6) when wet; silty, calcareous. *Mudstones* (10%); medium light gray (N6) to medium dark gray (N4) when dry, medium gray (N5) when wet; silty, calcareous, laminated. *Sandstones;* very fine to very coarse grained, conglomeratic, arkosic; tr% visual intergranular porosity.
Top of lower unit of Hueco Formation (Permian) at 5,050 ft	
5,050–5,500	Interbedded mudstones and sandstones, minor limestones and dolostones. *Mudstones;* red (50%) and gray (50%); calcareous. *Sandstones;* fine to very coarse grained, conglomeratic, poorly to moderately sorted, arkosic; mostly disaggregated into individual sand grains, indicating well-developed porosity. *Limestones;* medium dark gray (N4) when dry, olive gray (5Y4/1) to olive black (5Y2/1) when wet; argillaceous, pyritic lime mudstones and bioclastic packstones; bioclasts are fusulinids, bryozoans, and brachiopods; no visual porosity. *Dolostones;* brownish gray (5YR4/1) to olive gray (5Y4/1) when dry, brownish gray (5YR4/1) when wet; finely microcrystalline; no visual porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 5,504 ft	
5,500–6,140	Interbedded mudstones, sandstones, and limestones, minor coals. *Mudstones* (50%); grayish red (5R4/2) to dark reddish brown (10R3/4) when dry, moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) when wet; silty. *Mudstones* (50%); medium gray (N5) to dark gray (N3) when dry, greenish gray (5GY6/1) to medium dark gray (N4) to brownish gray (5YR4/1) when wet; silty, pyritic. *Sandstones;* white (N9) to medium light gray (N6), fine to very coarse grained, moderately sorted; uncemented to well cemented with calcite; well-cemented sandstones have 0–tr% visual intergranular porosity; poorly cemented sandstones are mostly disaggregated into individual sand grains, indicating well-developed porosity. *Limestones;* olive gray (5Y4/1) to medium gray (N5) when dry, light olive gray (5Y6/1) to brownish gray (5YR4/1) when wet; bryozoan–crinoidal–algal wackestones and packstones, algal–bryozoan–fusulinid wackestones and packstones, oolitic–algal–gastropodal packstones and grainstones; 0–tr% visual porosity. *Coals;* thin beds between 6,000 and 6,050 ft.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,145 ft	
6,140–6,580	Interbedded mudstones, sandstones, and limestones, minor coals. *Mudstones* (80%); medium dark gray (N4) to grayish black (N2) when dry, medium gray (N5) to dark gray (N3) when wet, mottled with red mudstone; silty, calcareous; some are laminated. *Mudstones* (20%); grayish red (10R4/2) to dark reddish brown (10R3/4) when dry, moderate reddish brown (10R4/6) to moderate red (5R4/6) when wet, mottled with gray mudstone; silty, sandy.

TABLE C6 (continued)

Depth interval (ft)	Description
	Sandstones; white (N9) to light gray (N7), fine to very coarse grained, poorly to moderately sorted; arkosic, calcite cement; no visual porosity. *Coals;* thin beds between 6,330 and 6,340 ft, 6,360 and 6,380 ft, 6,460 and 6,470 ft, 6,480 and 6,520 ft, and 6,560 and 6,570 ft.
Top of Strawn Series (Pennsylvanian) at 6,580 ft	
6,580–7,000	Interbedded mudstones, sandstones, and limestones. *Mudstones* (80%); medium gray (N5) to grayish black (N2) when dry, dark greenish gray (5G4/1) to grayish black (N2) when wet; silty; some contain brachiopods. *Mudstones* (20%); red. *Sandstones;* white (N9) to very light gray (N8) when dry, very light gray (N8) when wet; fine to very coarse grained, conglomeratic, poorly to well sorted; arkosic, calcite cement; 0–10% visual porosity. *Limestones;* medium gray (N5) to dark gray (N3) when dry, light brownish gray (5YR6/1) to black (N1) when wet; lime mudstones, brachiopodal–crinoidal wackestones, algal–crinoidal–fusulinid grainstones; no visual porosity.
Top of Precambrian at 7,009 ft	
7,000–7,220	*Granite.*

TABLE C7—Drill-cuttings descriptions, Stanolind No. 1 J. W. Fuller, located 660 ft FNL, 660 ft FEL, sec. 25 T8N R30E, Quay County. Elevation 4,459 ft. Total depth 6,747 ft in Precambrian. Completed 3/20/43. Dry and abandoned.

Depth interval (ft)	Description
Description starts in Abo Formation (Permian)	
Top of Abo Formation at 4,383 ft	
5,000–5,270	Interbedded sandstones and mudstones, minor anhydrites and salts. *Sandstones;* white (N9) to light red (5R6/6/) to grayish red (5R4/2) when dry, white (N9) to moderate red (5R4/6) to reddish brown (10R4/4) when wet; very fine to very coarse grained, poorly to moderately sorted, argillaceous; arkosic; 0–10% visual intergranular porosity. *Mudstones;* moderate reddish orange (10R6/6) to dusky red (10R3/2) when dry, red (5R5/6) to moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) when wet. *Anhydrites;* white to light gray; mostly diagenetic nodules, some are chickenwire nodules. *Salts;* occur as crystals; some thin salt beds may be present.
Top of upper unit of Hueco Formation (Permian) at 5,275 ft	
5,270–5,755	Interbedded mudstones and sandstones, minor anhydrites and salts. *Mudstones;* moderate reddish brown (10R4/6) to very dusky red (10R2/2) to grayish red (10R4/2) to medium gray (N5) when dry, moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) to light gray (N7) to dark gray (N3) when wet, mottled red and gray; silty, sandy; some are calcareous. *Sandstones;* fine to very coarse grained, conglomeratic; arkosic; generally disaggregated into individual sand grains, indicating well-developed porosity. *Anhydrites;* mostly chickenwire nodules. *Salts;* generally occur as individual crystals within the samples and may represent very thin beds or individual salt crystals; a fairly thick salt bed may be present between 5,315 and 5,320 ft.
Top of lower unit of Hueco Formation (Permian) at 5,753 ft	
5,755–6,010	Interbedded mudstones, sandstones, and dolostones. *Mudstones;* dark reddish brown (10R3/4) to grayish red (10R4/2) to light gray (N7) when dry; silty, sandy; some are calcareous. *Sandstones;* medium to very coarse grained; arkosic; generally disaggregated into individual grains, indicating well-developed porosity. *Dolostones;* white (N9) to light olive gray (5Y6/1) to brownish black (5YR3/1) when wet; compact microcrystalline; no visual porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 6,009 ft	
6,010–6,075	Interbedded sandstones, mudstones, minor dolostones. *Dolostones;* green, microcrystalline; no visual porosity.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,074 ft	
Top of Strawn Series (Pennsylvanian) at 6,280 ft	
6,075–6,730	Interbedded sandstones, dolostones, and mudstones. *Sandstones;* medium to very coarse grained, conglomeratic; arkosic; generally disaggregated into individual sand grains, indicating well-developed porosity; some sandstones are well indurated or cemented by dolomite and have no visual porosity. *Dolostones;* medium gray (N5) to dark gray (N3) to light brownish gray (5YR6/1) to light olive gray (5Y6/1) when dry, medium gray (N5) to olive gray (5Y4/1) to brownish gray (5YR3/1) when wet; compact microcrystalline; 0–tr% visual porosity. *Mudstones;* gray to red.
Top of Precambrian at 6,730 ft	
6,730–6,747	*Granite.*

TABLE C8—Drill-cuttings descriptions, Trans-Pecos Resources No. 1 Latigo Ranch A, located 1,980 ft FNL, 1,980 ft FEL, sec. 2 T9N R23E, Guadalupe County. Elevation 4,871 ft, ground level. Total depth 7,202 ft in Precambrian. Completed 7/9/82. Shut-in gas well.

Depth interval (ft)	Description
Description starts in Yeso Formation (Permian)	
3,100–3,120	Interbedded sandstones, mudstones, and anhydrites. *Sandstones;* pale reddish brown (10R5/4) when dry; very fine to medium grained, poorly to moderately sorted; no visual porosity. *Mudstones;* dusky red (10R2/2) to pale reddish brown (10R5/4) when dry; silty. *Anhydrites;* grayish orange pink (10R8/2) when dry.

TABLE C8 (continued)

Depth interval (ft)	Description
Top of Tubb sand zone of Yeso Formation (Permian) at 3,118 ft	
3,120–3,220	Sandstones, with minor interbedded mudstones. *Sandstones;* pale reddish brown (10R5/4) to moderate reddish orange (10R6/6) when dry; fine to very fine grained, well to very well sorted; generally disaggregated into individual sand grains, indicating well-developed porosity. *Mudstones;* dusky red (10R2/2) to pale reddish brown (10R5/4) when dry; silty. Mudstones between 3,140 and 3,150 ft are dark gray to black.
Top of Abo Formation (Permian) at 3,232 ft	
3,220–3,390	No cuttings.
3,390–4,450	Interbedded sandstones and mudstones. *Sandstones;* pale red (10R6/2) to grayish red (10R4/2) when dry, moderate reddish brown (10R4/6) to moderate reddish orange (10R6/6) when wet; fine to very coarse grained, many conglomeratic; arkosic; some are cemented by calcite or are argillaceous and have no visual porosity; others are poorly cemented and generally disaggregated into individual sand grains, indicating well-developed porosity. *Mudstones;* dark reddish brown (10R3/4) when dry, pale reddish brown (10R5/4) when wet; mottled with minor light-gray mudstone, silty, sandy.
Top of upper unit of Hueco Formation (Permian) at 4,455 ft	
4,450–4,860	Interbedded mudstones and sandstones. *Mudstones;* moderate reddish brown (10R4/6) to grayish red (10R4/2) to very light gray (N8) to light greenish gray (5G8/1) when wet; most are red; silty; gray mudstones are calcareous. *Sandstones;* fine to very coarse grained, conglomeratic, moderately to poorly sorted; generally disaggregated into individual sand grains, indicating well-developed porosity.
Top of lower unit of Hueco Formation (Permian) at 4,860 ft	
4,860–5,200	Interbedded mudstones and sandstones, minor dolostones. *Mudstones* (60%); grayish red (10R4/2) to dark reddish brown (10R3/4) when dry, moderate reddish orange (10R6/6) to dark reddish brown (10R3/4) when wet; some are calcareous. *Mudstones* (40%); light gray (N7) to grayish black (N2) when dry, light greenish gray (5GY8/1) to black (N1) when wet; silty; some are calcareous. *Sandstones;* fine to very coarse grained, moderately to well sorted; arkosic; generally disaggregated into individual sand grains, indicating well-developed porosity. *Dolostones;* medium light gray (N6) when dry, light olive gray (5Y6/1) when wet; compact microcrystalline; no visual porosity.
Top of upper unit of Canyon Series (Pennsylvanian) at 5,200 ft	
5,200–5,660	Interbedded dolostones, sandstones, and mudstones, minor limestones. *Dolostones;* light olive gray (5Y6/1) to medium dark gray (N4) when dry, light greenish gray (5GY8/1) to olive gray (5Y4/1) to yellowish brown (10YR6/2) when wet; compact microcrystalline to sucrosic; relict bioclastic wackestone and packstone textures; thinly interbedded with limestones from 5,420 to 5,520 ft; no visual porosity. *Sandstones;* pink to white, medium to very coarse grained, conglomeratic, moderately to poorly sorted; arkosic; generally disaggregated into individual sand grains, indicating well-developed porosity. *Mudstones* (50%); pale reddish brown (10R5/4) to grayish red (10R4/2) when dry, moderate reddish orange (10R6/6) to dark reddish brown (10R3/4) when wet; silty. *Mudstones* (50%); medium gray (N5) to dark gray (N3) when dry, medium dark gray (N4) to greenish gray (5GY6/1) when wet; silty, calcareous. Limestones are medium dark gray (N4) to dark gray (N3) when dry, pale brown (5YR5/2) to grayish brown (5YR3/2) when wet; lime mudstones and bioclastic wackestones and packstones; bioclasts are fusulinids, crinoids, brachiopods, and foraminifers; 0–tr% visual porosity.
Top of lower unit of Canyon Series (Pennsylvanian) at 5,658 ft	
5,660–6,170	Interbedded sandstones and mudstones, minor dolostones. *Sandstones;* white (N9) to light gray (N7) when dry, very light gray (N8) to medium light gray (N6) when wet; fine to very coarse grained, conglomeratic, poorly to well sorted; arkosic to quartzose; generally disaggregated into individual sand grains, indicating well-developed porosity. *Mudstones;* red and gray. *Dolostones;* olive gray (5Y4/1) when wet; compact microcrystalline; no visual porosity.
Top of Strawn Series (Pennsylvanian) at 6,175 ft	
6,170–7,130	Interbedded sandstones, dolostones, and mudstones, minor limestones *Sandstones;* very light gray (N8) to medium light gray (N6) when dry, fine to very coarse grained, conglomeratic, poorly to moderately sorted; quartzose; most are disaggregated into individual sand grains, indicating well-developed porosity; some are well compacted and well indurated and have no visual porosity. *Dolostones;* light olive gray (5Y6/1) to olive gray (5Y4/1) when dry, olive gray (5Y4/1) to brownish gray (5YR4/1) when wet; compact microcrystalline; 0–tr% visual porosity. *Mudstones* (70%); grayish red (5R4/2) to moderate reddish brown (10R4/6) when dry, blackish red (5R2/2) to dark reddish brown (10R3/4) to moderate reddish orange (10R5/6) when wet; silty, calcareous. *Mudstones* (30%); medium gray (N5) to dark gray (N3) when dry, olive gray (5Y5/1) to grayish black (N2) when wet; silty, calcareous; contain wood fragments. *Limestones;* very light gray (N8) to olive gray (5Y5/1) to pale yellowish brown (10YR6/2) when wet; lime mudstones and bioclastic wackestones and packstones; bioclasts are fusulinids, brachiopods, crinoids, bryozoans, and corals; no visual porosity.
Top of Precambrian at 7,136 ft	
7,130–7,180	*Granite.*

TABLE C9—Drill-cuttings descriptions, General Crude Oil Company No. 1 Simpson, located 660 ft FNL, 1,980 ft FEL, sec. 21 T10N R23E, Guadalupe County. Elevation 4,654 ft, ground level. Total depth 9,151 ft in Precambrian. Completed 7/31/55. Dry and abandoned.

Depth interval (ft)	Description
Description starts in upper unit of Canyon Series (Pennsylvanian)	
Top of upper unit of Canyon Series at 6,100 ft	
6,100–6,200	Interbedded sandstones, dolostones, and mudstones. *Sandstones;* fine to very coarse grained, conglomeratic, silty, argillaceous; arkosic; no visual porosity.

TABLE C9 (continued)

Depth interval (ft)	Description
	Dolostones; olive gray (5Y4/1) to olive black (5Y2/1) when wet; compact microcrystalline; 0–tr% visual porosity. *Mudstones*; red to gray, sandy; some contain crinoid columnals.
6,200–6,700	No cuttings.
6,700–6,800	Interbedded sandstones and mudstones. *Sandstones*; white (N9) to pinkish gray (5YR8/1) when dry, very light gray (N8) when wet; medium to very coarse grained, conglomeratic, poorly sorted; arkosic; tr% visual porosity.
6,800–6,900	No cuttings.
Top of lower unit of Canyon Series (Pennsylvanian) at 6,900 ft	
6,900–7,000	Interbedded sandstones, mudstones, and minor dolostones. *Sandstones*; white (N9), medium to very coarse grained, moderately to poorly sorted; arkosic; no visual porosity. *Mudstones*; gray to dark gray; some contain dolomitized bryozoans and crinoids. *Dolostones*; medium dark gray (N4) when dry, medium dark gray (N4) to olive gray (5Y4/1) when wet; microcrystalline bioclastic dolomudstones and dolowackestones; bioclasts are crinoids and algal remains; no visual porosity.
7,000–7,200	No cuttings.
7,200–7,300	Interbedded sandstones and mudstones, minor dolostones. *Sandstones*; white (N9), medium to coarse grained, poorly to well sorted; 10% visual intergranular porosity in some samples; other samples are disaggregated into individual sand grains and have well-developed porosity. *Mudstones*; mottled gray and dark grayish red.
7,300–7,600	No cuttings.
7,600–7,810	Interbedded sandstones and mudstones, minor dolostones. *Sandstones*; white (N9) to light gray (N7), fine to very coarse grained, conglomeratic, moderately to poorly sorted; arkosic; 0–tr% visual porosity. *Mudstones*; dark gray (N4) to blackish red (5R2/2) to grayish red (5R3/2) when dry, medium light gray (N6) to dark gray (N3) to dark reddish brown (10R3/4) when wet; silty.
Top of Strawn Series (Pennsylvanian) at 7,809 ft	
7,810–8,130	Interbedded sandstones and mudstones, minor dolostones and coals. *Sandstones*; white to light gray, fine to very coarse grained, moderately to poorly sorted; generally disaggregated into individual sand grains, indicating well-developed porosity. *Dolostones*; dark gray to black, microcrystalline, argillaceous; no visual porosity. *Coals*; thin beds between 7,920 and 7,930 ft; crystals of free sulfur have grown on the cuttings.
8,130–9,151	No cuttings.
Top of Arroyo Peñasco Formation (Mississippian) at 8,905 ft	
Top of Precambrian at 9,060 ft	

TABLE C10—Drill-cuttings descriptions, Cities Service No. 1 Driggers, located 1,980 ft FNL, 1,980 ft FEL, sec. 22 T11N R21E, Guadalupe County. Elevation 5,091 ft, derrick floor. Total depth 4,581 ft in Precambrian. Completed 5/22/58. Dry and abandoned. Worked over by McClellan Oil Corporation; junked and abandoned 3/20/82.

Depth interval (ft)	Description
Description starts in Yeso Formation (Permian)	
1,700–1,900	Interbedded sandstones, mudstones, anhydrites, and dolostones. *Sandstones*; pale red (10R6/2) to pale reddish brown (10R5/4) when dry, moderate reddish orange (10R6/6) to reddish brown (10R5/6) when wet; very fine to medium grained, moderately to well sorted; tr% visual intergranular porosity. Some contain 10–20% orange clay matrix and have no visual porosity. *Mudstones*; pale reddish brown (10R5/4) to grayish red (10R4/2) when dry, moderate reddish brown (10R4/6) when wet; silty. *Anhydrites*; white (N9) to brownish gray (5YR5/1) when wet; micro- to macrocrystalline; darker colored anhydrites are dolomitic. *Dolostones*; dark gray (N3) when dry, dark yellowish brown (10YR4/2) when wet; microcrystalline, sucrosic, anhydritic; no visual porosity.
Top of Abo Formation (Permian) at 1,900 ft	
1,900–2,140	Interbedded sandstones and mudstones. *Sandstones*; moderate reddish orange (10R6/6) to very light gray (N8) when dry, moderate reddish orange (10R6/6) to pale reddish brown (10R5/4) to very light gray (N8) when wet; very fine to medium grained, argillaceous, moderately to well sorted; arkosic; 0–tr% visual porosity. *Mudstones*; pale reddish brown (10R5/4) to grayish red (10R4/2) when dry, moderate reddish brown (10R4/6) when wet; silty.
2,140–2,850	Interbedded sandstones and mudstones. *Sandstones*; moderate orange pink (10R7/4) to very light gray (N8) when dry, pale reddish brown (10R5/4) to very light gray (N8) when wet; fine to very coarse grained, conglomeratic, tr% clay matrix, poorly to well sorted; arkosic; some of the coarser grained sandstones are disaggregated into individual sand grains, indicating well-developed porosity. *Mudstones*; reddish brown (10R4/4) to dark reddish brown (10R3/4) when dry, moderate reddish brown (10R4/6) when wet; silty.
Top of lower unit of Hueco Formation (Permian) at 2,850 ft	
2,850–3,060	Interbedded sandstones, limestones, and mudstones. *Sandstones*; fine to very coarse grained, moderately to poorly sorted; arkosic; most sandstones disaggregated into individual sand grains, indicating well-developed porosity. *Limestones*; white (N9) to medium dark gray (N4) when dry, light olive gray (5Y6/1) to brownish gray (5YR4/1) when wet; wackestones and packstones; no visual porosity. *Mudstones* (80%); pale reddish brown (10R5/4) to dark reddish brown (10R3/4) when dry, reddish brown (10R5/6) to very dusky red (10R2/2) when wet; silty, sandy; some are calcareous. *Mudstones* (20%); medium gray (N5) to dark gray (N3) when dry, medium dark gray (N4) to greenish gray (5GY5/1) when wet; silty, micaceous, pyritic, calcareous.
Top of Strawn Series (Pennsylvanian) at 3,060 ft	
3,060–3,150	Interbedded limestones, sandstones, and mudstones. *Limestones*; light olive gray (5Y6/1) to dark gray (N3) when dry, yellowish gray (5Y8/1) to brownish gray (5YR4/1) when wet; sandy, bioclastic wackestones and packstones; no visual porosity.

TABLE C10 (continued)

Depth interval (ft)	Description
	Sandstones; fine to very coarse grained, moderately to poorly sorted; arkosic; most sandstones disaggregated into individual sand grains, indicating well-developed porosity.
Top of Atokan Series (Pennsylvanian) at 3,150 ft	
3,150–3,260	Interbedded sandstones and mudstones, minor limestones. *Limestones*; sandy, argillaceous, bioclastic wackestones and packstones and crinoidal packstones that bear coralline algae, brachiopods, and bryozoans. No visual porosity.
Top of Precambrian at 3,260 ft	
3,260–4,575	*Granite.*

APPENDIX D—Petrographic descriptions of thin sections of selected cores and drill cuttings. Most thin sections were impregnated with blue epoxy in order to facilitate pore and reservoir study. Compositions were estimated to the nearest 10% using the charts of Bacelle and Bosellini (1965). Sandstone names follow the classification of Dott (1964). Limestone names follow the classification of Dunham (1962).

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
5,900–5,910 ft, drill cuttings
Abo Formation (Permian)

Rock name: Dolostone
Description: Peloidal dolomicrite. Contains 10% detrital silt- and sand-size quartz
Reservoir quality: Good. 10% visual intercrystal and vuggy porosity

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,080–6,090 ft, drill cuttings
Upper unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic grainstones, bioclastic wackestones and packstones)
Description: Bioclastic grainstones consist of extremely micritized, undetermined bioclasts cemented by drusy microspar calcite; a thin rim cement of calcite encases some grains. Bioclastic wackestones and packstones consist of peloids and micritized fusulinids, foraminifers, fragments of bryozoans, crinoids, and brachiopods, and some encrusting algae in a micrite matrix
Reservoir quality: Poor. No visual porosity

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,140–6,150 ft, drill cuttings
Upper unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic packstones)
Description: Consists of intraclasts, ostracods, fusulinids, and fragments of brachiopods, ostracods, and undetermined biota in a pelleted micrite matrix. Fusulinids and some undetermined biota have been micritized. Brachiopods, ostracods, and some undetermined biota have been replaced by microspar. In some cuttings, bioclasts and micrite matrix have been extensively replaced by microspar; these cuttings contain disseminated fine-grained crystals of euhedral to subhedral dolomite
Reservoir quality: Poor–fair. Tr% visual porosity occurs as interpelletal vugs in the micrite matrix

Cities Service No. 1 Widner
Sec. 17 T4N R31E, Curry County
6,040–6,050 ft, drill cuttings
Upper unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic wackestones)
Description: Consists of fragments of bryozoans, fusulinids, gastropods, encrusting algae, foraminifers, crinoids, sponges, and brachiopods in a dark-brown micrite matrix. In some cuttings, the bioclasts have been replaced by microspar
Reservoir quality: Poor. No visual porosity

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,400–6,410 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic wackestones, packstones, and grainstones)
Description: Consists of fragments of micritized bryozoans, phylloid algae, crinoids, gastropods, and brachiopods (replaced by microspar) in a micrite matrix. Tr% angular quartz silt
Reservoir quality: Poor. No visual porosity

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,500–6,510 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic wackestones)
Description: Consists of fragments of brachiopods, crinoids, and gastropods in a pelleted micrite matrix; bioclasts have been either micritized or replaced by microspar
Reservoir quality: Poor–fair. Tr% visual porosity occurs as vugs in micrite matrix

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,620–6,630 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Dolostone
Description: Consists of euhedral to subhedral, finely to coarsely crystalline, sucrosic dolomite
Reservoir quality: Poor–good. 0–10% visual intercrystal porosity. Coarsely crystalline dolostones are more porous than finely crystalline dolostones. Pores are 0.1–0.5 mm in diameter

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,640–6,650 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Dolostone
Description: Consists of euhedral to anhedral, fine- to coarse-grained dolomite; a few ghosts of unidentifiable fossils are present
Reservoir quality: Poor–fair. 0–tr% visual porosity. Pores are present only in cuttings with subhedral to euhedral crystals; pores are 0.1–0.3 mm in diameter

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,720–6,730 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic wackestones)
Description: Consists of fragments of brachiopods, bryozoans, crinoids, corals, and gastropods in a micrite matrix. Tr% angular quartz silt. Some brachiopods have spines connected to the shell. Many bioclasts have been slightly micritized
Reservoir quality: Poor. Tr% visual intercrystal porosity in the micrite matrix

Cities Service No. 1 Widner
Sec. 17 T4N R31E, Curry County
6,610–6,620 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (lime mudstones, bioclastic wackestones)
Description: Consists of fragments of brachiopods, fusulinids, gastropods, trilobites, and undetermined micritized and recrystallized bioclasts in a micrite matrix. Some micrite matrix has been replaced by microspar
Reservoir quality: Poor. No visual porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
5,620–5,630 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (lime mudstones, bioclastic wackestones)
Description: Wackestones consist of recrystallized and extensively micritized bioclasts in a pelleted micrite matrix; some bioclasts are identifiable as bryozoans and foraminifers
Reservoir quality: Poor. No visual porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
5,870–5,880 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Limestone (bioclastic packstones)
Description: Consists of fragments of crinoids, bryozoans, gastropods, brachiopods, and undetermined biota in a pelleted micrite matrix. Most bioclasts have been micritized; a few have been replaced by microspar
Reservoir quality: Poor. Tr% visual intercrystal porosity in areas where micrite matrix has been replaced by microspar

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
5,420–5,426 ft, drill cuttings
Lower unit of Hueco Formation (Permian)

Rock name: Sandstone (arkosic arenite)

APPENDIX D (continued)

Composition: 50% quartz (mostly monocrystalline)
20% feldspar (highly altered to clays)
tr% rock fragments (granitic)
tr% mica (detrital muscovite)
tr% chert
tr% hematite
30% calcite cement

Texture:
Modal grain size: Coarse sand (grain size ranges from fine to very coarse sand)
Sorting: Moderate
Grain-to-grain contacts: Mostly point and long. Depositional fabric preserved by early-stage calcite cement
Cement: Calcite, has partially replaced quartz and feldspar framework grains

Reservoir quality: Poor. No visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
5,730–5,740 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones)
Description: Consists of fragments of bryozoans, brachiopods, and crinoids in a micrite matrix; bioclasts have been either micritized or partially replaced by calcite microspar; some bryozoans are encrusted with algae; micrite matrix has aggraded to microspar in places
Reservoir quality: Poor. No visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
5,980–5,990 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (oolitic packstones)
Description: Fragments of bryozoans, brachiopods, algae, crinoids, and trilobites form nuclei of oolites enclosed in a micrite matrix. Many of the bioclast nuclei have been replaced by microspar. Many nuclei and their oolitic coatings have been micritized. 10% of grains are bioclastic wackestones and packstones; bioclasts are bryozoans, brachiopods, and trilobites, tr% of grains are algal oncolites
Reservoir quality: Poor. No visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
6,100–6,110 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones)
Description: Consists of micritized fragments of bryozoans, brachiopods, corals, and stromatoporoids(?) in a micrite matrix
Reservoir quality: Poor. No visual porosity

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
5,420–5,430 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones and packstones)
Description: Consists of abraded fragments of bryozoans, corals, crinoids, fusulinids, and gastropods in a micrite matrix; some micrite has aggraded to microspar
Reservoir quality: Poor. No visual porosity

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
5,420–5,430 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Dolostone (dolopackstones and dolowackestones)
Description: Consists of fine- to medium-grained anhedral to subhedral dolomite with 10% calcite. Calcite occurs as sparry crystals and crinoid plates. Dolomite has ghosts of crinoids and ostracods
Reservoir quality: Poor. Tr% visual porosity; porosity is secondary, resulting from microfractures less than 0.02 mm wide and from dissolution of dolomite

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
5,490–5,500 ft, drill cuttings
Upper unit of Canyon Series (Pennsylvanian)

Rock name: Dolostone
Description: Consists of micro- to macrocrystalline dolomite and tr–10% detrital silt-size quartz
Reservoir quality: Poor. No visual porosity

Shell Oil Company No. 1 Stephenson
Sec. 2 T3N R32E, Curry County
6,850–6,860 ft, drill cuttings
Lower unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones and packstones, oolitic grainstones)
Description: Bioclastic wackestones and packstones consist of fusulinids and fragments of bryozoans, brachiopods, gastropods, and algae in a micrite matrix; bryozoans are micritized; brachiopods, gastropods, and some bryozoans have been replaced by microspar.
Oolitic grainstones consist of oolites cemented by fibrous, calcite rim cements and a drusy mosaic of calcite cement
Reservoir quality: Poor–fair. Most cuttings have no visual porosity; some cuttings have tr–10% visual oomoldic porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
6,310–6,320 ft, drill cuttings
Lower unit of Canyon Series (Pennsylvanian)

Rock name: Limestone (bioclastic–oolitic grainstones and pelletal wackestones)
Description: Bioclastic–oolitic grainstones consist of oolites, foraminifers, ostracods, gastropods, lime-mud pellets, and fragments of crinoids and brachiopods cemented by calcite microspar; all framework grains have a micritized rind.
Pelletal wackestones consist of fragments of brachiopods, bryozoans, crinoids, and foraminifers in a pelleted lime-mud matrix; bioclasts have been partially or wholly replaced by microspar
Reservoir quality: Poor. No visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
6,190–6,200 ft, drill cuttings
Lower unit of Canyon Series (Pennsylvanian)

Rock name: Sandstone (subarkose)
Composition: 70% quartz (monocrystalline grains with overgrowths of syntaxial quartz cement)
20% feldspar (extensively altered to clays; crushed brittly during compaction; a few feldspars have been partially dissolved)
10% rock fragments (granitic)

Texture:
Modal grain size: Coarse sand (grain size ranges from very fine sand to gravel)
Sorting: Moderate to poor
Grain-to-grain contacts: Obscured by quartz overgrowths
Cement: Quartz overgrowths, a late-stage cement that infills pore spaces between mechanically compacted framework grains
Reservoir quality: Fair. Tr–10% visual porosity. Porosity is secondary, resulting mostly from dissolution of quartz overgrowths; tr% porosity resulted from dissolution of feldspars

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
6,030–6,040 ft, drill cuttings
Lower unit of Canyon Series (Pennsylvanian)

Rock name: Sandstone (subarkose)
Composition: 80% quartz (monocrystalline)
10% feldspar (highly altered to clays; a few feldspars have been partially dissolved)
10% rock fragments (granitic)
tr% calcite cement

APPENDIX D (continued)

Texture:
- Modal grain size: Coarse sand (grain size ranges from coarse silt to gravel)
- Sorting: Poor
- Grain-to-grain contacts: Mostly point and long, a few concavo-convex
- Cement: Calcite, an early-stage cement that preserves depositional fabric

Reservoir quality: Fair. Tr–10% porosity. Porosity is secondary, resulting mostly from dissolution of early-stage calcite cement; tr% porosity results from dissolution of feldspars

Cities Service No. 1 Widner
Sec. 17 T4N R31E, Curry County
7,190–7,200 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Limestone (bioclastic packstone)
Description: Comprised of fusulinids and fragments of crinoids, corals, and brachiopods in a micrite matrix; contains trace amounts of angular quartz silt
Reservoir quality: Poor. No visual porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
6,500–6,510 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Limestone (lime mudstones and bioclastic wackestones and grainstones)
Description: Grainstones comprised of oolites and fragments of crinoids, bryozoans, ostracods, and phylloid algae cemented by drusy calcite; calcite rim cements on all grains; framework grains have been highly micritized. Lime mudstones and bioclastic wackestones consist of fragments of ostracods and bryozoans in a micrite matrix
Reservoir quality: Poor. No visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
6,790–6,800 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Sandstone (quartz arenite)
Composition:
- 70% quartz (uni- and polycrystalline, straight and undulatory extinction; syntaxial quartz overgrowths)
- tr% feldspar (potash feldspar)
- tr% rock fragments (granite)
- tr% clay (authigenic, fills pores)
- 30% carbonate cement

Texture:
- Modal grain size: Medium sand (grain size ranges from very fine to coarse sand)
- Sorting: Moderate
- Grain-to-grain contacts: Mostly point
- Cement: Quartz overgrowths precipitated first, followed by carbonate which replaces quartz framework and quartz overgrowths

Reservoir quality: Fair–good. Visual porosity ranges from tr to 20%. Porosity is secondary, resulting from dissolution of quartz and carbonate cements. Some cuttings have a well-developed intergranular pore system

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
6,800–6,810 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones and packstones)
Description: Comprised of fragments of brachiopods, bryozoans, fusulinids, crinoids, and ostracods in a micrite matrix
Reservoir quality: Poor, no visual porosity

Husky Oil Company & General Crude Oil Company No. 1 Hanchett State
Sec. 16 T8N R24E, Guadalupe County
6,990–7,000 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Sandstone (subarkose)
Composition:
- 80% quartz (detrital grains have overgrowths of syntaxial quartz cement)
- 20% feldspar (highly altered to clays, squashed between quartz grains; many feldspars have been partially or wholly dissolved.
- tr% rock fragments (granitic)
- tr% mica (muscovite and chlorite)

Texture:
- Modal grain size: Fine sand (ranges from very fine to fine sand)
- Sorting: Good
- Grain-to-grain contacts: Obscured by quartz overgrowths
- Cement: Syntaxial quartz overgrowths have resulted in a tight interlocking framework of quartz crystals

Reservoir quality: Poor–fair. 10% visual porosity, resulting from dissolution of feldspar grains that are isolated from each other in a quartz matrix

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
6,240–6,250 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Limestone (lime mudstone)
Description: Trace amounts of crinoids, brachiopod fragments, and quartz silt in a micrite matrix
Reservoir quality: Poor. No visual porosity

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
6,240–6,250 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Dolostone
Description: Consists of anhedral, micro- to macrocrystalline dolomite crystals that form a tight interlocking network; contain tr% sand-size fragments of detrital quartz and granitic rock fragments
Reservoir quality: Poor–fair. Tr% visual porosity in microfractures <0.1 mm wide and in vugs 0.2–0.6 mm in diameter; vugs have developed along microfractures

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
6,750–6,760 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Sandstone (subarkose)
Composition:
- 80% quartz (monocrystalline; detrital grains have overgrowths of syntaxial quartz cement)
- 20% feldspar (highly altered to clays; some feldspars have been wholly or partially dissolved)
- tr% rock fragments (granitic fragments and very fine-grained silty sandstone)
- tr% clay (fills pores; some are alteration products of feldspars)
- tr% dolomite cement

Texture:
- Modal grain size: Medium sand (grain size ranges from fine sand to gravel)
- Sorting: Moderate to poor
- Grain-to-grain contacts: Mostly point and long
- Cement: Dolomite cement, early-stage diagenetic, preserves depositional fabric; quartz overgrowths fill relict pores not occluded by dolomite or compaction

Reservoir quality: Fair. 10% visual porosity, mostly as relict primary pores; 1–2% porosity is secondary, resulting from dissolution of feldspars and dolomite; tr% porosity is in microfractures

Trans-Pecos Resources No. 1 Latigo Ranch A
Sec. 2 T9N R23E, Guadalupe County
6,920–6,930 ft, drill cuttings
Strawn Series (Pennsylvanian)

Rock name: Limestone (bioclastic wackestones, packstones, and grainstones)
Description: Consists of broken and abraded fragments of crinoids, brachiopods, and bryozoans in a micrite matrix; bioclasts have been micritized or replaced by microspar; patches of micrite matrix have been replaced by microspar

APPENDIX D (continued)

Reservoir quality: Poor–fair. Tr–5% visual intercrystal porosity in matrix and in microspar replacements of bioclasts

CO_2-in-Action No. 1 J. L. Hicks
Sec. 19 T9N R24E, Guadalupe County
6,408.3 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (subarkose)
Composition:
70% quartz (detrital grains have overgrowths of syntaxial quartz cement)
20% feldspar (many feldspars have been wholly or partially dissolved)
10% pyrite (fine-grained; mostly pyritized wood fragments but some pyrite fills pores)
tr% mica
tr% hematite
tr% zircon (detrital)
tr% calcite cement

Texture:
Modal grain size: Medium sand (grain size ranges from very fine to coarse sand)
Sorting: Moderate
Grain-to-grain contacts: Mostly point, some long; quartz overgrowths give appearance that almost all contacts are long
Cement: Syntaxial quartz overgrowths on detrital quartz grains, 10–20% of rock. Calcite cement fills voids left by dissolution of feldspars
Reservoir quality: Fair–good. 10% visual porosity in open fractures and as secondary porosity, resulting from dissolution of feldspars. Fractures are as wide as 3.5 mm

CO_2-in-Action No. 1 J. L. Hicks
Sec. 19 T9N R24E, Guadalupe County
6,420.5 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (arkosic arenite)
Composition:
40% quartz
20% feldspar (some have been partially dissolved)
tr% rock fragments (granitic)
tr% mica
tr% pyrite
40% dolomite cement

Texture:
Modal grain size: Very coarse sand (grain size ranges from fine sand to gravel)
Sorting: Poor
Grain-to-grain contacts: Mostly point, some long; most framework grains float in dolomite cement
Cement: Dolomite has a blocky texture
Reservoir quality: Poor. Tr% visual porosity is secondary, resulting from dissolution of isolated feldspars

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
6,677.6 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (lithic arenite)
Composition:
50% quartz (most quartz is polycrystalline and has undulatory extinction; a few detrital grains have overgrowths of syntaxial quartz cement)
10% feldspar (moderately to severely altered to clays; many feldspars have been partially or wholly dissolved)
40% rock fragments (35% are granitic; 5% are siliciclastic mudstones and siltstones)
tr% mica (muscovite)

Texture:
Modal grain size: Very coarse sand (grain size ranges from very fine sand to gravel)
Sorting: Moderate
Grain-to-grain contacts: Mostly point and long, a few concavo-convex
Reservoir quality: Good. 20% visual porosity. Porosity is secondary, resulting from dissolution of feldspars (both as detrital grains and in rock fragments)

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,127 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (lithic arenite)
Composition:
40% quartz (predominantly monocrystalline)
10% feldspar (generally slightly altered to clays)
30% rock fragments (granitic fragments and silty siliciclastic mudstones; many granitic fragments have a micropegmatite texture; mudstones are squashed around less ductile framework grains, forming a pseudo-matrix)
10% clay (detrital, supports silt-size quartz in a clay-rich lamination 5 mm thick)
10% calcite cement

Texture:
Modal grain size: Coarse sand (grain size ranges from clay to very coarse sand)
Sorting: Poor
Grain-to-grain contacts: Mostly point, some long; concavo-convex contacts abundant around squashed mudstone rock fragments
Cement: Calcite, intergranular, poikilotopic cement confined to sandy laminations, replaces framework grains and preserves depositional fabric
Reservoir quality: Poor. Tr% visual porosity in microfractures less than 0.1 mm wide

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,137 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (arkosic arenite)
Composition:
50% quartz (mostly monocrystalline)
30% feldspar (generally highly altered to ductile clays; a few feldspars are partially dissolved)
20% rock fragments (granite and ductile, silty siliciclastic mudstone)
tr% chalcopyrite
tr% mica (detrital muscovite)
tr% clay (detrital)

Texture:
Modal grain size: Coarse sand (grain size ranges from clay to very coarse sand)
Sorting: Moderate
Grain-to-grain contacts: Mostly point and long, a few concavo-convex
Reservoir quality: Tr% visual porosity in relict primary pores, in cavities formed by dissolution of feldspars, and in microfractures less than 0.04 mm wide

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,142 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (lithic arenite)
Composition:
50% quartz (mono- and polycrystalline, undulatory extinction; some grains have late stage syntaxial quartz overgrowths)
20% feldspars (most grains highly altered to clays; some feldspars have been partially or wholly dissolved)
25% rock fragments (granitic, some with myrmekite and micropegmatite textures; feldspars in rock fragments are highly altered to clays)
5% dolomite (replaces framework grains and fills pores formed by dissolution of feldspars)
tr% calcite (precipitated in pores formed by dissolution of feldspars)
tr% pyrite
tr% chlorite (detrital)

Texture:
Modal grain size: Very coarse sand (grain size ranges from coarse sand to gravel)
Sorting: Moderate
Grain-to-grain contacts: Mostly point and long, some concavo-convex
Cement: Syntaxial quartz overgrowths fill relict primary pores; dolomite and calcite fill pores formed by dissolution of feldspars
Reservoir quality: Good. 10% visual porosity; most pores formed by dissolution of feldspars; a few small pores are relict primary pores

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,163.3 ft, core sample
Strawn Series (Pennsylvanian)

Rock name: Sandstone (arkosic arenite)
Composition:
60% quartz (mostly polycrystalline grains with undulatory extinction; most detrital grains have syntaxial quartz overgrowths)

APPENDIX D (continued)

	30% feldspar (most feldspars are highly altered to clays; many feldspars have been partially dissolved)
	10% rock fragments (granitic)
	tr% mica (muscovite)
	tr% pyroxene
Texture:	
Modal grain size:	Coarse sand (grain size ranges from fine sand to gravel)
Sorting:	Poor
Grain-to-grain contacts:	Obscured by syntaxial overgrowths on detrital quartz
Cement:	Syntaxial quartz overgrowths on detrital quartz grains
Reservoir quality:	Good. 10% visual porosity; most porosity is secondary, resulting from dissolution of feldspars; a tr% porosity is relict primary porosity

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,183.7 ft, core sample
Strawn Series (Pennsylvanian)

Rock name:	Limestone (brachiopodal wackestone)
Description:	Consists of fragments of brachiopods and a few bryozoans and crinoids in a matrix of calcareous siliciclastic mud. Some bioclasts have been replaced by microspar
Reservoir quality:	Poor. No visual porosity

Gila Exploration No. 1 Latigo Ranch D
Sec. 26 T10N R23E, Guadalupe County
7,274.9 ft, core sample
Strawn Series (Pennsylvanian)

Rock name:	Sandstone (calcareous quartz arenite)
Composition:	40% quartz (slightly etched by calcite cement)
	tr% feldspar (detrital microcline)
	10% fossils (fragments of brachiopods, bryozoans, and coralline algae)
	50% calcite cement
Texture:	
Modal grain size:	Medium-coarse sand (grain size ranges from coarse silt to gravel)
Sorting:	Poor
Cement:	Irregular blocky patchwork
Reservoir quality:	Poor. No visual porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
7,000–7,010 ft, drill cuttings
Atokan Series (Pennsylvanian)

Rock name:	Sandstone (quartz arenite)
Composition:	90% quartz (monocrystalline detrital grain with syntaxial quartz overgrowths)
	tr% feldspar (slightly altered to clays)
	tr% rock fragments (chert)
	10% calcite cement
Texture:	
Modal grain size:	Fine to medium sand (grain size ranges from coarse silt to coarse sand)
Sorting:	Moderate to good
Grain-to-grain contacts:	Obscured by overgrowths of syntaxial quartz cement
Cement:	Syntaxial quartz overgrowths; calcite cement is blocky, occurs in patches, replaces framework grains and quartz overgrowths
Reservoir quality:	Poor. Tr% visual porosity; porosity is intergranular, occurring between quartz overgrowths

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
7,090–7,100 ft, drill cuttings
Arroyo Peñasco Formation (Mississippian)

Rock name:	Limestone (bioclastic–oolitic grainstones)
Description:	Consists of oolites and micritized fragments of bryozoans, crinoids, and brachiopods cemented by drusy calcite. Detrital grains have a thin epitaxial rim cement of calcite
Reservoir quality:	Poor. No visual porosity

Abercrombie & Hawkins No. 1 Nappier
Sec. 22 T5N R26E, De Baca County
7,120–7,130 ft, drill cuttings
Arroyo Peñasco Formation (Mississippian)

Rock name:	Sandstone (subarkose)
Composition:	80% quartz (detrital grains have syntaxial quartz overgrowths)
	20% feldspar (severely altered to clays)
	tr% clay (detrital)
Texture:	
Modal grain size:	Very fine sand (grain size ranges from clay to medium sand)
Sorting:	Poor
Grain-to-grain contacts:	Point and long
Cement:	Syntaxial overgrowths on detrital quartz grains
Reservoir quality:	Poor. Tr% visual porosity; generally well-compacted, "tight"

Selected conversion factors*

TO CONVERT	MULTIPLY BY	TO OBTAIN
Length		
inches, in	2.540	centimeters, cm
feet, ft	3.048×10^{-1}	meters, m
yards, yds	9.144×10^{-1}	m
statute miles, mi	1.609	kilometers, km
fathoms	1.829	m
angstroms, Å	1.0×10^{-8}	cm
Å	1.0×10^{-4}	micrometers, μm
Area		
in^2	6.452	cm^2
ft^2	9.29×10^{-2}	m^2
yds^2	8.361×10^{-1}	m^2
mi^2	2.590	km^2
acres	4.047×10^{3}	m^2
acres	4.047×10^{-1}	hectares, ha
Volume (wet and dry)		
in^3	1.639×10^{1}	cm^3
ft^3	2.832×10^{-2}	m^3
yds^3	7.646×10^{-1}	m^3
fluid ounces	2.957×10^{-2}	liters, l *or* L
quarts	9.463×10^{-1}	l
U.S. gallons, gal	3.785	l
U.S. gal	3.785×10^{-3}	m^3
acre-ft	1.234×10^{3}	m^3
barrels (oil), bbl	1.589×10^{-1}	m^3
Weight, mass		
ounces avoirdupois, avdp	2.8349×10^{1}	grams, gr
troy ounces, oz	3.1103×10^{1}	gr
pounds, lb	4.536×10^{-1}	kilograms, kg
long tons	1.016	metric tons, mt
short tons	9.078×10^{-1}	mt
oz mt^{-1}	3.43×10^{1}	parts per million, ppm
Velocity		
ft sec^{-1} (= ft/sec)	3.048×10^{-1}	m sec^{-1} (= m/sec)
mi hr^{-1}	1.6093	km hr^{-1}
mi hr^{-1}	4.470×10^{-1}	m sec^{-1}

TO CONVERT	MULTIPLY BY	TO OBTAIN
Pressure, stress		
lb in^{-2} (= lb/in^2), psi	7.03×10^{-2}	kg cm^{-2} (= kg/cm^2)
lb in^{-2}	6.804×10^{-2}	atmospheres, atm
lb in^{-2}	6.895×10^{3}	newtons (N)/m^2, N m^{-2}
atm	1.0333	kg cm^{-2}
atm	7.6×10^{2}	mm of Hg (at 0° C)
inches of Hg (at 0° C)	3.453×10^{-2}	kg cm^{-2}
bars, b	1.020	kg cm^{-2}
b	1.0×10^{6}	dynes cm^{-2}
b	9.869×10^{-1}	atm
b	1.0×10^{-1}	megapascals, MPa
Density		
lb in^{-3} (= lb/in^3)	2.768×10^{1}	gr cm^{-3} (= gr/cm^3)
Viscosity		
poises	1.0	gr cm^{-1} sec^{-1} *or* dynes cm^{-2}
Discharge		
U.S. gal min^{-1}, gpm	6.308×10^{-2}	l sec^{-1}
gpm	6.308×10^{-5}	m^3 sec^{-1}
ft^3 sec^{-1}	2.832×10^{-2}	m^3 sec^{-1}
Hydraulic conductivity		
U.S. gal day^{-1} ft^{-2}	4.720×10^{-7}	m sec^{-1}
Permeability		
darcies	9.870×10^{-13}	m^2
Transmissivity		
U.S. gal day^{-1} ft^{-1}	1.438×10^{-7}	m^2 sec^{-1}
U.S. gal min^{-1} ft^{-1}	2.072×10^{-1}	l sec^{-1} m^{-1}
Magnetic field intensity		
gausses	1.0×10^{5}	gammas
Energy, heat		
British thermal units, BTU	2.52×10^{-1}	calories, cal
BTU	1.0758×10^{2}	kilogram-meters, kgm
BTU lb^{-1}	5.56×10^{-1}	cal kg^{-1}
Temperature		
°C + 273	1.0	°K (Kelvin)
°C + 17.78	1.8	°F (Fahrenheit)
°F − 32	5/9	°C (Celsius)

**Divide by* the factor number to reverse conversions.
Exponents: for example 4.047×10^{3} (see acres) = 4,047; 9.29×10^{-2} (see ft^2) = 0.0929.

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Typeface: Palatino

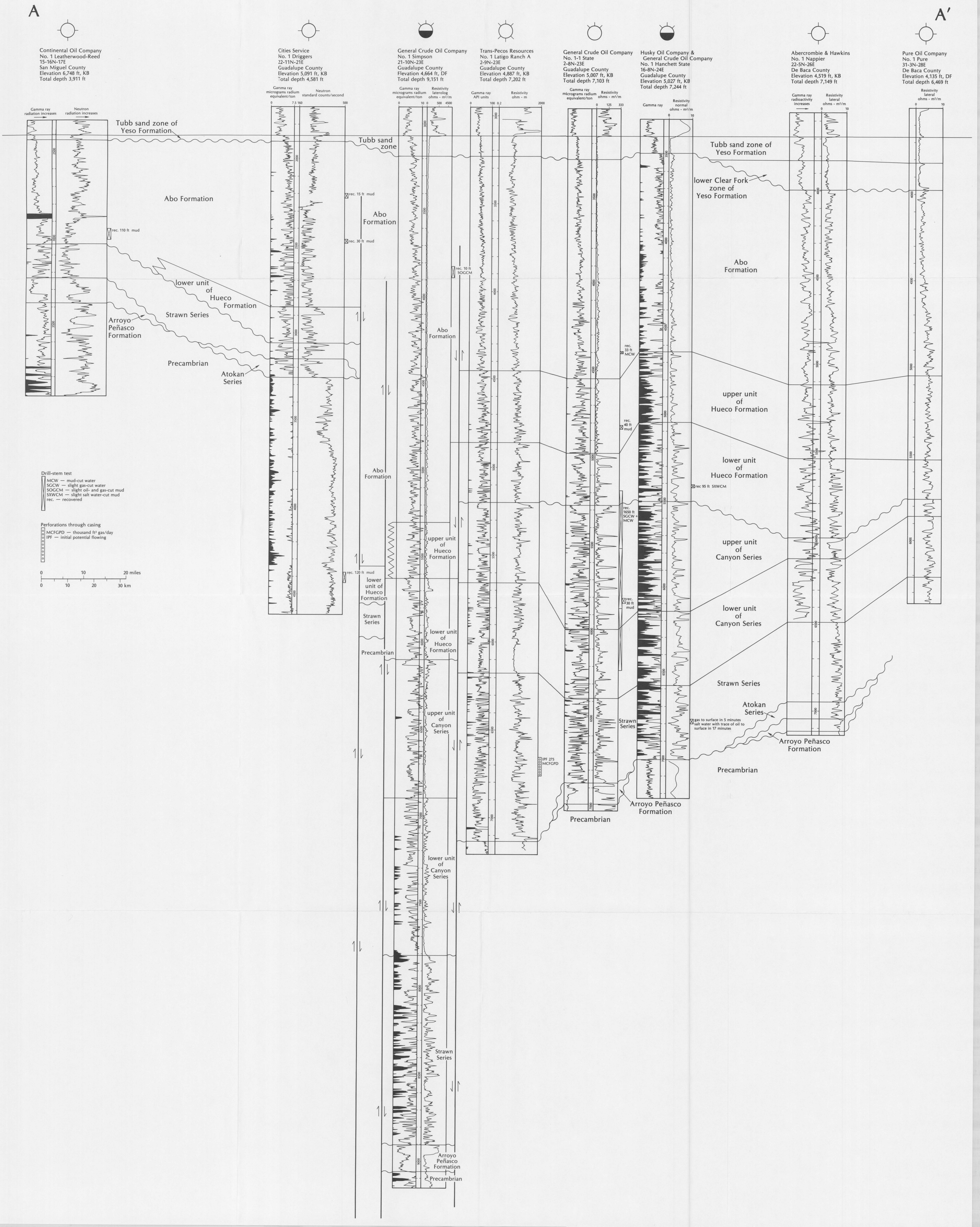
Presswork: Miehle Single Color Offset
Harris Single Color Offset

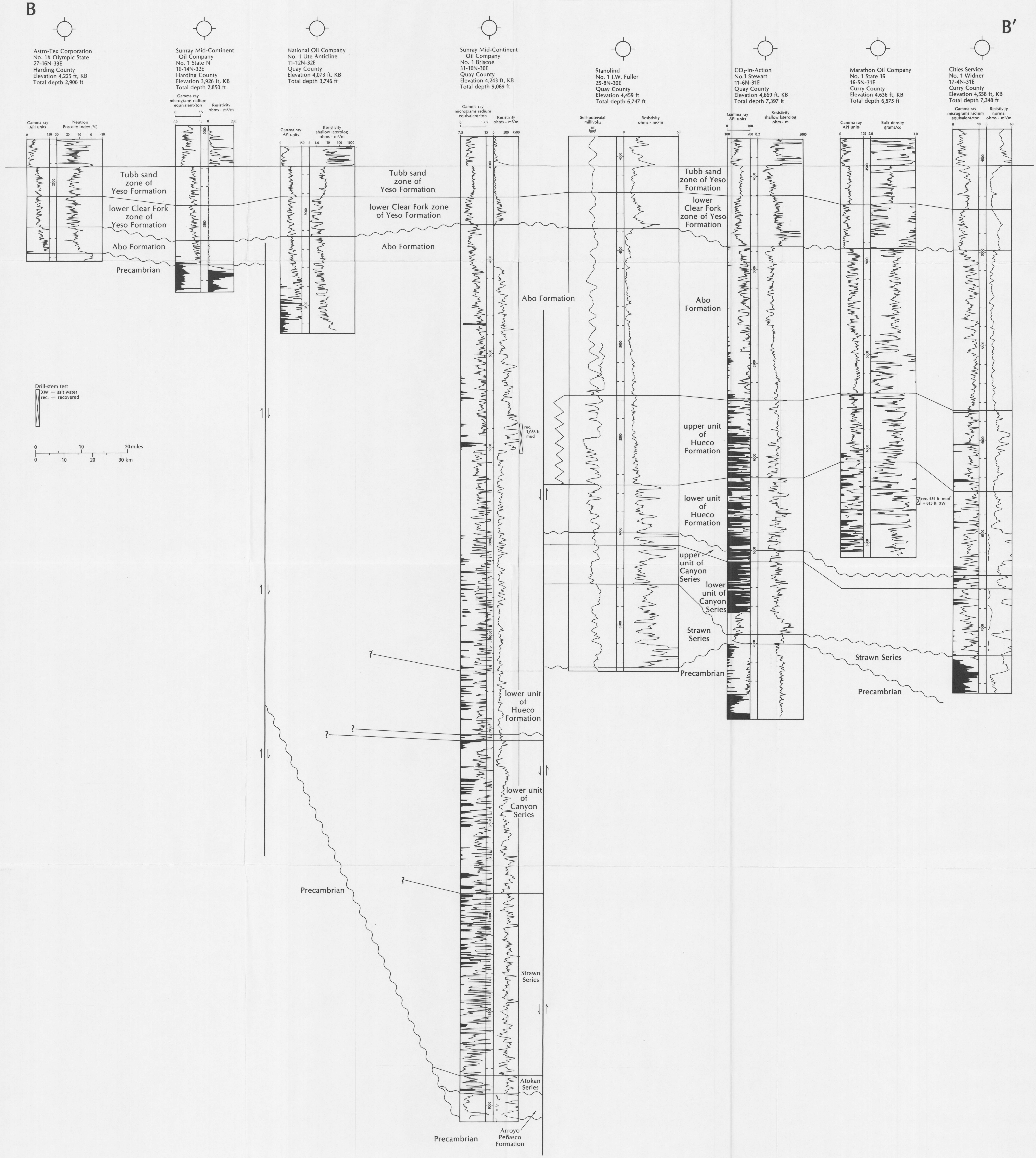
Binding: Smyth sewn

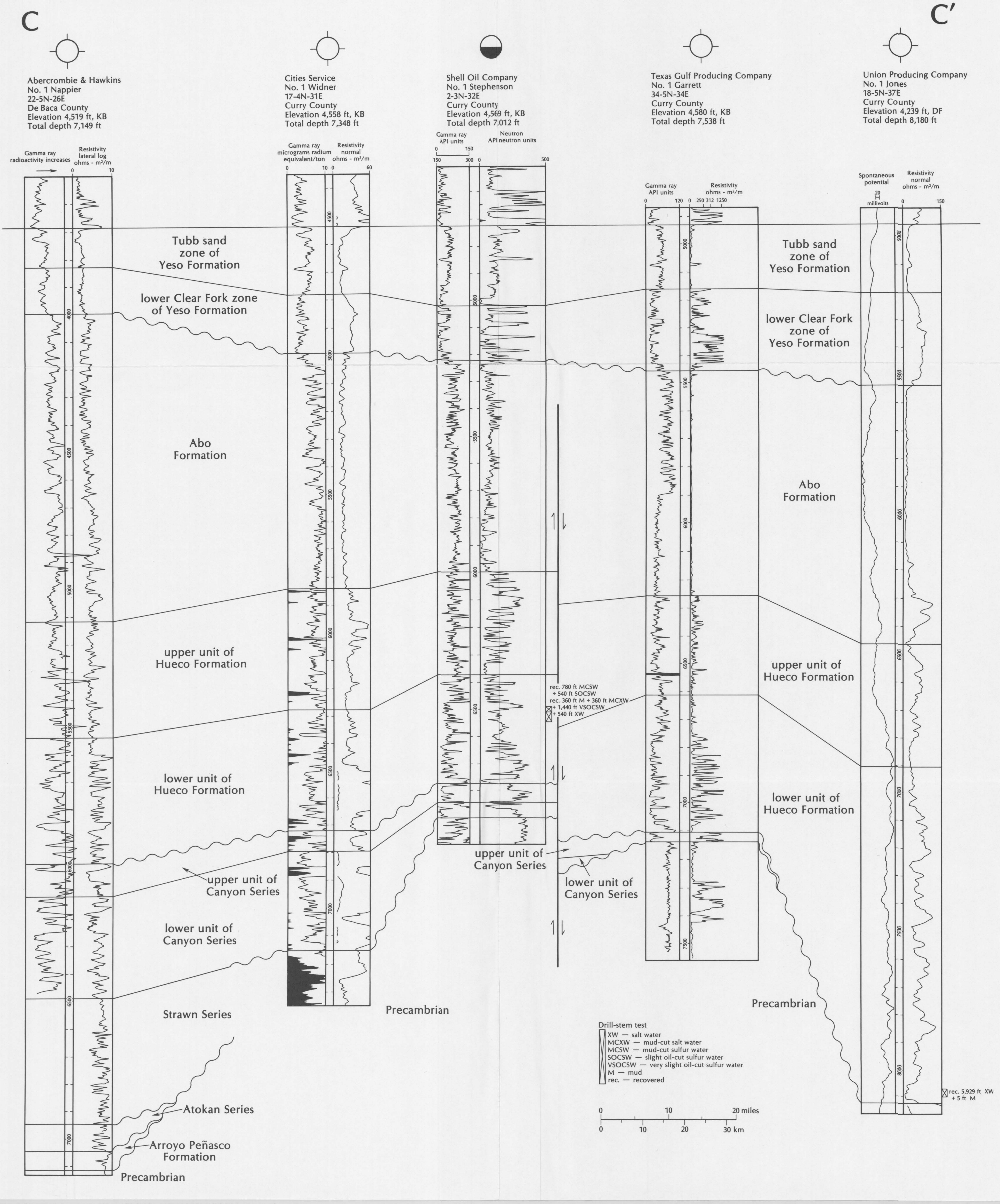
Paper: Cover on 17-pt. Kivar
Text on 70-lb white matte

Ink: Cover—PMS 320
Text—Black

Quantity: 1000


A
A'
Continental Oil Company
No. 1 Leatherwood-Reed
15-16N-17E
San Miguel County
Elevation 6,748 ft, KB
Total depth 3,911 ft
Cities Service
No. 1 Driggers
22-11N-21E
Guadalupe County
Elevation 5,091 ft, KB
Total depth 4,581 ft
General Crude Oil Company
No. 1 Simpson
21-10N-23E
Guadalupe County
Elevation 4,664 ft, DF
Total depth 9,151 ft
Trans-Pecos Resources
No. 1 Latigo Ranch A
2-9N-23E
Guadalupe County
Elevation 4,887 ft, KB
Total depth 7,202 ft
General Crude Oil Company
No. 1-1 State
2-8N-23E
Guadalupe County
Elevation 5,007 ft, KB
Total depth 7,103 ft
Husky Oil Company &
General Crude Oil Company
No. 1 Hanchett State
16-8N-24E
Guadalupe County
Elevation 5,027 ft, KB
Total depth 7,244 ft
Abercrombie & Hawkins
No. 1 Nappier
22-5N-26E
De Baca County
Elevation 4,519 ft, KB
Total depth 7,149 ft
Pure Oil Company
No. 1 Pure
31-3N-28E
De Baca County
Elevation 4,135 ft, DF
Total depth 6,469 ft
Gamma ray radiation increases
Neutron radiation increases
Gamma ray micrograms radium equivalent/ton
Neutron standard counts/second
Resistivity laterolog ohms - m²/m
Gamma ray API units
Resistivity ohm - m
Resistivity ohms - m²/m
Gamma ray
Resistivity normal ohms - m²/m
Gamma ray radioactivity increases
Resistivity lateral ohms - m²/m
Tubb sand zone of Yeso Formation
Tubb sand zone
lower Clear Fork zone of Yeso Formation
Abo Formation
lower unit of Hueco Formation
upper unit of Hueco Formation
Strawn Series
Arroyo Peñasco Formation
Precambrian
Atokan Series
upper unit of Canyon Series
lower unit of Canyon Series
rec. 110 ft mud
rec. 15 ft mud
rec. 30 ft mud
rec. 120 ft mud
rec. 10 ft SOGCM
rec. 33 ft MCW
rec. 40 ft mud
rec. 1650 ft SGCW + MCW
rec. 30 ft mud
rec 95 ft SXWCM
IPF 275 MCFGPD
gas to surface in 5 minutes salt water with trace of oil to surface in 17 minutes
Drill-stem test
MCW — mud-cut water
SGCW — slight gas-cut water
SOGCM — slight oil- and gas-cut mud
SXWCM — slight salt water-cut mud
rec. — recovered
Perforations through casing
MCFGPD — thousand ft³ gas/day
IPF — initial potential flowing
0 10 20 miles
0 10 20 30 km


B
B′
Astro-Tex Corporation
No. 1X Olympic State
27-16N-33E
Harding County
Elevation 4,225 ft, KB
Total depth 2,906 ft
Sunray Mid-Continent Oil Company
No. 1 State N
16-14N-32E
Harding County
Elevation 3,926 ft, KB
Total depth 2,850 ft
National Oil Company
No. 1 Ute Anticline
11-12N-32E
Quay County
Elevation 4,073 ft, KB
Total depth 3,746 ft
Sunray Mid-Continent Oil Company
No. 1 Briscoe
31-10N-30E
Quay County
Elevation 4,243 ft, KB
Total depth 9,069 ft
Stanolind
No. 1 J.W. Fuller
25-8N-30E
Quay County
Elevation 4,459 ft
Total depth 6,747 ft
CO2-in-Action
No.1 Stewart
11-6N-31E
Quay County
Elevation 4,669 ft, KB
Total depth 7,397 ft
Marathon Oil Company
No. 1 State 16
16-5N-31E
Curry County
Elevation 4,636 ft, KB
Total depth 6,575 ft
Cities Service
No. 1 Widner
17-4N-31E
Curry County
Elevation 4,558 ft, KB
Total depth 7,348 ft
Gamma ray API units
Neutron Porosity Index (%)
Gamma ray micrograms radium equivalent/ton
Resistivity ohms - m²/m
Resistivity shallow laterolog ohms - m²/m
Self-potential millivolts
Resistivity shallow laterolog ohm - m
Bulk density grams/cc
Resistivity normal ohms - m²/m
Tubb sand zone of Yeso Formation
lower Clear Fork zone of Yeso Formation
Abo Formation
Precambrian
upper unit of Hueco Formation
lower unit of Hueco Formation
upper unit of Canyon Series
lower unit of Canyon Series
Strawn Series
Atokan Series
Arroyo Peñasco Formation
Drill-stem test
XW — salt water
rec. — recovered
rec. 1,088 ft mud
rec. 434 ft mud + 615 ft XW
0 10 20 miles
0 10 20 30 km


C
C′
Abercrombie & Hawkins
No. 1 Nappier
22-5N-26E
De Baca County
Elevation 4,519 ft, KB
Total depth 7,149 ft
Cities Service
No. 1 Widner
17-4N-31E
Curry County
Elevation 4,558 ft, KB
Total depth 7,348 ft
Shell Oil Company
No. 1 Stephenson
2-3N-32E
Curry County
Elevation 4,569 ft, KB
Total depth 7,012 ft
Texas Gulf Producing Company
No. 1 Garrett
34-5N-34E
Curry County
Elevation 4,580 ft, KB
Total depth 7,538 ft
Union Producing Company
No. 1 Jones
18-5N-37E
Curry County
Elevation 4,239 ft, DF
Total depth 8,180 ft
Gamma ray radioactivity increases
Resistivity lateral log ohms - m²/m
Gamma ray micrograms radium equivalent/ton
Resistivity normal ohms - m²/m
Gamma ray API units
Neutron API neutron units
Gamma ray API units
Resistivity ohms - m²/m
Spontaneous potential millivolts
Resistivity normal ohms - m²/m
Tubb sand zone of Yeso Formation
lower Clear Fork zone of Yeso Formation
Abo Formation
upper unit of Hueco Formation
lower unit of Hueco Formation
upper unit of Canyon Series
lower unit of Canyon Series
Strawn Series
Atokan Series
Arroyo Peñasco Formation
Precambrian
rec. 780 ft MCSW + 540 ft SOCSW
rec. 360 ft M + 360 ft MCXW + 1,440 ft VSOCSW + 540 ft XW
rec. 5,929 ft XW + 5 ft M
Drill-stem test
XW — salt water
MCXW — mud-cut salt water
MCSW — mud-cut sulfur water
SOCSW — slight oil-cut sulfur water
VSOCSW — very slight oil-cut sulfur water
M — mud
rec. — recovered
0 10 20 miles
0 10 20 30 km


D
D′
Sunray Mid-Continent Oil Company
No. 1 R. Padilla
4-8N-19E
Guadalupe County
Elevation 5,365 ft, KB
Total depth 3,800 ft
Gamma ray micrograms radium equivalent/ton
Resistivity normal ohms - m²/m
Trans-Pecos Resources
No. 1 Latigo Ranch A
2-9N-23E
Guadalupe County
Elevation 4,887 ft, KB
Total depth 7,202 ft
Gamma ray API units
Resistivity ohm - m
Miami Petroleum Company
No. 1 Hoover Ranch A
2-10N-27E
Quay County
Elevation 4,268 ft, KB
Total depth 6,415 ft
Gamma ray
Resistivity laterolog ohm - m
Sunray Mid-Continent Oil Company
No. 1 Briscoe
31-10N-30E
Quay County
Elevation 4,243 ft, KB
Total depth 9,069 ft
Gamma ray micrograms radium equivalent/ton
Resistivity ohms - m²/m
Tubb sand zone of Yeso Formation
lower Clear Fork zone of Yeso Formation
Abo Formation
upper unit of Hueco Formation
lower unit of Hueco Formation
Strawn Series
Arroyo Peñasco Formation
Precambrian
upper unit of Canyon Series
lower unit of Canyon Series
Atokan Series
rec. 1,088 ft mud
IPF 375 MCFGPD
Drill-stem test
rec. — recovered
Perforations through casing
MCFGPD — thousand ft³ gas/day
IPF — initial potential flowing
0 10 20 miles
0 10 20 30 km