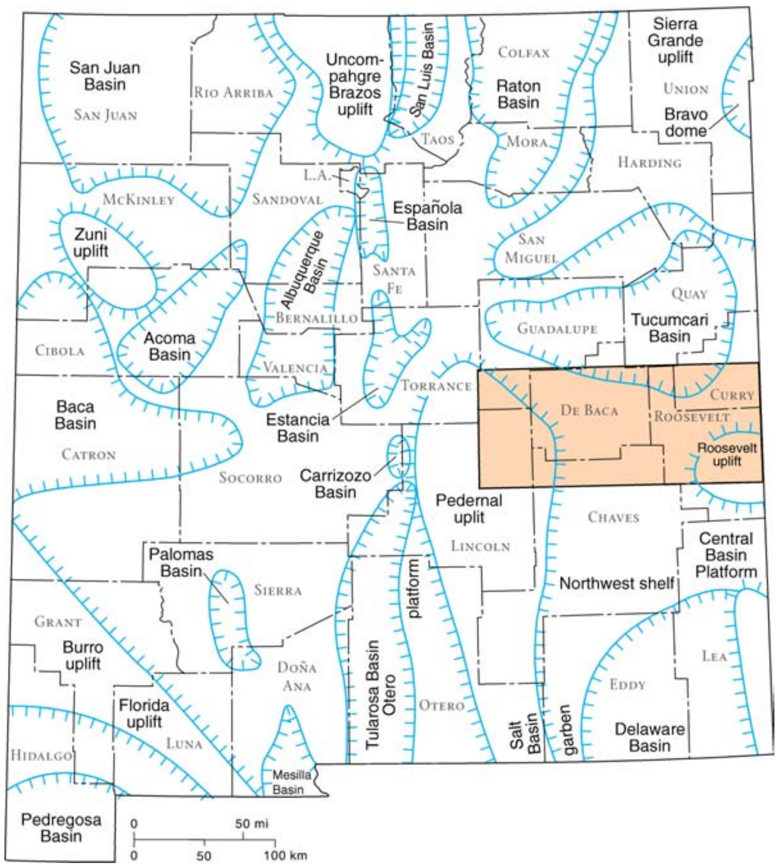
Petroleum potential of the Sin Nombre area, DeBaca, Roosevelt, Curry, Lincoln, Guadalupe, and Chaves Counties, New Mexico: A reconnaissance report



by

Ronald F. Broadhead and Glen Jones

New Mexico Bureau of Geology and Mineral Resources
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Socorro, NM 87801

Petroleum Potential of Sin Nombre Area, DeBaca, Roosevelt, Curry, Lincoln, Guadalupe, and Chaves Counties, New Mexico: a Reconnaissance Report

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ABSTRACT

The Sin Nombre area sits astride the boundary between the Permian Basin to the south and the Tucumcari Basin to the north. It covers an area of approximately 7000 mi^2 in DeBaca, northern Roosevelt, southern Curry, northern Chaves, northeastern Lincoln, and southwestern Guadalupe Counties, New Mexico. Approximately 100 BCF gas and 6 million bbls oil have been produced from 17 oil and gas pools in the southeast and south-central portions of Sin Nombre. Low-permeability sandstones of the Abo Formation (Permian) have yielded most of the gas but Pennsylvanian limestones and Silurian and Ordovician dolostones are also important gas reservoirs. Silurian dolostones and Pennsylvanian limestones have been the primary oil reservoirs.

Significant potential remains for additional, undiscovered and unproduced oil and gas resources. Marginal gas discoveries in the central part of the Sin Nombre area may have remained unproduced because of a paucity of pipelines along the northwestern fringe of the Permian Basin. Although drilling density is low, oil and gas shows encountered by unsuccessful exploratory wells indicate that large portions of the area have been at least partially charged by hydrocarbons. Hydrocarbons in the southern part of the Sin Nombre area would most likely have migrated north from source rocks in the Permian Basin. Hydrocarbons in the northern part of the Sin Nombre area would have migrated southward from source rocks in the Tucumcari Basin. Opportunities for traps included localized, basement-controlled structural highs throughout the stratigraphic section as well as northward pinchouts of lower Paleozoic reservoirs.

INTRODUCTION

The Sin Nombre area is that part of eastern New Mexico that lies between the Northwest shelf of the Permian Basin to the south and the Tucumcari Basin to the north (Fig. 1). Areal extent is approximately 7000 mi^2 in DeBaca, northern Roosevelt, southern Curry, northern Chaves, northeastern Lincoln, and southwestern Guadalupe Counties. Major volumes of oil and natural gas have been produced from the New Mexico part of the Permian Basin. During 2000, 63.8 million bbls oil and 533 billion ft^3 (BCF) gas were produced from the New Mexico portion of the Permian Basin. The northwestern part of the Permian Basin laps onto the southern edge of the Sin Nombre area. Oil and gas production within the Sin Nombre area has been obtained from the San Andres Formation (Permian), the Abo Formation (Permian), Pennsylvanian strata, Mississippian strata, the Fusselman Formation (Silurian), and the Montoya Formation (Ordovician; see Fig. 2 for stratigraphic column).

Oil and natural gas have been obtained from 17 oil and gas pools within Sin Nombre. Approximately 100 BCF gas and 6 million bbls oil have been produced from these pools within the boundaries of the Sin Nombre area. Most of the gas has been produced from low-permeability sandstone reservoirs within the Abo Formation, but Pennsylvanian and Mississippian limestones and Fusselman and Montoya dolostones are also important reservoirs. The most significant oil reservoirs to date have been Fusselman dolostones and Pennsylvanian limestones.

The purpose of this report is to document past oil and gas drilling, exploration and production activity and to provide an overview of the petroleum geology and petroleum potential of the Sin Nombre area. The report is meant to provide a useful source of data for those involved in the exploration for oil and natural gas in the Sin Nombre area and is also designed to provide an introduction to the petroleum geology of the area. Data presented in this report were obtained mostly from the New Mexico Library of Subsurface Data at the New Mexico Bureau of Geology and Mineral Resources. Supplementary data were obtained from the New Mexico Oil Conservation Division. The maps included in this report were developed explicitly for this report using data obtained from the sources mentioned above.

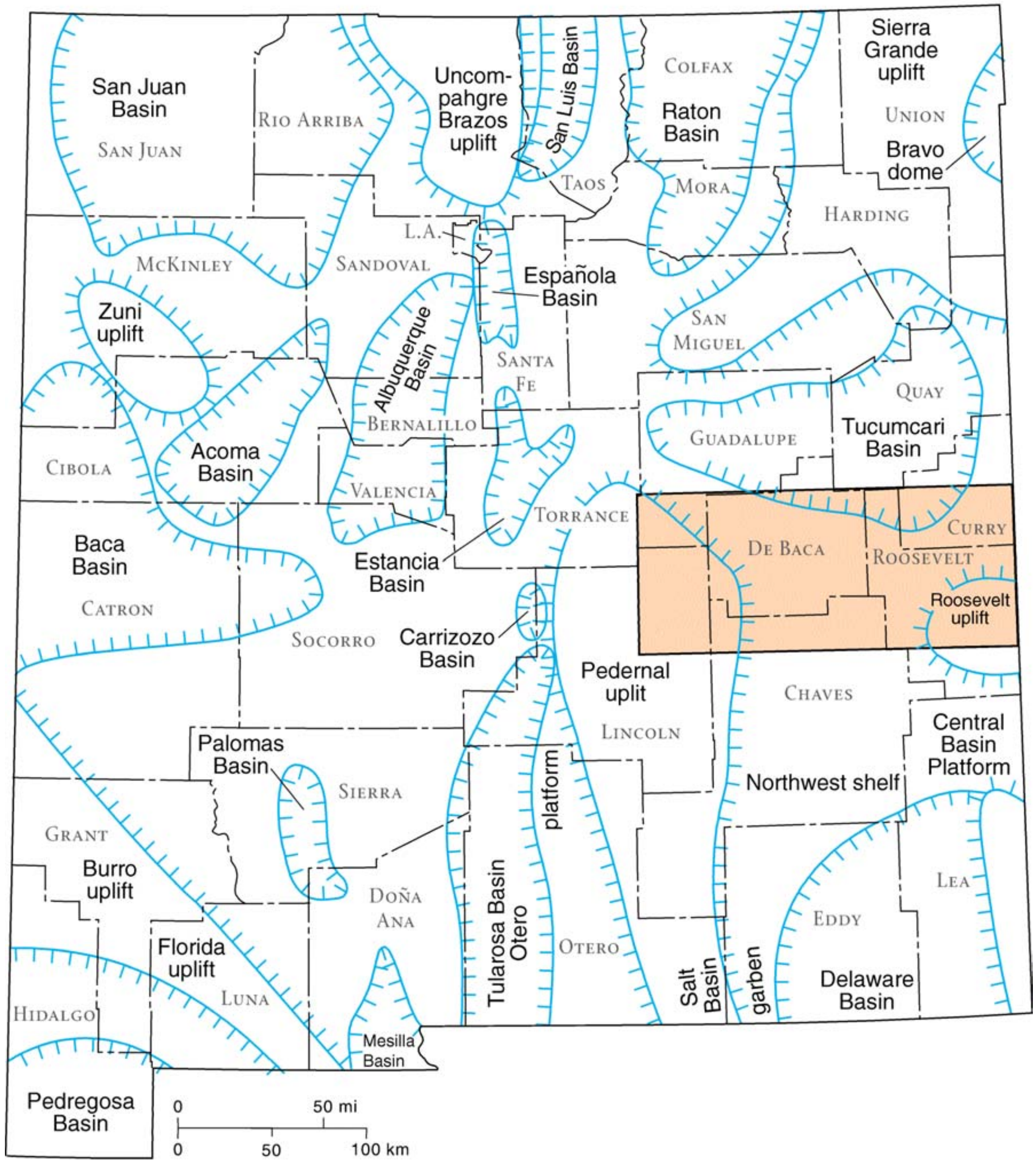

Figure 1. Location of Sin Nombre area (orange) and principal geologic basins of New Mexico.

This report contains four major parts. **The first part of the report** is this pdf document which presents key geologic and oil and gas maps and data for the Sin Nombre area and presents a summary of the petroleum geology.

Quaternary		undivided continental sediments
Tertiary		Ogallala Fm.
Triassic	Upper	Redonda Fm.
		Chinle Gp.
	Middle	Santa Rosa Ss.
Permian	Guadalupian	Artesia Gp.
	Leonardian	San Andres Fm.
		Glorieta Ss.
		Yeso Fm.
		Abo Fm.
	Wolfcampian	Hueco Gp.
Pennsylvanian	Virgilian	undivided
	Missourrian	
	Des Moinesian	
	Atokan	
	Morrowan	
Mississippian		undivided
Silurian		Fusselman
Ordovician		Montoya
Precambrian		igneous, metamorphic, volcanic

Figure 2. Stratigraphic column of Phanerozoic sedimentary units in the Sin Nombre area.

Numerous exploratory wells have tested the San Andres within the Sin Nombre area (Fig. 11). Most of the wells in the southern part of the area have not yielded shows; salt water has been recovered in many of these exploratory tests. In the northern part of the Sin Nombre area a number of San Andres tests have yielded oil and gas shows (Fig. 11). Perhaps oil and gas leaked updip from the Chaveroo Cato trend to the south. If so, the oil and gas may be trapped by porosity zones that pinchout updip to the north and northwest. Pitt and Scott (1981) mapped east-west trending porosity pinchouts within the San Andres in the Sin Nombre area. Alternatively, oil and gas in the northern part of Sin Nombre may have a local source (see Broadhead et al., 2002).

The second part of the report is a database of oil and gas exploratory and development wells (*Sin Nombre wells.xls*); the well database contains key well data for each well including location (expressed both in the section-township-range cadastral system of the U.S. Bureau of Land Management and as latitude-longitude coordinates), well depths, depths to top of key stratigraphic units, production data, well test data, and information on shows. The well database is more fully described in Appendix I of this document.

The third part of the report is a database of surface structures (*Sin Nombre surface structures.xls*) that contains data on geologic structures mapped at the surface and presented in the published literature that may affect the trapping and accumulation of hydrocarbons in the subsurface; most of the structures listed in the database are anticlines. The surface structure database is more fully described in Appendix II of this document.

The fourth part of the report is a series of geographic information systems (GIS) maps of key parameters useful in oil and gas assessments, including a map of surface structures, subsurface structure contour maps, and maps that indicate the locations of oil and gas production and nonproductive wells with oil and gas shows; these latter maps were developed for five stratigraphic units in the area: the San Andres Formation (Permian), the Abo Formation (Permian), the Pennsylvanian System, the Fusselman Formation (Silurian), and the Montoya Formation (Permian). The GIS maps are presented in *ArcReader* format. These maps are presented statically as part of this pdf document, but the GIS portrayal allows the user to overlay the maps on top of each other.

ArcReader is a free program made available by ESRI Corp. that allows the user to view the maps after the free *ArcReader* software is downloaded from this CD-ROM but does not allow modification of the maps with new data that the user may have. For this reason, all maps are also presented on this CD-ROM as an *ArcMap* project. If the user has *ArcMap* software, then the maps may be modified to fit additional data or additional map types may be created either from the well database or from databases that the user may supply. All GIS maps utilize the data presented in the well and surface structure databases. In order to use *ArcReader*, you must have one of the following three operating systems installed on your computer: 1) *Windows 2000*; 2) *Windows XP*; or 3) *Windows NT 4.0 with Service Pack 6a or later*.

ACKNOWLEDGEMENTS

This contract was funded by the New Mexico State Land Office (Dr. Ray Powell, Jr., Commissioner of Public Lands) through contract 02-24 to the New Mexico Bureau of Geology and Mineral Resources, a division of New Mexico Institute of Mining and Technology (New Mexico Tech). Larry Kehoe, Assistant Commissioner for Mineral Resources of the State land Office, and Jami Bailey, Deputy Director of the Oil, Gas & Minerals Division of the State Land Office were instrumental in acquiring funding for this work. Joe Mraz and Eleanore Nestlerode of the State Land Office provided helpful input into the design and purpose of this project and also suggested the name "*Sin Nombre*". The *Sin Nombre* name is not intended to describe the geography of this sparsely populated region, but rather its geologic position between two well-documented basins. Wade Brown, a computer science student at New Mexico Tech entered much of the data in the spreadsheets and also programmed the spreadsheets. Kathy Glesener and Leo Gabaldon drafted the illustrations.

STRUCTURE

Three geologic structure maps were prepared for this project. The maps are presented with this text as well as in *ArcReader* and *ArcMap* projects on this CD-ROM. One map depicts geologic structures that have been mapped at the ground surface (surface structures) and have been reported in the published literature (Fig. 3). The second map is a structure contour map that indicates the structural configuration of the top of the Precambrian (Fig. 4). The third map is a structure contour map that indicates the structural configuration of the top of the Abo Formation (Permian; Fig. 5).

Surface structure map

The surface structure map (Fig. 3) shows geologic structures that have been mapped at the surface in the Sin Nombre area. The structural features on this map were compiled from Winchester (1933), Mourant and Shomaker (1970), Kelley (1972), and the Bureau of Economic Geology (1974, 1978). Surface structures are summarized in a Microsoft Excel database (*Sin Nombre surface structures.xls*) that accompanies this report.

Portrayed surface structures are limited to anticlines and faults that may form hydrocarbon traps. Regional structures such as monoclines are not shown. The regional structures are better portrayed on the structure contour maps of the Abo Formation and Precambrian basement (Figs. 4, 5).

Many of the surface structures have deformed Triassic strata. Therefore, they are post-Triassic in age or have a post-Triassic component of movement. Similar structures to the north of the Sin Nombre area in northern Curry and DeBaca Counties are thought to be Laramide (Late Cretaceous - Early Tertiary) in age (Broadhead et al., 2002). Many of the surface structures in the region are thought to represent recurrent movement of buried structures of Pennsylvanian and Early Permian age that were associated with formation of the Ancestral Rocky Mountains. These older structures were reactivated during Laramide compression and perhaps during Tertiary extension as well.

Surface Structure

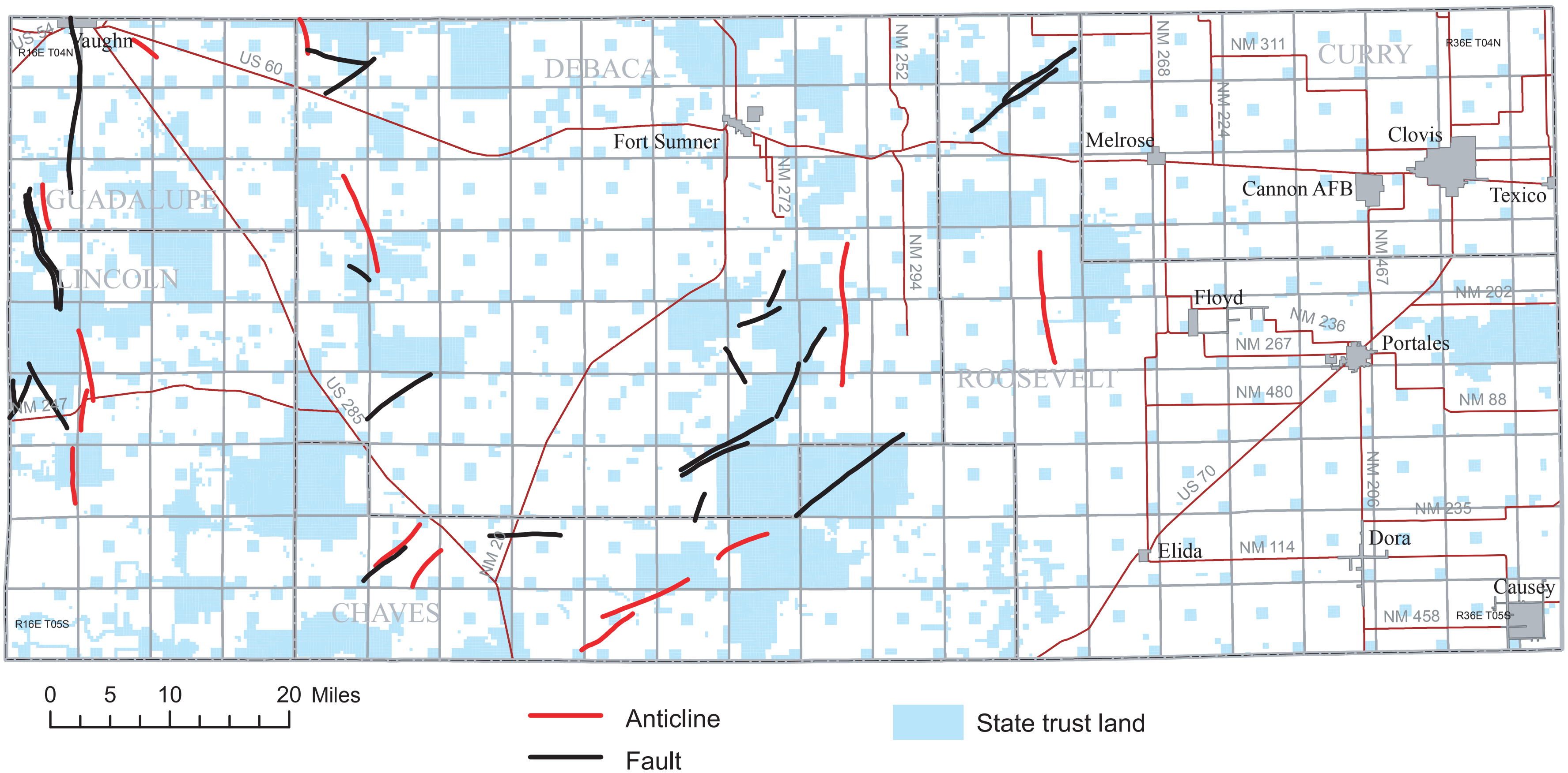

Figure 3. Map of anticlines and faults exposed at the surface (surface structures). See text for data sources and see Appendix II for description of structures.

Precambrian Structure

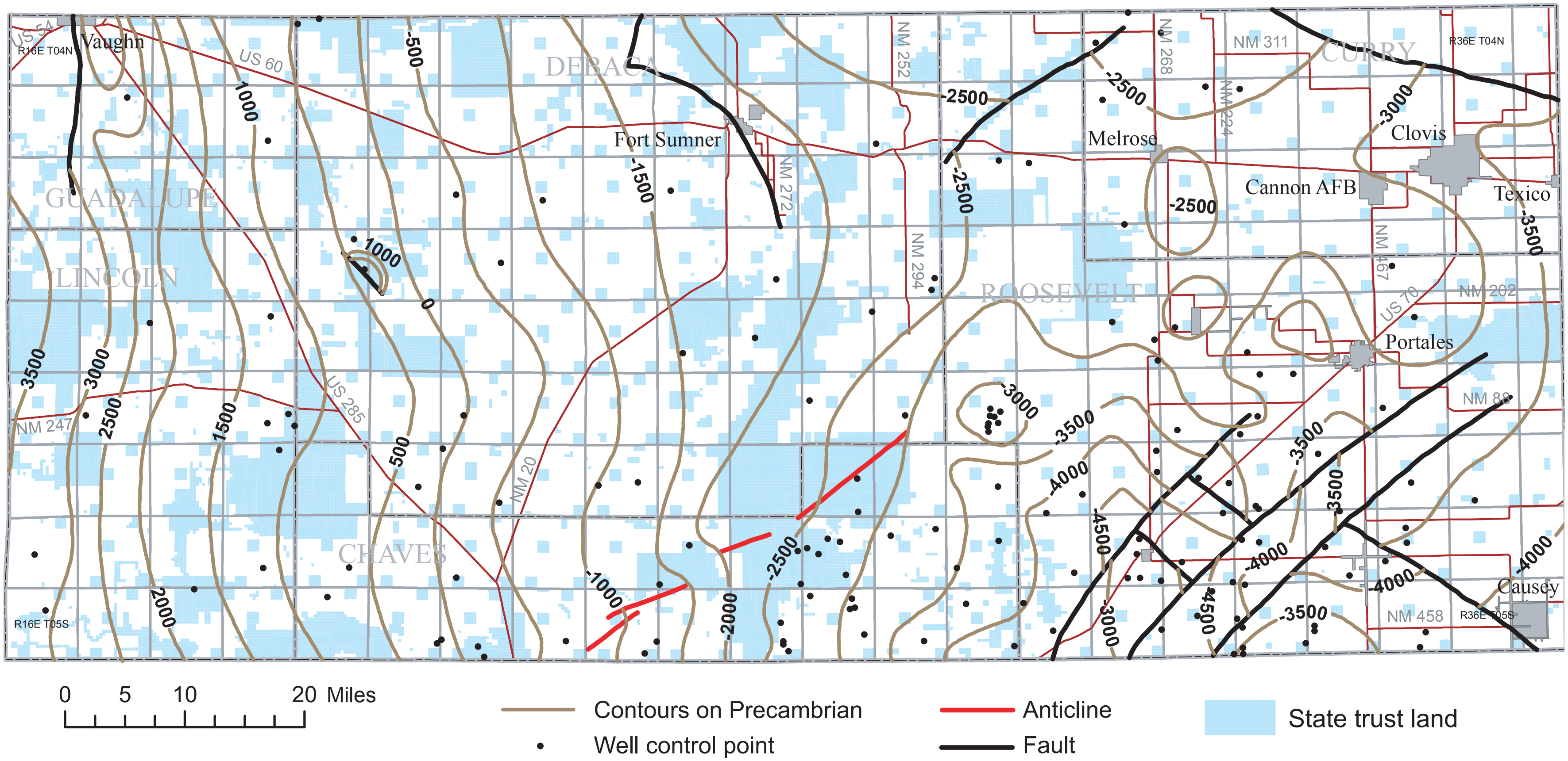

Figure 4. Structure contour map on top of Precambrian basement. Contour interval equals 500 ft.

Abo Structure

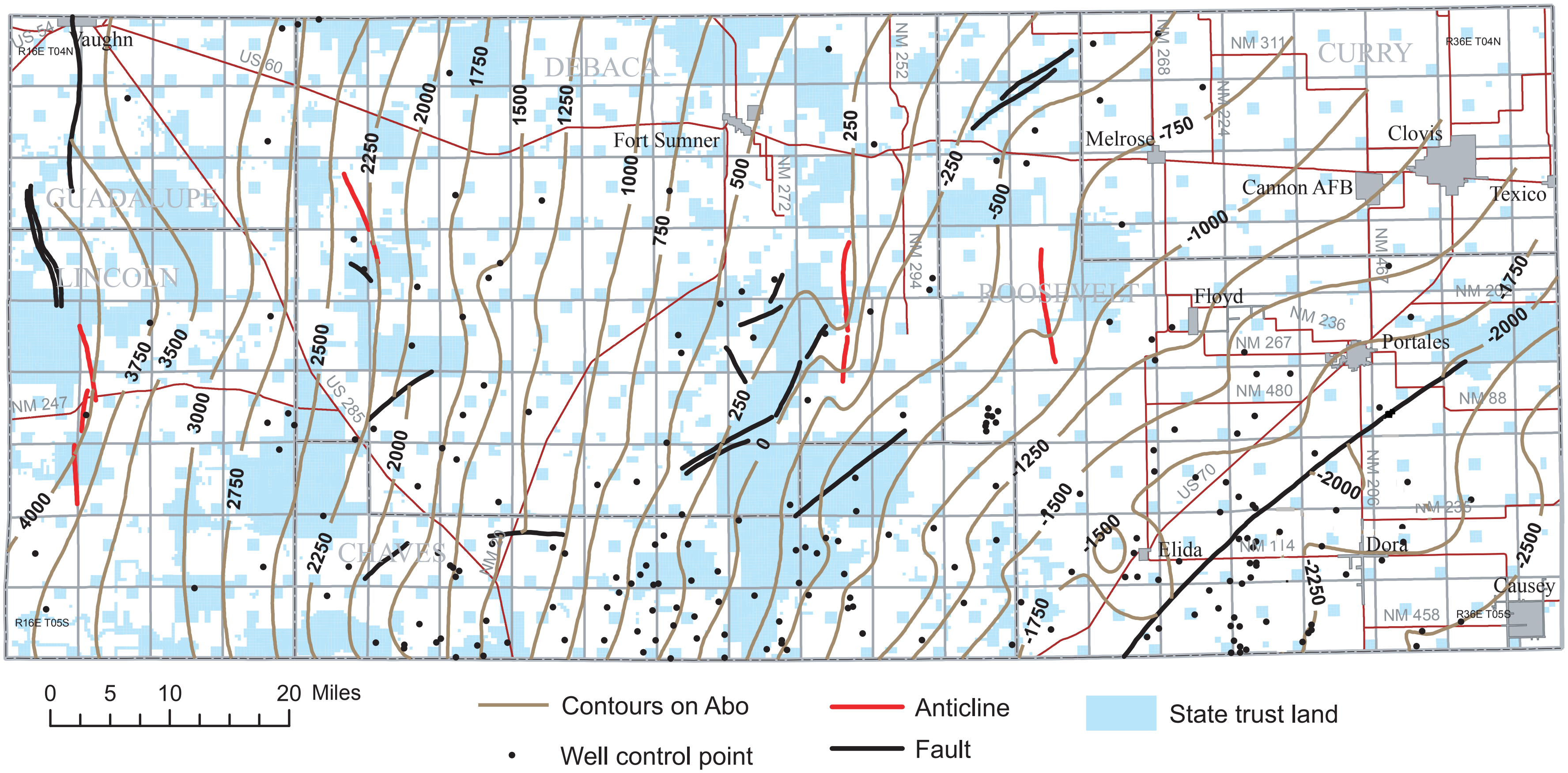

Figure 5. Structure contour map on top of Abo Formation. Contour interval equals 250 ft.

Precambrian and Abo structure contour maps

Contouring techniques: Primary data used in map preparation are from petroleum exploration wells (see accompanying Microsoft Excel database *Sin Nombre wells.xls*). In most of these wells, depth to the Abo Formation and the top of Precambrian was identified from wireline borehole logs and sample logs on file at the New Mexico Bureau of Geology and Mineral Resources. Where wireline logs and sample logs were not available, tops from scout cards were used. Because scout card tops are not always reliable and because they reflect inconsistencies in stratigraphic definitions among geologists, they were used less rigorously in contouring that tops correlated with wireline logs and sample logs.

For some wells, stratigraphic tops correlated with the wireline logs and sample logs were ambiguous. In these cases, stratigraphic tops were correlated only after drill cuttings were examined as part of this project. This was also the case for key wells which had no available wireline or sample logs.

Contouring was aided by several other types of data. These other data include the mapped surface structures previously discussed, regional Bouguer gravity anomaly and aeromagnetic anomaly maps, and geomorphic features. Seismic reflection surveys were not available for this project.

The regional Bouguer gravity anomaly map of Keller and Cordell (1983) and the regional aeromagnetic anomaly map of Cordell (1983) were used for this project. Regional gravity and aeromagnetic anomalies were found not to correspond to larger-scale variations in structure as defined by well data. The presence of thick sections of low-grade metasedimentary and metavolcanic rocks within the Precambrian (DeBaca terrain, see Muehlberger and others, 1967) as well as the presence of substantial Tertiary-age igneous intrusive rocks in the western part of the project area have limited the use of gravity and magnetic maps in structural interpretation because of overprinting of strong variations in basement lithology on the signatures resulting from the structural configuration of the Precambrian and the Abo. The relatively small vertical relief across structures is apparently insufficient to generate magnetic and gravity variations of sufficient intensity to exceed the variations generated by the variability of basement lithologies, at least without further filtering of the data.

Geomorphic data from topographic maps were also used in contouring. Many straight stream segments in the area appear to have resulted from differential erosion along faults. Most probably, these are mostly late Paleozoic faults that were gently reactivated by Laramide compression or post-Laramide extension. However, it is not possible to determine the sense or magnitude of offset of faults without additional subsurface data from either from wells or from seismic reflection lines. The geomorphic data were used only to map and project faults that were identified from vertical offsets apparent from well data. The well data suggest that many straight stream segments may be associated with faults that have vertical offsets of less than 100 ft and perhaps as little as 10 ft at the Precambrian surface; these faults are generally too small to be identified and mapped with the low density of wells in the Sin Nombre area. It is quite likely that faults with only a small amount of offset at the Precambrian surface are not readily detectable in 2D seismic lines. Pennsylvanian-age or Early Permian-age erosion of fault scarps where offset is small may have resulted in a beveled surface where the top of the Precambrian does not show a discrete offset across the fault.

Precambrian structure map: Precambrian structure is dominated by a uniform eastward dip of approximately 1^{o} across the entire Sin Nombre area (Fig. 4). The elevation of the Precambrian basement decreases from 3500 ft above sea level along the western boundary to 4500 ft below sea level in the southeast. Structure on the west is dominated by the eastern flank of the Pedernal uplift, an Ancestral Rocky Mountains structure of Pennsylvanian and Early Permian age. In this area, clastic red beds of the Abo Formation (Permian: Wolfcampian) rest directly on the Precambrian (Figs. 6, 7). Towards the east, progressively older sedimentary strata overlie Precambrian basement (Figs. 8, 9, 10). The central part of the Sin Nombre area is dominated by an east-plunging structural nose that separates the Northwest shelf of the Permian Basin on the south from the Tucumcari Basin on the north.

The southeast part of the Sin Nombre area is a positive structural element formed by the north end of the Roosevelt uplift. This positive structural feature is also known as the Portales arch (Pitt, 1973). Some workers consider this structure to be the western terminus of the Matador arch of Texas. The Roosevelt uplift has been mapped as being cut by several high-angle faults (Fig. 4). These faults were identified by structural offsets apparent from well data. Many of the faults were drawn parallel to the northeast-southwest structural trend that dominates much of eastern New Mexico. Other faults are parallel to the northwest-southeast structural trend that extends into New Mexico from adjacent parts of Texas and Chihuahua. Additional faults could almost certainly be identified from seismic lines. The largest faults in the area have maximum vertical offsets of only a few hundred feet, considerably less than what is seen in the Tucumcari Basin to the north (see Broadhead et al., 2002).

Abo structure map: Abo structure is dominated by an eastward structural dip of approximately 0.6° (Fig. 5). The elevation of the top of the Abo Formation decreases from 4000 ft above sea level along the western boundary of the Sin Nombre area to 2500 ft below sea level in the southeast. The eastward dip is less than that exhibited by the upper surface of the Precambrian. The east plunging structural nose evident on the Precambrian surface that separates the Permian Basin from the Tucumcari Basin is not evident on the Abo structure map. By Abo time, both the low area off the eastern flank of the Pedernal uplift and the structural divide between the Permian and Tucumcari Basins had been buried by strata of Pennsylvanian and Abo age.

Most of the faults and domal structures evident on the upper surface of the Precambrian in Roosevelt County are not evident on the Abo structure map. These are Pennsylvanian to Early Permian structures associated with the Ancestral Rocky Mountains. By the end of Abo time, movement of these structures ceased and they became buried beneath the clastic detritus of the Abo Formation.

Only one of the faults shown on the Precambrian structure map had continued significant movement past the end of Abo deposition. This fault trends northeast-southwest and has a maximum 250 ft offset at the top of the Abo (Fig. 5). Vertical offset at the top of the Precambrian varies from 400 ft to almost 2000 ft, indicating that most movement along the fault occurred before the end of Abo deposition.

STRATIGRAPHY

Rocks from Precambrian through Triassic age are present in the Sin Nombre area (Fig. 2). A thin veneer of poorly consolidated to unconsolidated Tertiary and Quaternary sands, gravels, silts, and clays overlies the Precambrian through Triassic rocks. This section describes the general stratigraphy of the Sin Nombre area.

Precambrian

Precambrian rocks of the Sin Nombre area are granites, gneisses, volcanics, and metasediments (Muehlberger et al., 1967). Volcanic rocks are metarhyolites and amphibolites. Metasedimentary rocks are schists and quartzites. The metarhyolites and metasedimentary rocks constitute an unknown thickness of layered Precambrian section that overlies a complex crystalline core. All of these lithologies appear to have been intruded by amphibolites and other mafic igneous rocks.

Ordovician

Ordovician strata of the Montoya Formation unconformably overlie Precambrian basement in the southeastern part of the Sin Nombre area (Fig. 6). The Montoya Formation is not present elsewhere (Figs. 7-10). The Montoya consists of white cherty dolostone. Maximum thickness is approximately 150 ft.

Silurian

Silurian strata of the Fusselman Formation unconformably overlie the Montoya dolostones in the southeast part of the Sin Nombre area (Fig. 6). The Fusselman is not present elsewhere (Figs. 7-10). The Fusselman consists of white to tan dolostones. Maximum thickness is approximately 200 ft.

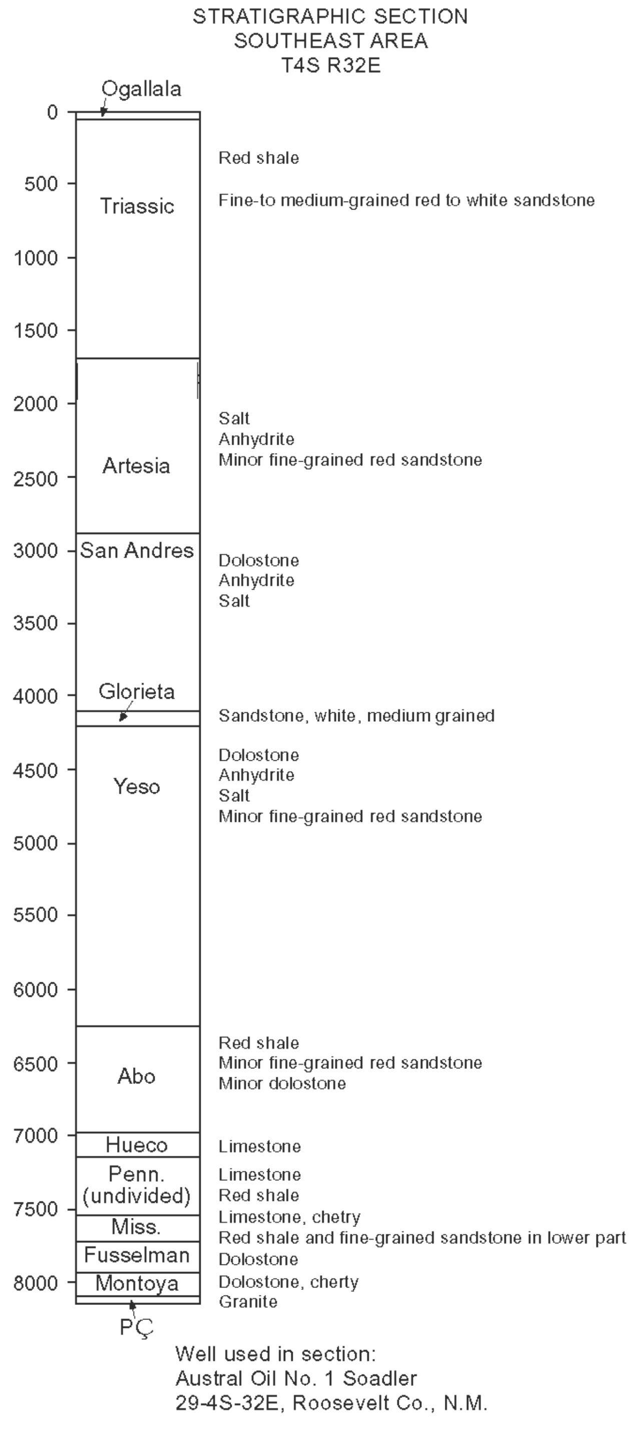

Figure 6. Stratigraphic section of southeast part of Sin Nombre area.

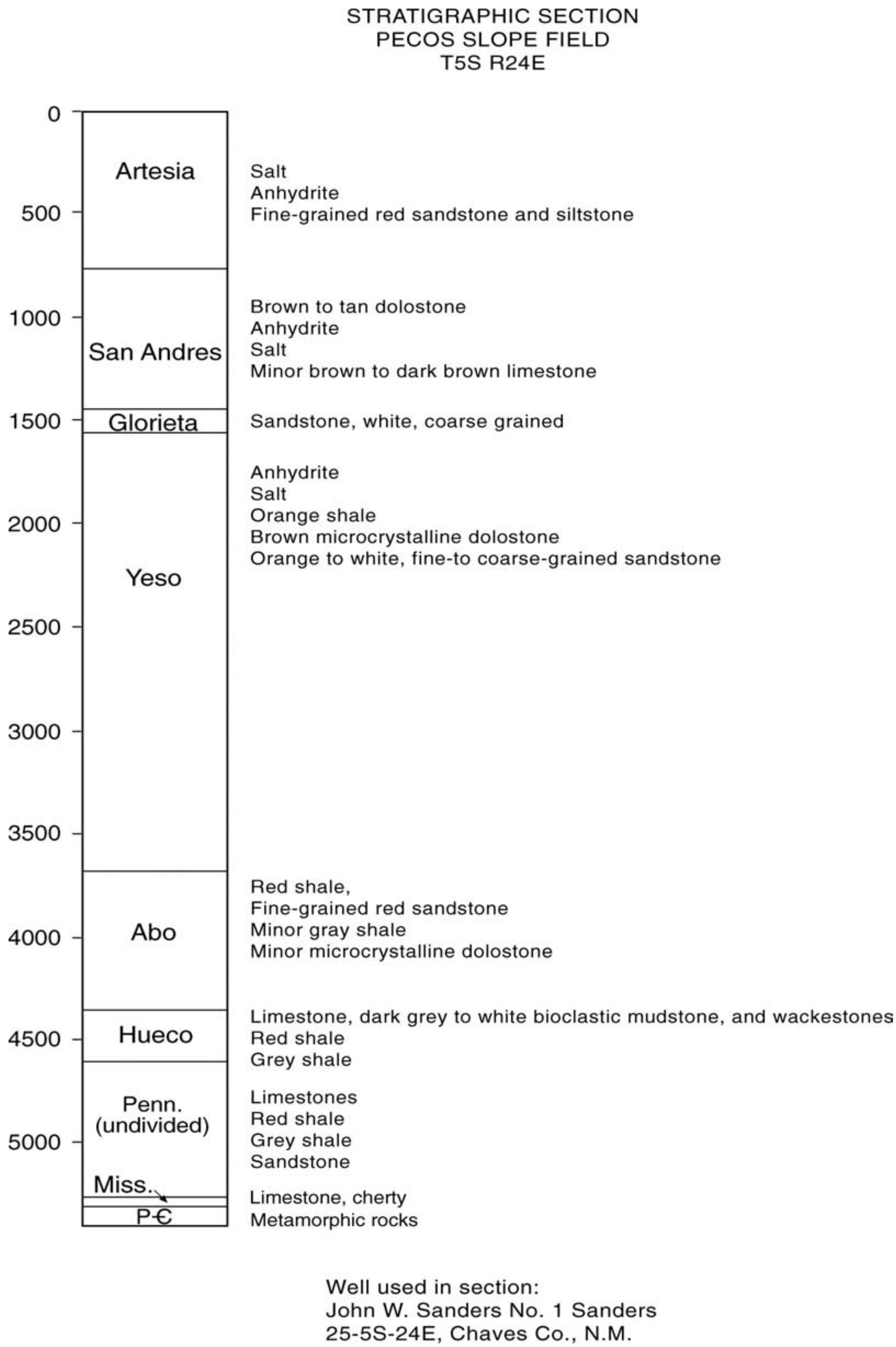

Figure 7. Stratigraphic section of south-central part of Sin Nombre area, in the vicinity of the Pecos Slope Abo gas pool.

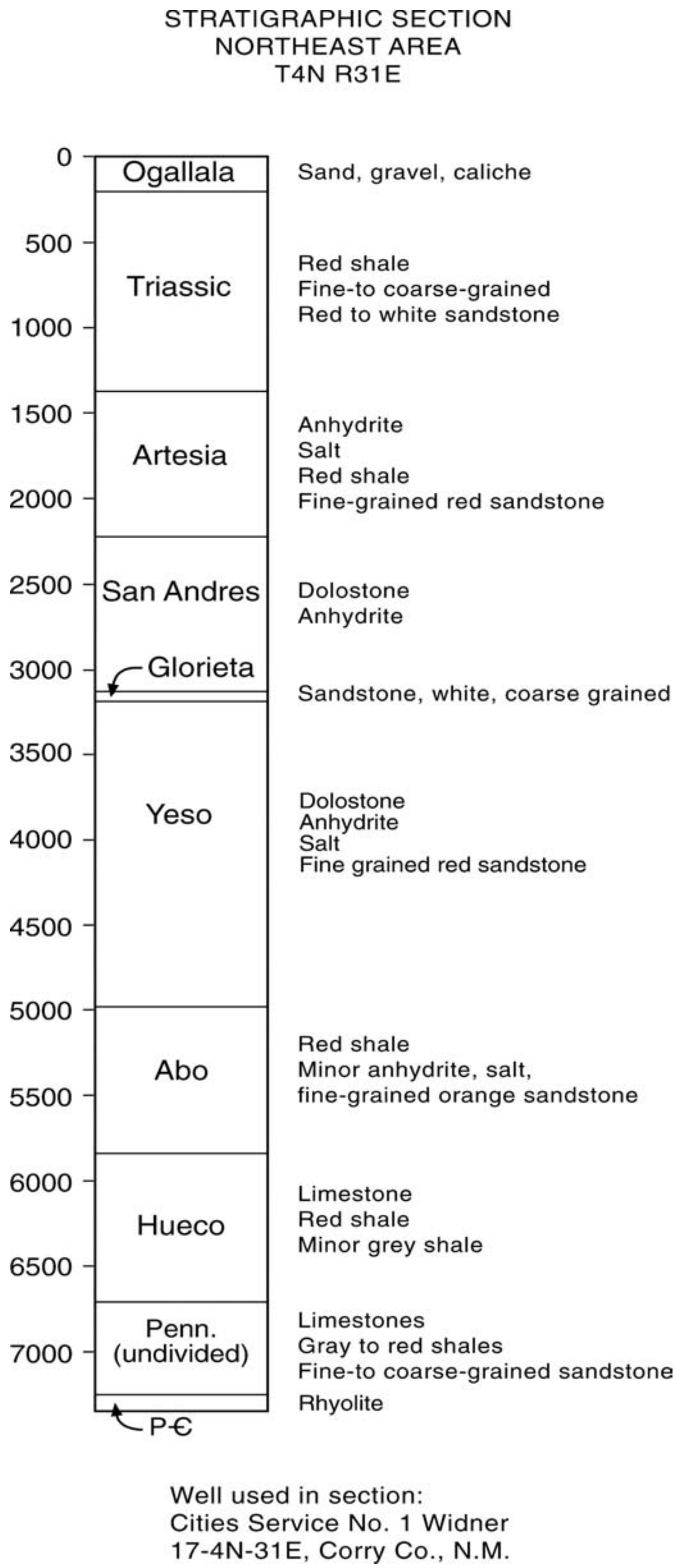

Figure 8. Stratigraphic section of northeast part of Sin Nombre area.

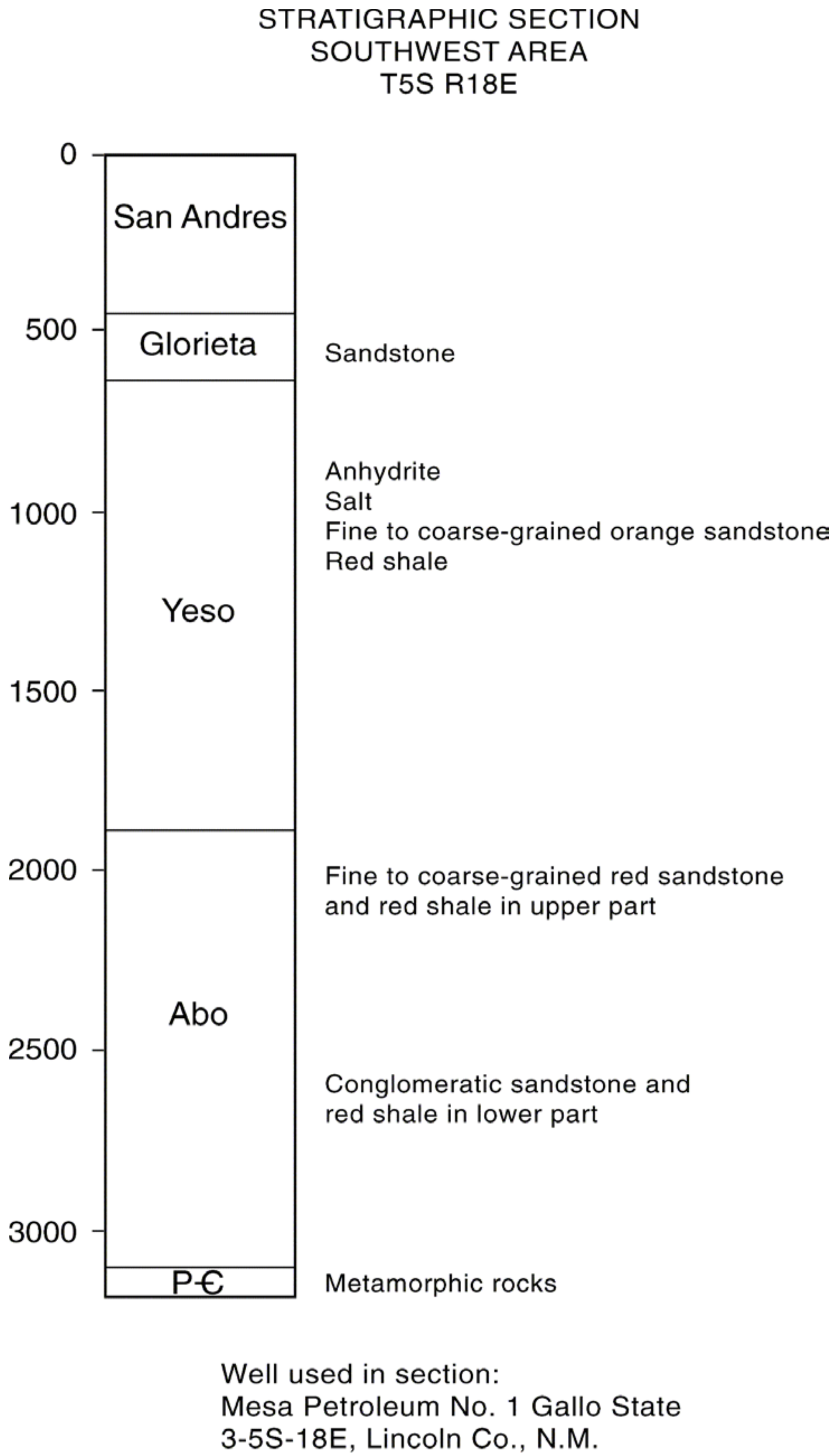

Figure 9. Stratigraphic section of southwest part of Sin Nombre area.

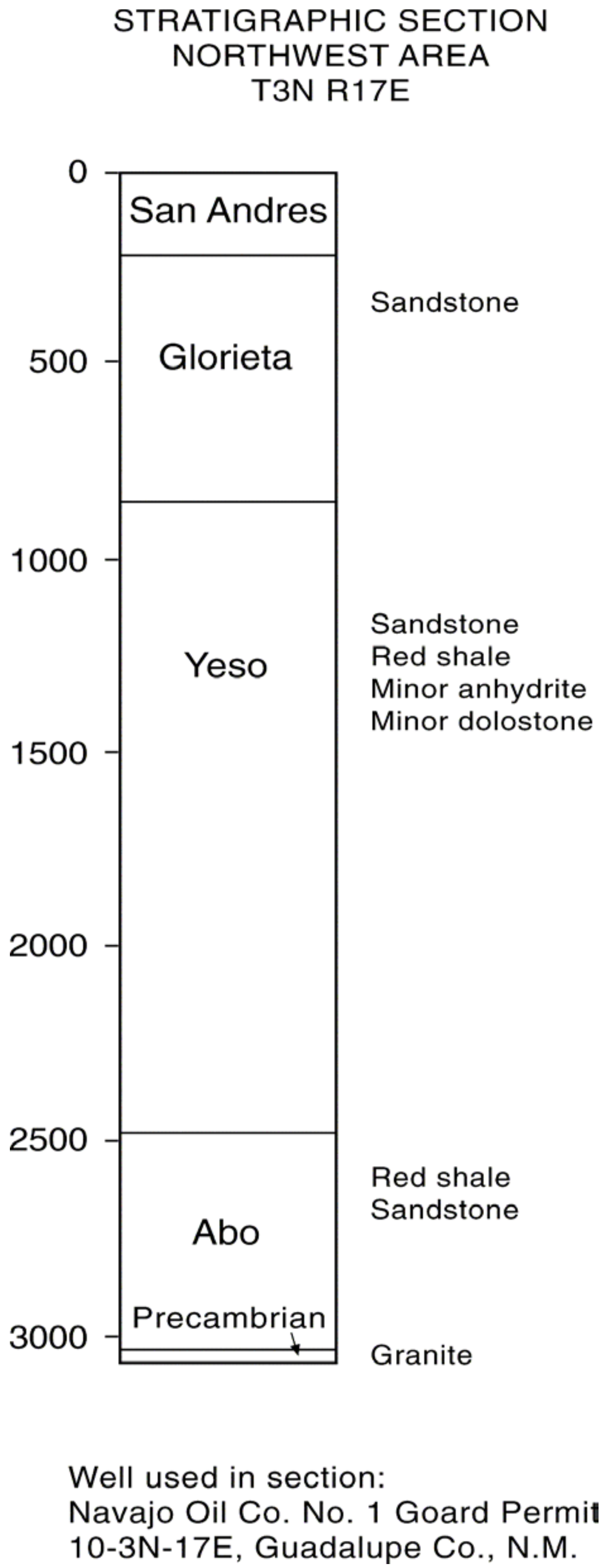

Figure 10. Stratigraphic section of northwest part of Sin Nombre area.

Mississippian

Mississippian strata unconformably overlie Silurian dolostones in the southeast part of the Sin Nombre area (Fig. 6). In this area Mississippian strata are approximately 200 ft thick and consist mostly of white cherty limestones. Minor red shales and fine-grained sandstones are present near the base of the section. The Mississippian thins to the north and west. In the south-central part of the Sin Nombre area at the Pecos Slope field, it is only 30 ft thick and unconformably overlies the Precambrian (Fig 7). The Mississippian is absent in the northern and western parts of Sin Nombre (Figs. 8-10).

Pennsylvanian

Pennsylvanian strata unconformably overlie Mississippian strata in the southeast and south-central parts of the Sin Nombre area (Figs. 6, 7). The Pennsylvanian is 650 ft thick at the Pecos Slope field and thins eastward to 400 ft over the Roosevelt uplift. To the north, the Pennsylvanian rests unconformably on Precambrian basement and is approximately 500 ft thick (Fig. 8). The Pennsylvanian is absent from the Pedernal uplift on the west (Figs. 9, 10). Within the Sin Nombre area, the Pennsylvanian consists of marine limestone, red to gray shale, and minor coarse-grained arkosic sandstone.

Permian

Permian strata in the Sin Nombre area are Wolfcampian (Early Permian) to Guadalupian (Late Permian) in age (Fig. 2). Lithostratigraphic units are (ascending): Hueco Group (Wolfcampian), Abo Formation (Wolfcampian to Leonardian), Yeso Formation (Leonardian), Glorieta Sandstone (Leonardian), San Andres Formation (Leonardian), and the Artesia Group (Guadalupian).

Hueco Group (Wolfcampian): The Hueco Group overlies Pennsylvanian strata in the central and eastern parts of the Sin Nombre area. It is 250 ft thick near the Pecos Slope Field (Fig. 7) and thins to approximately 200 ft over the Roosevelt uplift (Fig. 6). To the northeast, it thickens to 850 ft (Fig. 8). To the west, it pinches out on the flank of the Pedernal uplift (Figs. 9, 10). The Hueco consists predominantly of limestones and red shales and minor gray shales and fine- to coarse-grained arkosic sandstones. Percentage of limestone appears to increase to the south and to the northeast.

Abo Formation (Wolfcampian to Leonardian): The Abo Formation rests conformably on Hueco strata in the central and eastern parts of the Sin Nombre area (Figs. 6-8). To the west, it rests unconformably on Precambrian basement (Figs. 9, 10). The Abo is 650 to 750 ft thick in the south-central and southeast areas (Figs. 6, 7). It thickens slightly to 850 ft in the northeast (Fig. 8). To the northwest, the Abo thins to 550 ft (Fig. 10). In the southwest, it is 1200 ft thick (Fig. 9); however, the lower 500 ft are correlative with Hueco strata and only the upper 700 ft are equivalent to the Abo described elsewhere in the Sin Nombre area (Broadhead, 1984a). The Abo consists predominantly of red shales and interbedded fine-grained arkosic sandstones at Pecos Slope (Broadhead, 1984a; Bentz, 1992). To the west, the lower Abo (Hueco Equivalent) contains thickly bedded arkosic conglomerates that are Hueco in age. In the southeastern part of the Sin Nombre area, the clastic red beds of the Abo are interbedded with marine dolostones; most of the dolostones are present within the lower 200 ft.

Yeso Formation (Leonardian): The Yeso Formation rests disconformably upon the Abo Formation. The Yeso is approximately 2000 ft thick in the south-central and southeast parts of Sin Nombre (Figs. 6, 7). It thins to the west to 1200 to 1600 ft as it onlaps the Pedernal uplift (Figs. 9, 10) and to 1800 ft in the northeast (Fig. 8). The Yeso consists of interbedded dolostone, anhydrite, salt, red to orange shale, and red to orange, fine- to coarse-grained sandstone. Percentage sandstone and shale increases to the west as the Yeso onlaps the Pedernal uplift.

Glorieta Sandstone (Leonardian): The Glorieta Sandstone rests on the Yeso Formation. It consists of white, medium- to coarse-grained, rounded sandstone. The Glorieta is 50 to 100 ft thick throughout most of the Sin Nombre area. It thickens to more than 600 ft in the northwest (Fig. 10), but much of the Glorieta in the northwest is probably laterally correlative with the lower parts of the San Andres Formation and reflects a northwest transition from marine carbonate and evaporite facies of the San Andres to coastal and marginal marine sands of the Glorieta.

San Andres Formation (Leonardian): The San Andres Formation conformably overlies and intertongues with the Glorieta Sandstone. The San Andres crops out over a large part of the western quarter of the Sin Nombre area and dips eastward beneath younger Permian strata. The San Andres consists primarily of dolostone, anhydrite, and salt. It is 1200 ft thick in the southeast part of the Sin Nombre area (Fig. 6). It thins to 900 ft in the northeast (Fig. 8), 700 ft at the Pecos Slope field (Fig. 7), and less than 200 ft along the west side of the Sin Nombre area where the upper part crops out at the ground surface. Pitt and Scott (1981) discussed regional porosity pinchouts and lithology of the lower San Andres in east-central New Mexico.

Artesia Group (Guadalupian): The Artesia Group unconformably overlies the San Andres Formation. The Artesia Group crops out or is overlain by Tertiary and Quaternary sediments throughout large parts of the western half of the Sin Nombre area. It has been removed by erosion from the westernmost parts. The Artesia Group is comprised of anhydrite, salt, red shale, and fine-grained red sandstone. Percentage of clastic constituents increases toward the north and the west. The Artesia Group is approximately 750 ft thick at the Pecos Slope field (Fig. 7) where the upper part has been removed by Tertiary, Quaternary, and Recent erosion. To the southeast, it is 1000 ft thick and is overlain by younger Permian strata (Fig. 6). It thins to 850 ft in the northeast (Fig. 8). Tait et al. (1962) and Broadhead (1984b) have discussed the internal stratigraphy of the Artesia Group in the region.

Triassic

Triassic strata are present over the eastern two-thirds of the Sin Nombre area where they either crop out or are overlain by up to 200 ft of Tertiary and Quaternary sands and gravels. The Triassic unconformably overlies Permian strata. The Triassic section attains a maximum thickness of approximately 1600 ft in the southeast and thins to the north and west. Triassic strata consist of maroon, lacustrine to fluvial shales with fine- to coarse-grained, poorly sorted, red to white fluvial sandstones and minor lenticular beds of gypsum and finely crystalline limestones (Mourant and Shomaker, 1970; McGowen et al., 1979; Broadhead, 1984b; Lucas et al., 2001). The Santa Rosa Sandstone comprises the lower 110 to 240 ft and is a significant aquifer of potable water (Mourant and Shomaker, 1970).

In the Tucumcari Basin, the Santa Rosa sandstone contains two significant accumulations of heavy oil thought to have been sourced within the Pennsylvanian section (Budding, 1979; McKallip, 1984; Broadhead, 1984b; Broadhead et al., 2002). The Chinle Group, also of Triassic age, overlies the Santa Rosa Sandstone and contains minor, lenticular sandstones, which form minor aquifers. The Redonda Formation has a maximum thickness of 300 ft and consists of reddish fine-grained sandstones, siltstones, and shales overlies the Chinle Group. The Redonda Formation forms the uppermost part of the Triassic section.

Tertiary and Quaternary

The Ogallala Formation (Tertiary: Pliocene) unconformably overlies Triassic strata. The Ogallala consists of up to 100 ft of poorly consolidated gravel, sand, silt, and clay. It is the most important aquifer of potable water in the region (Mourant and Shomaker, 1970).

Unconsolidated eolian, playa, and fluvial sands, gravels, silts and clays of Quaternary age unconformably overlie the Ogallala (Mourant and Shomaker, 1970; Bureau of Economic Geology, 1974, 1978). These are exposed at the surface throughout large portions of the eastern two-thirds of the Sin Nombre area. Thickness exceeds 200 ft in places (Mourant and Shomaker, 1970). The younger part of the Quaternary section is an important source of stock and irrigation water but aquifers in the older part of the Quaternary may be highly saline (Mourant and Shomaker, 1970).

OIL AND GAS PRODUCTION, SHOWS AND POTENTIAL

Oil and natural gas have been produced from six stratigraphic units within the Sin Nombre area: the San Andres Formation (Permian), the Abo Formation (Permian), the Pennsylvanian System, the Mississippian System, the Fusselman Formation (Silurian), and the Montoya Formation (Ordovician). The Abo Formation has yielded the most gas, almost 74 billion ft^3 (BCF), and the Fusselman has yielded the most oil, 3.7 million bbls (see Table 1). Significant shows of oil and gas have also been encountered in these units in abandoned exploratory test wells. Oil and gas pools and shows will be discussed for each of these six stratigraphic units, beginning with the shallowest which is the most densely drilled. Hydrocarbon shows have also been reported from the Triassic, the Artesia Group (Permian), the Glorieta sandstone (Permian), the Yeso Formation (Permian), and from Precambrian basement.

San Andres Formation (Permian: Leonardian)

Only marginally commercial gas has been produced from the San Andres Formation within the Sin Nombre area. A single well, the Marshall No. 1 Soltenberg produced gas briefly from the San Andres in the Tule pool (Fig. 11). The well produced a cumulative total of 1741 MCF during 1993 but has not been produced since. A second well, the Flag Redfern No. 1 State 17, located in Sec. 17 T1S R25E DeBaca County, was tested for gas in the San Andres and had an initial potential of 565 thousand ft^3 gas per day (MCFD). The well is located more than 15 miles north of pipelines in the Pecos Slope Abo pool; the remoteness from a pipeline system may have contributed to the accumulation not being developed or produced.

Nearest established, commercial production from San Andres reservoirs is located 4 to 10 miles south of the Sin Nombre area along a major trend that stretches eastward from T6S R26E to T7S R38E. That trend is formed by more than 30 oil pools, including Chaveroo, Tom Tom, and Cato. Cumulative oil production from the Chaveroo, Tom Tom and Cato pools exceeds 37 million bbls oil. Traps along the trend are formed by porosity zones that pinchout updip to the north within the lower San Andres (Gratton and LeMay, 1969; Yedlosky and McNeal, 1969; Cowan and Harris, 1986; Ward et al, 1986; and Keller, 1992).

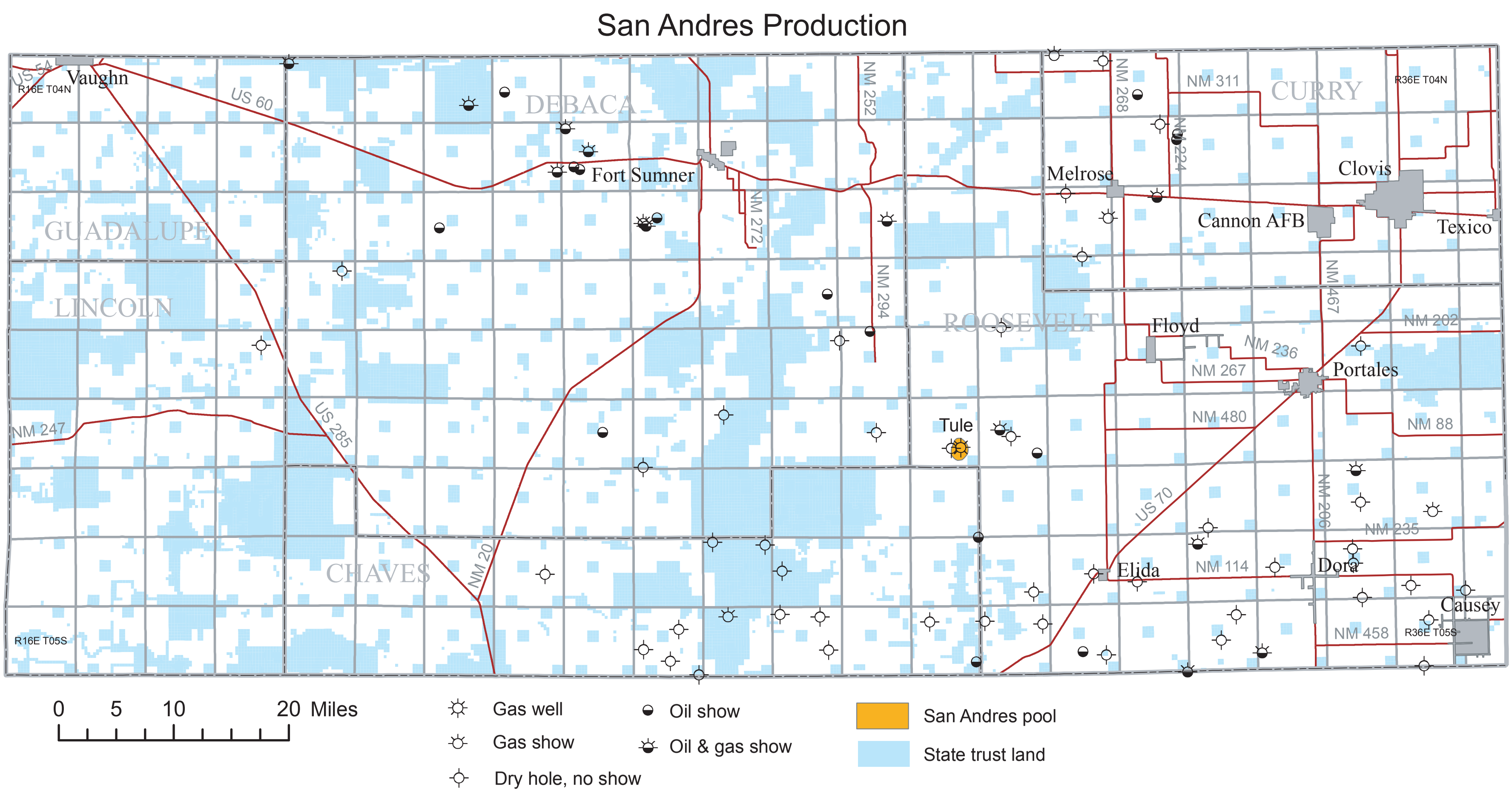

Figure 11. Production, shows, and unsuccessful tests in the San Andres Formation. Shown are wells that have established production from the San Andres, wells with oil and gas shows in the San Andres, and wells that tested the San Andres with drill stem tests or casing perforations but which had no shows. See well database (SinNombre wells.xls) for well data.

Numerous exploratory wells have tested the San Andres within the Sin Nombre area (Fig. 11). Most of the wells in the southern part of the area have not yielded shows; salt water has been recovered in many of these exploratory tests. In the northern part of the Sin Nombre area a number of San Andres tests have yielded oil and gas shows (Fig. 11). Perhaps oil and gas leaked updip from the Chaveroo Cato trend to the south. If so, the oil and gas may be trapped by porosity zones that pinchout updip to the north and northwest. Pitt and Scott (1981) mapped east-west trending porosity pinchouts within the San Andres in the Sin Nombre area. Alternatively, oil and gas in the northern part of Sin Nombre may have a local source (see Broadhead et al., 2002).

Abo Formation (Permian: Wolfcampian to Leonardian)

The Abo Formation is the most productive stratigraphic unit within the Sin Nombre area. Cumulative production within the Sin Nombre area is 73.7 BCF gas and 78.5 million bbls condensate from 238 wells. Production is from the Pecos Slope, Pecos Slope West and Pecos Slope North pools (Fig. 12). The largest part of the Pecos Slope and Pecos Slope West pools lies to the south of the Sin Nombre area. Cumulative gas production from the entire Pecos Slope Abo pool is 384 BCF (Table 1); less than 20 percent of this has come from the Sin Nombre area with remainder having been produced from that part of the pool south of the Sin Nombre area. Cumulative gas production from the Pecos Slope Abo West pool is 32.3 BCF (Table 1); only 3 percent of this gas has been obtained from within the Sin Nombre area with the remainder having been produced from that part of the pool south of the Sin Nombre area.

The upper two-thirds of the Abo is productive at Pecos Slope and Pecos Slope West. Abo reservoirs are red, fine- to very fine-grained, low-permeability, lenticular, fluvial-deltaic sandstones (Broadhead, 1984; Bentz, 1992). Seals are provided by interbedded red siliciclastic shales. Average net pay is 30 ft (Bentz, 1992). Average porosity of productive sandstones is 12 to 14 percent (Bentz, 1988). Average in situ permeability is 0.0067 millidarcies (New Mexico Oil Conservation Division Case File 7093).

Abo Production

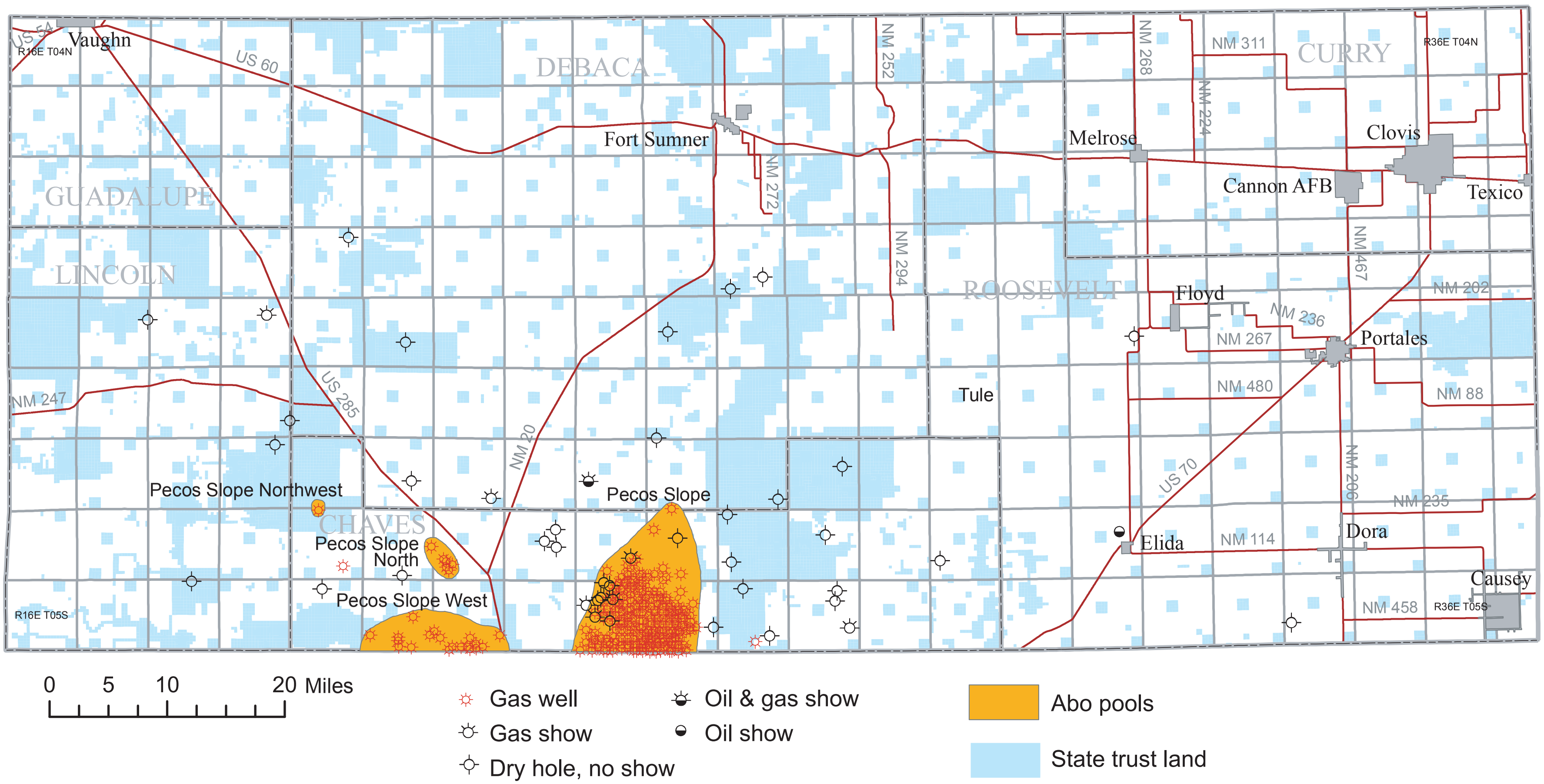

Figure 12. Production, shows, and unsuccessful tests in the Abo Formation. Shown are wells that have established production from the Abo, wells with oil and gas shows in the Abo, and wells that tested the Abo with drill stem tests or casing perforations but which had no shows. See well database (SinNombre wells.xls) for well data.

Table 1. Cumulative oil, gas and water production from oil and gas pools in the Sin Nombre area. Data from New Mexico Oil Conservation Division as reported by New Mexico Oil and Gas Engineering Committee.

Pool name	Productive Stratigraphic Unit	Oil/condensate production, Cumulative 12/31/2000 thousand bbls	Gas Production, Cumulative 12/31/2000 million ft^3	Water Production, Cumulative 12/31/2000 thousand bbls	Number Active wells, 12/31/2000[1]
Pecos Slope[2]	Abo	47	383935	265	854
Pecos Slope West[2]	Abo	0.04	32310	26	194
Pecos Slope North	Abo	0	63	0	4
Tule	Pennsylvanian	11	2304	170	4
Newmill	Pennsylvanian	0	440	0	1
Peterson North	Pennsylvanian	494	301	168	6
Peterson	Pennsylvanian	887	5614	1069	5
Peterson South	Pennsylvanian	586	13395	655	14
Dora	Pennsylvanian	19	39	6	1
Dora North	Pennsylvanian	225	430	6	2
Stingray	Pennsylvanian	0.8	0	2	0
Undesignated	Pennsylvanian	76	1125		1
Peterson	Mississippian	150	465	33	5
Peterson	Fusselman	308	208	5718	1
Peterson South	Fusselman	3387	2876	21998	10
Tule	Montoya	15	1790	8	3
Dos Ranchos	Montoya	0	37	54	1
Tule	San Andres	0	2	0	1

[1] Number of active wells includes wells that produced oil or gas at the end of 2000 and wells listed as shut-in or temporarily abandoned. Number of active wells does not include wells formerly productive that have now been plugged and abandoned.
[2] Most production in the Pecos Slope and Pecos Slope West pools has been obtained from south of the Sin Nombre area. Those two important gas pools have produced 74 BCF gas from within the Sin Nombre area. The data in this table are for the entire pool, including those portions that are outside of the Sin Nombre area.

The trapping mechanism at Pecos Slope and Pecos Slope West is poorly understood. The distribution of reservoir sandstones (Fig. 13a) and Abo structure (Fig. 13b) indicates stratigraphy plays a partial role in trapping; production is confined to the sandy, distal lobes of the fluvial-deltaic system. The northern, updip limits of production at Pecos Slope and Pecos Slope West are not defined by discrete structural or lithologic breaks. Instead, there seems to be a transition from downdip gas-productive sandstones in the south to updip water-bearing sandstones in the north (Fig. 13a: Bentz, 1988, 1992). It is possible that the northern margins of the gas accumulations are related to either a capillary pressure barrier or a northward loss of internal shale seals within the fluvial system (Broadhead, 1993).

As a result of the discovery of the Pecos Slope pools in the late 1970's, there were a number of attempts to establish additional gas production from the Abo in northern Chaves and southern DeBaca Counties (Fig. 12). Most of the wells drilled in these exploratory efforts unsuccessfully tested the Abo. However, a few wells did encounter gas shows or tested relatively low flow rates of gas that may have been productive had pipelines been located nearby. These positive test wells broadly outline areas of future gas potential and indicate that gas has migrated into the Abo north of the Pecos Slope and Pecos Slope West pools.

Pennsylvanian System

Significant volumes of oil and gas have been produced from Pennsylvanian strata in the Sin Nombre area. A cumulative total of 2.3 million bbls oil and 23.6 BCF gas have been produced from eight pools (Fig. 14; Table 1). At the end of 2000, there were 34 active wells in Pennsylvanian reservoirs within the Sin Nombre area (Table 1). All established pools are in the southeast quadrant of the Sin Nombre area. Pennsylvanian oil pools in the area are structural-stratigraphic traps formed by drape of Pennsylvanian strata over early Pennsylvanian structures (Fig. 15; Green and Schlueter, 1988; Ahlen, 1988; Speer, 1993). Porosity is vugular and results from leaching of phylloid algal plates and other skeletal material. An early Pennsylvanian bed of detrital material is present on the flanks of some structures (Green and Schlueter, 1988; Fig. 15); this detrital section is composed of debris eroded from the top of the structure and includes fragments of limestone, dolostone, chert, red shale, and gray shale. Oil shows have been reported from this detrital section at the Peterson field (Green and Schlueter, 1988) and therefore it should be considered as an exploration target when encountered in flank locations of Pennsylvanian-age structures. Productive Pennsylvanian reservoirs in the Peterson area have been correlated as Canyon (Upper Pennsylvanian: Missourian). Productive reservoirs in the Newmill area have been correlated as Strawn (Middle Pennsylvanian: Desmoinesian).

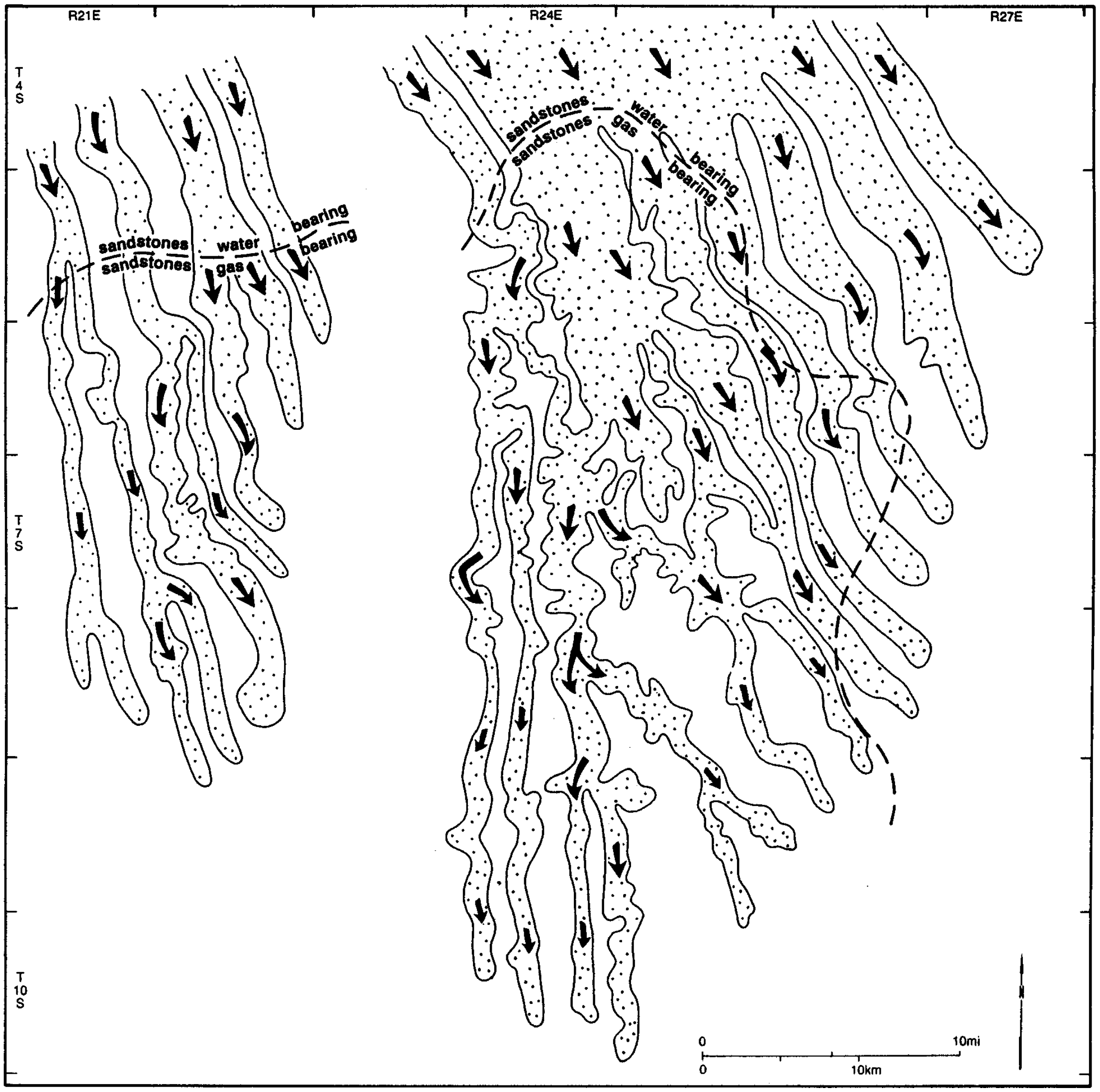

Figure 13a. Major Abo sandstone channels with paleoflow directions and boundaries of gas-bearing and water-bearing sandstones, Pecos Slope area. Simplified from Bentz (1988).

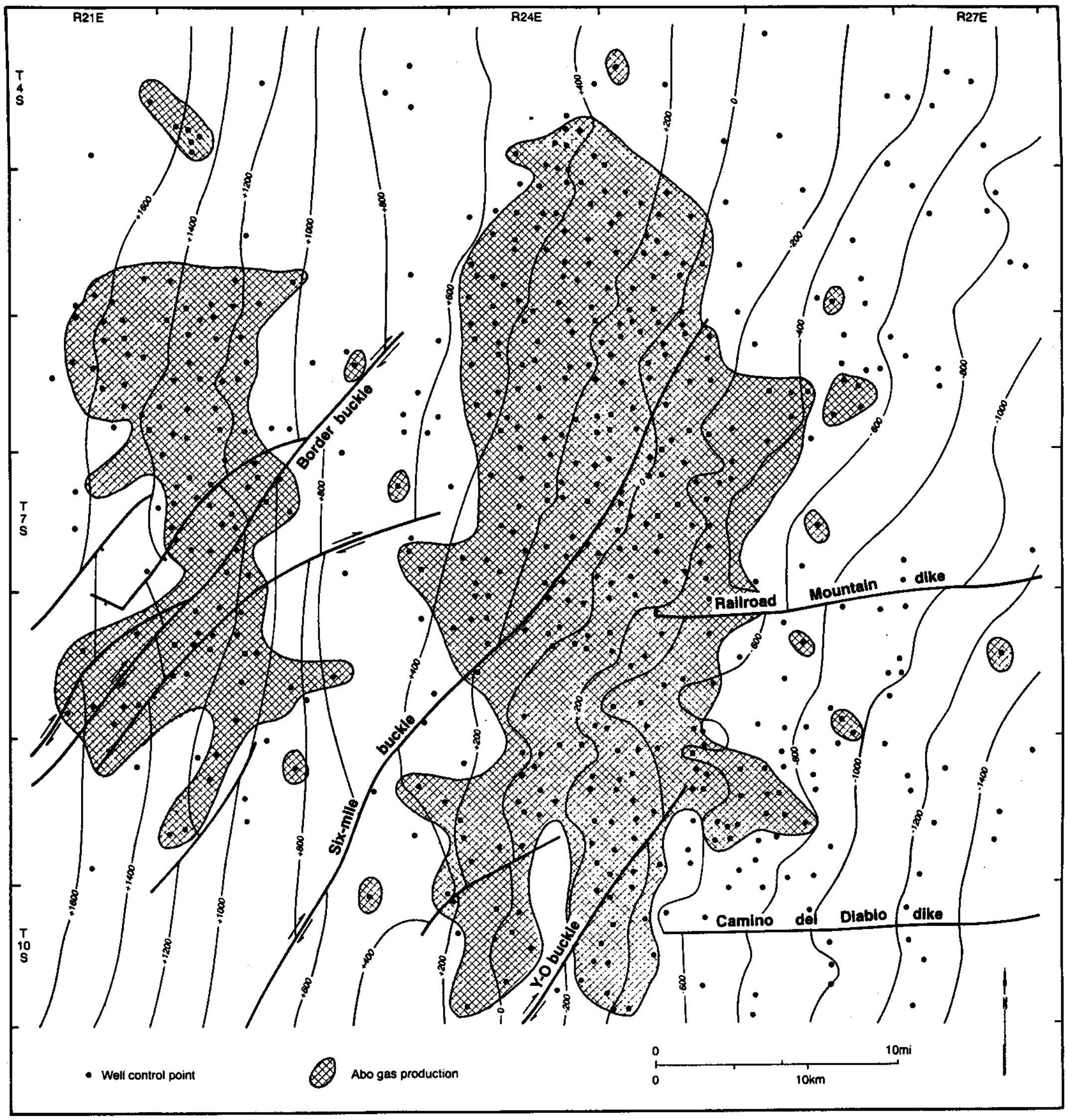

Figure 13b. Structure on top of Abo Formation, Pecos Slope and Pecos Slope West gas pools. From Broadhead (1993), after Kelley (1971), Scott et al., 1983), Broadhead (1984a), and Bentz (1992).

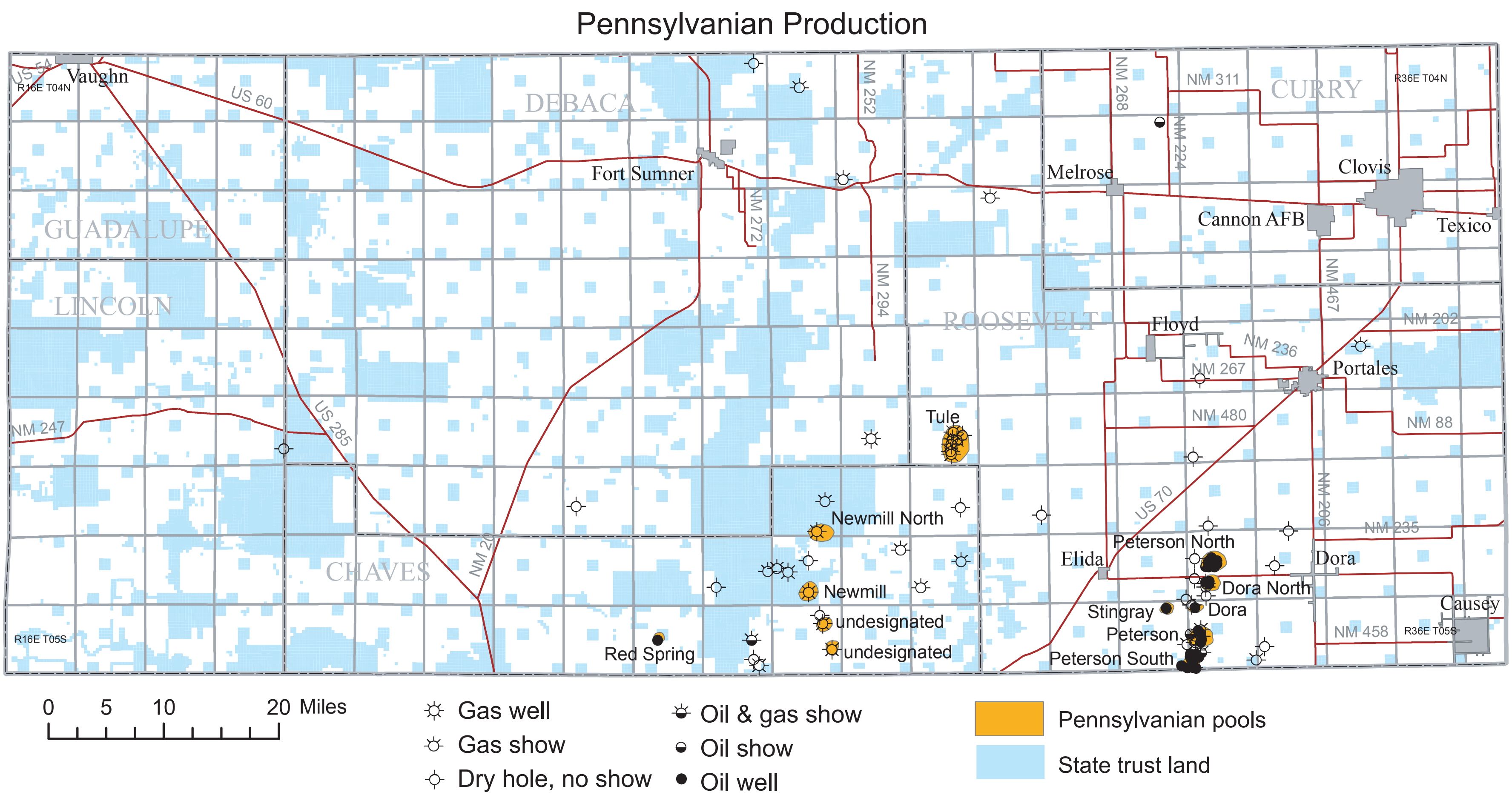

Figure 14. Production, shows, and unsuccessful tests in Pennsylvanian strata. Shown are wells that have established production from the Pennsylvanian, wells with oil and gas shows in the Pennsylvanian, and wells that tested the Pennsylvanian with drill stem tests or casing perforations but which had no shows. See well database (SinNombre wells.xls) for well data.

Wells drilled in offstructure locations in the Peterson area have been nonproductive and have generally recovered water on tests of reservoirs (Fig. 14). However, gas has been encountered in Pennsylvanian reservoirs by several exploratory wells in northeastern Chaves County, indicating that hydrocarbons have migrated into the Pennsylvanian or have been generated in the Pennsylvanian in this area. Oil and gas in the Peterson, Tule, or Newmill areas either originated locally or migrated northward out of the Permian Basin. Structures in southern Curry and northern Roosevelt Counties (Fig. 4) have not been adequately tested at the Pennsylvanian level and opportunities exist for analogs to the Peterson and Peterson South pools.

The Pennsylvanian of the northern part of the Sin Nombre area has been sparsely tested. Four wells in this region have tested either oil or gas from Pennsylvanian carbonates (Fig. 14). Only one well has tested water. With the complex intertongueing of clastic and carbonate facies, there is ample opportunity for oil and gas entrapment. The structural configuration of the Precambrian basement (Fig. 4) reveals an east-west trending structural divide just south of this area. This structural divide separates the Tucumcari Basin from the Permian Basin. Any oil or gas in the north would have migrated southward from fully mature source rocks in the deeper parts Tucumcari Basin or would have been generated locally from less mature sources (see Broadhead et al., 2002).

Mississippian System

Undifferentiated strata of Mississippian age form relatively minor reservoirs in the Sin Nombre area. Production is obtained from the Peterson Mississippian pool. A cumulative total of 150 thousand bbls oil and 465 million ft^3 (MMCF) gas have been produced from the Mississippian at Peterson (Table 1). There were five active wells in the Peterson Mississippian pool at the end of 2000. Reservoirs are limestones preserved on the flanks of early Pennsylvanian structures (Fig. 15). The Mississippian limestones are unconformably overlain by Pennsylvania strata. Several wells drilled within southern Roosevelt and northeastern Chaves Counties have encountered gas shows within the

Mississippian section, indicating that these strata have been at least partially charged with hydrocarbons.

Fusselman Formation (Silurian)

The Fusselman Formation is an important reservoir for oil and associated gas in the Sin Nombre area. Production is obtained from the Peterson and Peterson South pools (Fig. 16). A cumulative total of 3.7 million bbls of oil and 3.1 BCF gas (Table 1) have been produced from 15 wells. There were 11 active wells in these two pools at the end of 2000.

Fusselman reservoirs are formed by dolomudstones with vugular porosity and by fine-grained sucrosic dolostones (Green and Schlueter, 1988). The trap at Peterson South is formed by truncation of an angular unconformity on the north flank of an eroded Pennsylvanian-age structure. The Peterson pool is formed by closure on an anticline from which only the upper part of the Fusselman has been eroded.

Green and Schlueter (1988) concluded that the trap at Peterson was incompletely filled by hydrocarbons. Perhaps the volume of hydrocarbons that migrated into the trap was insufficient to completely fill it. It is also possible that the hydrocarbon seals are leaky and are not capable of containing a thicker column of oil and gas than is present within the Peterson Fusselman pool.

A number of wells have tested the Fusselman in the southeastern part of the Sin Nombre area (Fig. 16). Most of these wells have recovered water from the Fusselman and none have recovered hydrocarbons. Water is reported as salt water in most cases. This suggests that the Fusselman has been charged with hydrocarbons only on local structures or perhaps updip area along its northern and northwestern pinchouts. The Fusselman is not present in the northern and western parts of the Sin Nombre area.

Montoya Formation (Ordovician)

The Montoya Formation is an important productive stratigraphic unit at the Tule pool in westernmost Roosevelt County (Fig. 17). It has also been productive at the Dos Ranchos pool in northeastern Chaves County. A cumulative total of 1.8 BCF gas and 15 thousand bbls of condensate have been produced from the two Montoya reservoirs in the

Sin Nombre area. There were three active wells in the Tule Montoya pool during 2000. The Dos Ranchos pool was discovered in 1985 and was abandoned in 1993.

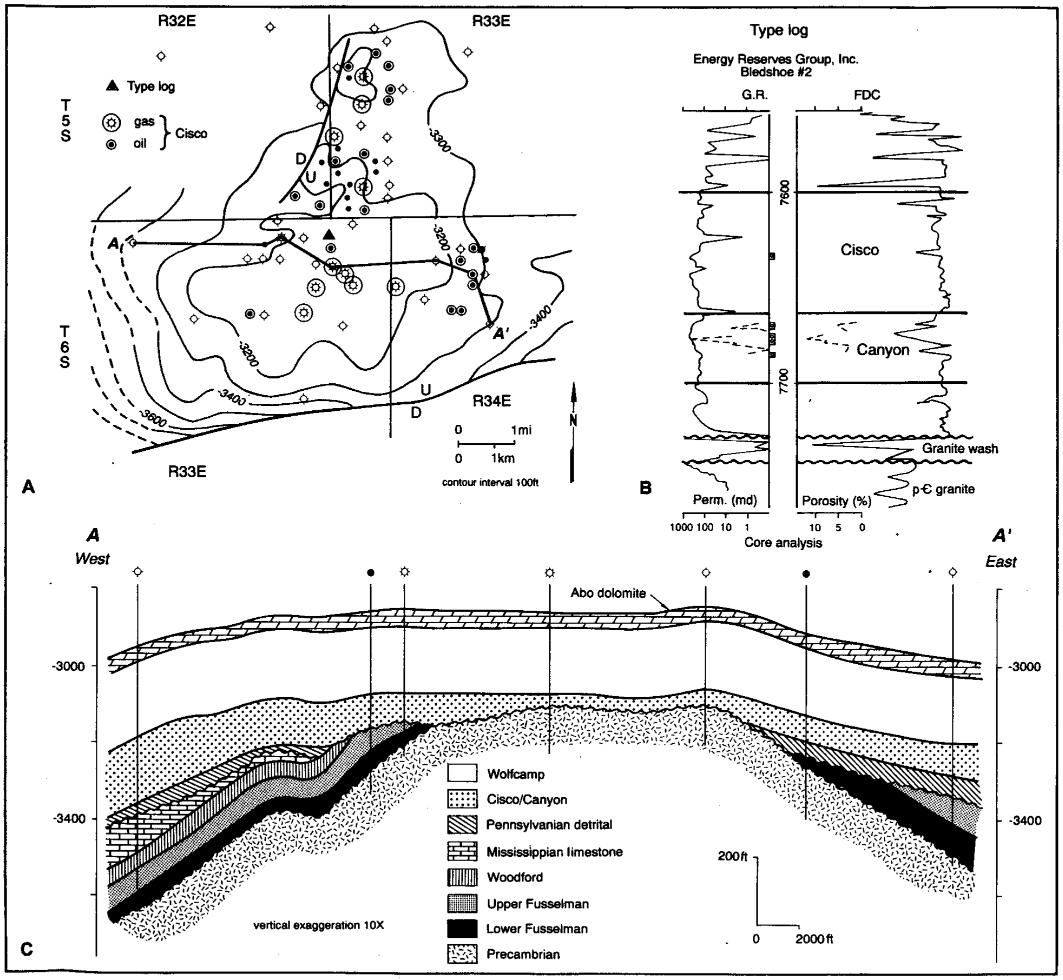

Figure 15. Peterson and South Peterson fields, Roosevelt County, New Mexico. **A**. Structure contour map on top of Cisco (Upper Pennsylvanian: Virgilian) strata. **B.** Typical log through the Cisco (Upper Pennsylvanian: Virgilian) and Canyon (Upper Pennsylvanian: Missourian) sections. **C.** Structural cross section through Peterson South field, showing traps formed in subcrop pinchout settings. From Speer (1993) after Green and Schlueter (1988).

Fusselman Production

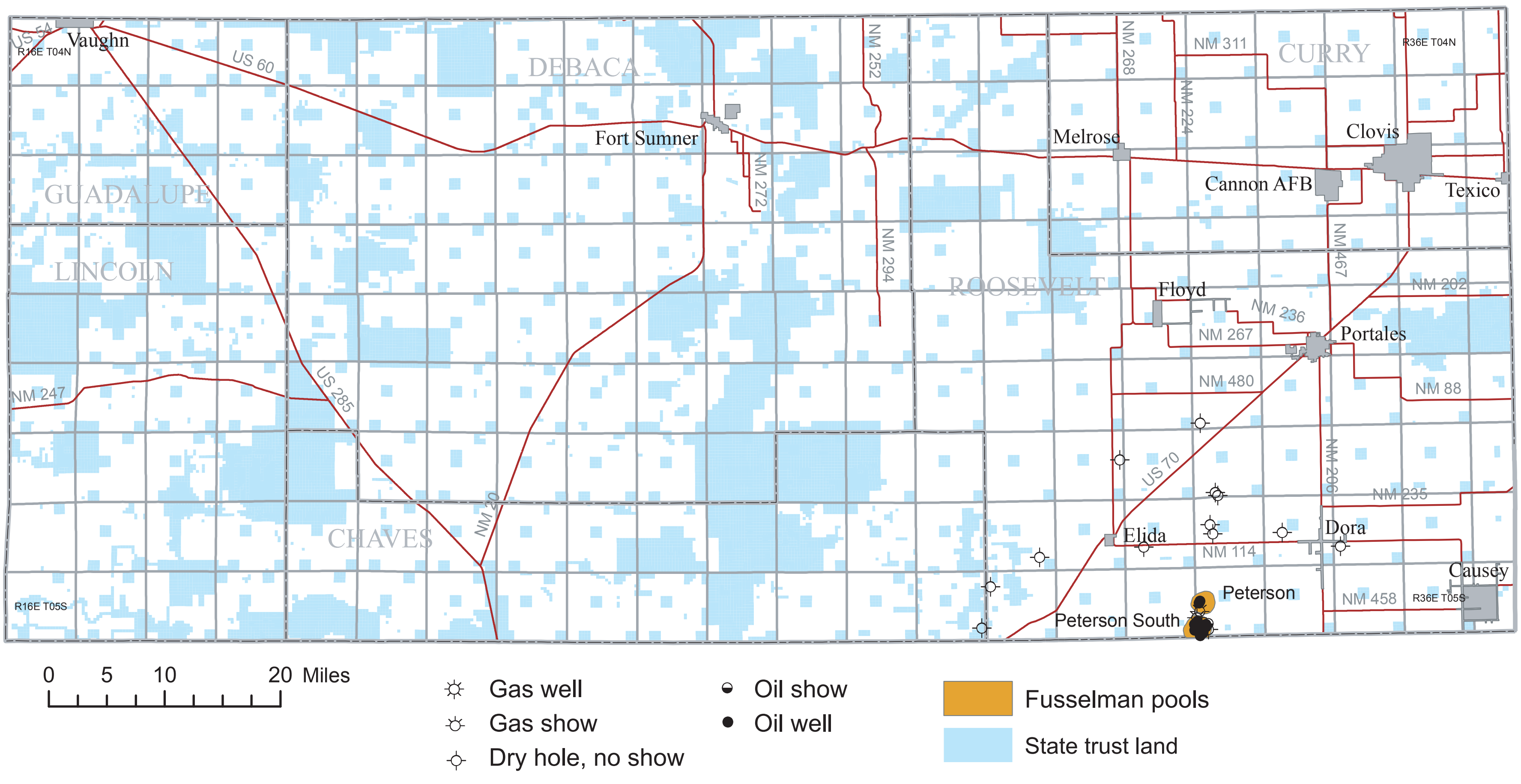

Figure 16. Production, shows, and unsuccessful tests in the Fusselman Formation. Shown are wells that have established production from the Fusselman, wells with oil and gas shows in the Fusselman, and wells that tested the Fusselman with drill stem tests or casing perforations but which had no shows. See well database (SinNombre wells.xls) for well data.

Montoya Production

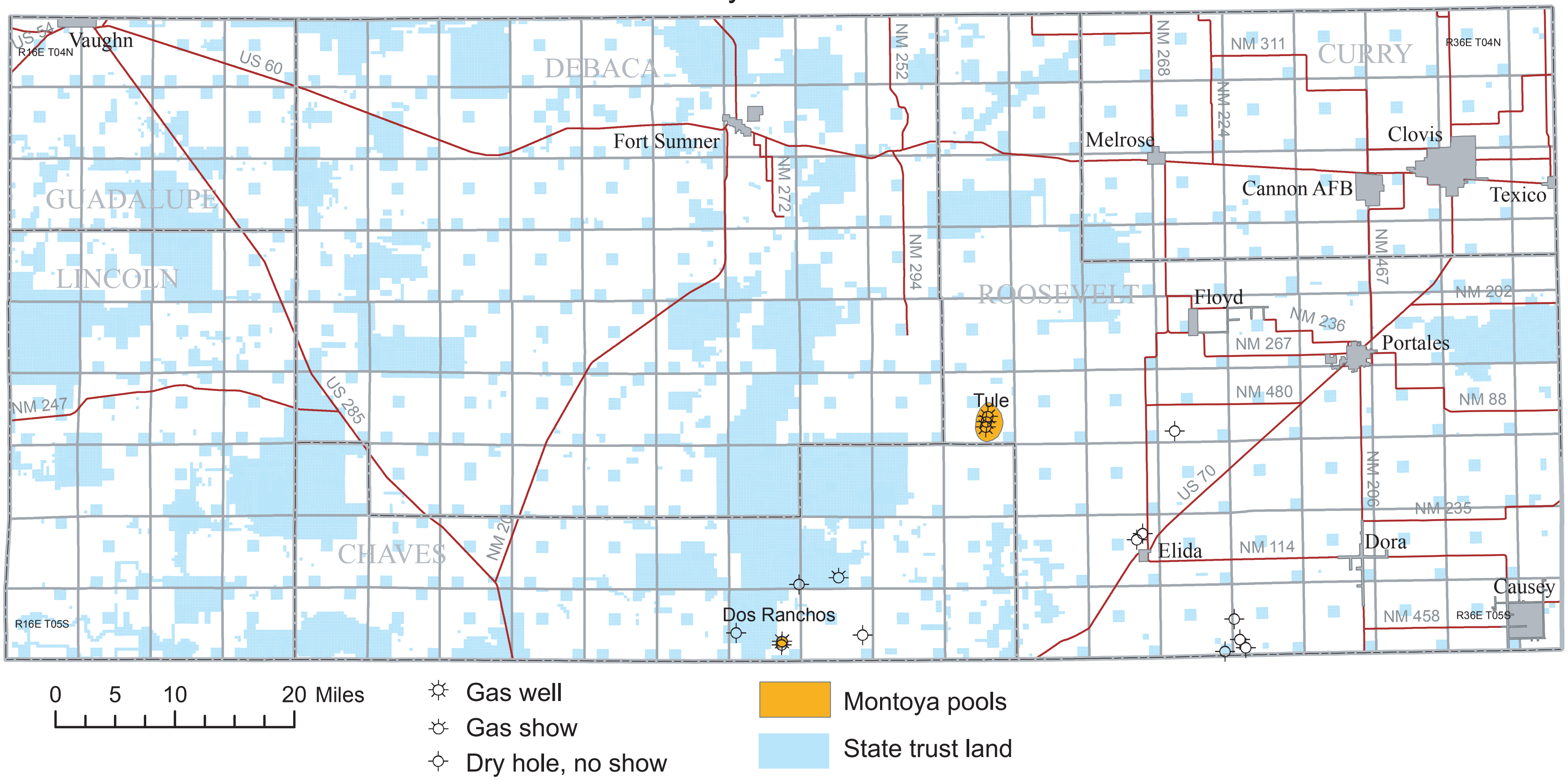

Figure 17. Production, shows, and unsuccessful tests in the Montoya Formation. Shown are wells that have established production from the Montoya, wells with oil and gas shows in the Montoya, and wells that tested the Montoya with drill stem tests or casing perforations but which had no shows. See well database (SinNombre wells.xls) for well data.

The trap at the Tule Montoya pool is described as paleotopographic (Ahlen, 1988). Production is established on a Pennsylvanian-age structure. The reservoir is a finely crystalline sucrosic dolostone with vugular pores (Ahlen, 1988). Porosity is 10 percent. The full extent of the accumulation at Tule has not been delineated by drilling.

Several exploratory wells drilled southeast of Tule and north of Dos Ranchos have encountered salt water in the Montoya. This suggests that reservoirs are widespread and that exploration might be concentrated in updip locations, whether on structures such as Tule or along the northern and northwestern pinchout of the Montoya.

SUMMARY AND CONCLUSIONS

The Sin Nombre area sits astride the boundary between the Permian Basin to the south and the Tucumcari Basin to the north. It covers an area of approximately 7000 mi^2. As such, it is situated between one of the principal oil and gas provinces in the world (the Permian Basin) and an unproductive and sparsely drilled frontier basin (the Tucumcari Basin). Approximately 100 BCF gas and 6 million bbls oil have been produced from 17 oil and gas pools in the southeast and south-central portions of Sin Nombre. Low-permeability sandstones of the Abo Formation (Permian) have yielded most of the gas but Pennsylvanian limestones and Silurian and Ordovician dolostones are also important gas reservoirs. Silurian dolostones and Pennsylvanian limestones have been the primary oil reservoirs.

Significant potential remains for additional, undiscovered and unproduced oil and gas resources. Marginal gas discoveries in the central part of the Sin Nombre area may have remained unproduced because of a paucity of pipelines along the northwestern fringe of the Permian Basin. Although drilling density is low, oil and gas shows encountered by unsuccessful exploratory wells indicate that large portions of the area have been at least partially charged by hydrocarbons. Hydrocarbons in the southern part of the Sin Nombre area would most likely have migrated north from source rocks in the Permian Basin. Hydrocarbons in the northern part of the Sin Nombre area would have migrated southward from source rocks in the Tucumcari Basin. Opportunities for traps included localized, basement-controlled structural highs that affect the pre-Permian section as well as northward pinchouts of Ordovician, Silurian, Mississippian, Pennsylvanian, and Permian reservoirs.

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APPENDIX I

Structure Database Part 1 -

Wells, Well Structural Data, and Production and Shows in Wells

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A database of oil and gas wells, subsurface structure data, and oil and gas shows and production in Microsoft Excel format (*Sin Nombre wells.xls*) accompanies this report. This database contains data on well location, total depth, dates of drilling, surface elevation, structural elevation of the top surface of the Abo Formation and Precambrian surface, as well as data on oil and gas shows and production encountered in the wells. The following data fields are present for each well.

API Number: The unique API well number. Some wells in the New Mexico Bureau of Geology databases have no API number. For these wells, an identifying number was constructed from the section-township-range location data, for example 14N32E16, which indicates a location in sec. 16 T14N R32E; if more than one well is present in any one section, then each of the wells in that section has a letter added after our synthetic API number so that each well has a unique number in this database, e.g. 14N32E16A. If an API number becomes available, the user may wish to substitute it for our substitute number.)

Operator: name of the company or individual that operated the well during drilling. Note that ownership of productive wells may have changed during the producing life of the well. Therefore, the present operator cited in the New Mexico production databases may not be the operator that drilled the well.

Lease name: name of the lease the well was drilled on.

Well number: lease number of the well.

Section: the legal land section the well is located in.

Township: the township the well is located in.

Range: the range the well is located in.

County

Location: section-township-range (an alternate means of presenting the location of the well).

Footage: location of well in feet from section boundaries

Longitude: in decimal degrees

Latitude: in decimal degrees

Spud date: month/year

Completion date: month/year

Total depth: of the well, in feet

Surface elevation: the elevation of the surface of the surface in feet above sea level

Surface datum: KB = Kelly Bushing; DF = derrick floor; GL = ground level

Tops source: source of depth to stratigraphic tops given in this report (EL = geophysical borehole or wireline logs; SL = sample log; samples = samples examined for this report; ML = mudlog; SC = tops obtained from scout card)

Depth to top of Abo Formation: in feet

Subsea depth top of Abo Formation: in feet above (+) or below (-) sea level

Depth to top of Precambrian: in feet

Subsea depth top of Precambrian: feet above or below sea level

Completed status of well: **D&A** = dry and abandoned; **Oil** = completed as oil well; **Gas** = completed as gas well

Field name: for producing wells, the name of the oil or gas field the well is productive in. The pool name equals the field name plus the name of the productive formation.

First producing formation: for producing wells, **t**he stratigraphic unit that forms the reservoir within the well. For wells productive from more than one stratigraphic unit, the first producing formation is defined as the shallowest of the reservoirs. For a well which obtained production from a second reservoir upon re-entry after the initial completion, the first producing formation is the stratigraphic unit of the first chronologic completion.

Second producing formation: for wells that have been productive from more than one stratigraphic unit, this is either the deeper of the two reservoirs (for wells in which two separate reservoirs were brought into production simultaneously) or the last completed reservoir (for wells which were re-entered subsequent to initial completion and a second reservoir brought into production as a result of the re-entry).

Top depth first producing formation: the depth to the uppermost productive perforations in the first producing formation.

Base depth first producing formation: the depth to the lowermost productive perforations in the first producing formation.

Top depth second producing formation: the depth to the uppermost productive perforations in the second producing formation.

Base depth second producing formation: the depth to the lowermost productive perforations in the second producing formation.

Initial gas production first producing formation: the initial production, in MCFGD (thousand ft^3 gas per day) from the first producing formation.

Initial gas production second producing formation: the initial production, in MCFGD (thousand ft^3 gas per day) from the second producing formation.

Initial oil production first producing formation: the initial production, in BOPD (bbls oil gas per day) from the first producing formation.

Initial oil production second producing formation: the initial production, in BOPD (bbls oil per day) from the second producing formation.

Initial water production first producing formation: the initial production, in BWPD (bbls water gas per day) from the first producing formation.

Initial water production second producing formation: the initial production, in BWPD (bbls water per day) from the second producing formation.

Initial GOR, 1st Prod Fm: the initial gas-oil ratio, in ft^3 gas per bbl oil, from the first producing formation.

Oil gravity, 1st producing formation: the gravity of oil, in API degrees, from the first producing formation.

Oil gravity, 2nd producing formation: the gravity of oil, in API degrees, from the second producing formation.

All data were derived from files and records in the Library of Subsurface Data at the New Mexico Bureau of Geology and Mineral Resources Library of Subsurface Data. Longitude and latitude for most wells were with the Geographix Exploration System Landgrid Module and the Whitestar Corp. digital land grid

Depths to the top of the Abo Formation and Precambrian basement were correlated by the senior author. The primary tools used for correlation were geophysical wireline logs in the New Mexico Library of Subsurface Data at the New Mexico Bureau of Geology and Mineral Resources. For many wells, depth to the top of the Precambrian and the Abo were confirmed with additional examination of sample logs or mud logs. Where needed, drill cuttings were examined to identify or verify depth of the top of Precambrian. For many older wells (pre-1960) and some more modern wells, sample logs and drill cuttings are the only source of stratigraphic data because the wells lack wireline logs. In a few wells for which logs were not available, stratigraphic tops from scout cards were used. It was noted, however, that scout card tops are inconsistent in this area. This is especially true for the top of the Precambrian, which is characterized by a wide variety of igneous, metasedimentary, and metavolcanic rocks in the region.

Oil and Gas Shows

The well database contains substantial information on oil and gas shows compiled from records on file at the New Mexico Bureau of Mines and Mineral Resources. Oil and gas shows are identified by the stratigraphic unit they occur in. The following stratigraphic terms were employed.

Triassic (undivided)

Artesia Group (Permian)

San Andres Formation (Permian)

Glorieta Sandstone (Permian)

Yeso Formation (Permian)

Tubb member of Yeso Formation (Permian)

Abo Formation (Permian)

Hueco Group (Permian)

Pennsylvanian strata (undivided)

Mississippian strata (undivided)

Fusselman Formation (Silurian)

Montoya Formation (Ordovician)

Ellenburger Formation (Ordovician)

Precambrian

Data examined for shows included completion reports and scout cards. Particular attention was paid to drill stem tests and attempted well completions.

For **drill stem tests**, the fluid recovery from the test was considered as evidence for a show. If a drill stem test recovered either oil or gas, the test was considered to have an oil show or a gas show. Also reported were negative tests that recovered water with no oil or gas. If the drill stem test recovered only drilling mud, then it was not used in this database because the mud could have either entered the test tool through an unsealed packer or it could have invaded the zone of interest during drilling and subsequently flowed back I nto the borehole during the test. In this report, the depth of the test interval is reported as is the type of fluid or fluids recovered (oil, gas, or water)

Completion tests are defined in this report as an attempt to produce oil or gas by perforating casing and a subsequent attempt to recover fluid. After perforation, the target reservoir may have been stimulated by acid treatment or artificial fracturing. In this report, the depth of the perforated interval is reported as is the type of fluid or fluids recovered. Also reported is the result of either no show (NS) or no production (NP), which are sometimes the only results available.

The following abbreviations are used in the database to describe shows.

DST-G: gas recovered on the drill stem test. The depth interval of the test is reported.

DST-O: oil recovered on the drill stem test. The depth interval of the test is reported.

DST-W (XW, sulf W): water (salt water, sulfur water) recovered on drill stem test. The depth interval of the test is reported.

PERF-G: gas recovered through casing perforations. The gross depth interval of the perforations is reported.

PERF-O: oil recovered through casing perforations. The gross depth interval of the perforations is reported.

DST-W (XW, sulf W): water (salt water, sulfur water) recovered through casing perforations. The gross depth interval of the perforations is reported.

COR-G: gas recovered in core. The depth interval of the core is reported.

COR-O: oil recovered in core. The depth interval of the core is reported.

DST-W (XW, sulf W): water (salt water, sulfur water) recovered in core. The gross depth interval of the core is reported.

ML-G: mudlog with gas show. The depth interval of the show is reported.

ML-O: mudlog with oil show. The depth interval of the show is reported.

OS-G: other show of gas. In most cases, this is a well record stating "show of gas" with no hard description of the nature of the show.

OS-O: other show of oil. In most cases, this is a well record stating "show of oil" with no hard description of the nature of the show.

CT-G: well drilled with cable tool rig, recovered gas.

CT-O: well drilled with cable tool rig, recovered oil.

Show codes: These are simplified codes that convey information on oil and gas shows for stratigraphic units productive within the Sin Nombre area. The show codes are presented in order to facilitate mapping with GIS systems. The following show codes were used:

> **Oil well**: the well was completed as an oil well.
>
> **Gas well**: the well was completed as a gas well.
>
> **G**: the well had a gas show, but was nonproductive from the formation.
>
> **O**: the well has an oil show, but was nonproductive from the formation.
>
> **NS**: the formation was tested in the well, but had no recorded show.
>
> **NP**: the formation was tested in the well, but production was not established.

Oil production 2001, 1st Fm bbls: annual oil production in 2001 from the first producing formation, in barrels. Data obtained from the New Mexico Ongard system via the Go-Tech website at New Mexico Tech (http://octane.nmt.edu).

Oil production 2001, 2nd Fm bbls: annual oil production in 2001 from the second producing formation. Data obtained from the New Mexico Ongard system via the Go-Tech website at New Mexico Tech (http://octane.nmt.edu).

Gas production 2001, 1st Fm MCF: annual gas production in 2001 from the first producing formation, in thousand ft^3. Data obtained from the New Mexico Ongard system via the Go-Tech website at New Mexico Tech (http://octane.nmt.edu).

Gas production 2001, 2nd Fm MCF: annual gas production in 2001 from the second producing formation, in thousand ft^3. Data obtained from the New Mexico Ongard system via the Go-Tech website at New Mexico Tech (http://octane.nmt.edu).

Comments

APPENDIX II

Structure Database Part 2 -

Surface Structures

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This database in Microsoft Excel format (Sin Nombre *surface structures.xls*) is a companion to the INFO map of mapped surface structures. It is presented in Microsoft Excel format. Where available, several attributes are given for each structure, including:

Name of structure
Location (township, range)
Location within township (described verbally, not quantitatively)
Reported structural closure, feet if available
Other comments, including thickness of closure and area within closed contours, if known
Source of data, given in reference list at the end of the main part of this report