PETROLUM POTENTIAL OF THE SIN NOMBRE AREA, EAST-CENTRAL NEW MEXICO*

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Search and Discovery Article #10036 (2003)

*Online adaptation of presentation at AAPG Southwest Section Meeting, Fort Worth, TX, March, 2003 (www.southwestsection.org)

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Abstract

The Sin Nombre area of east-central New Mexico 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 include localized, basement-controlled structural highs throughout the stratigraphic section as well as northward pinchouts of lower Paleozoic reservoirs and truncation of Paleozoic strata against major east-west trending faults in the subsurface.

Introduction

The Sin Nombre area of eastern New Mexico lies between the Northwest shelf of the Permian Basin to the south and the Tucumcari Basin to the north (Figure 1). Areal extent is approximately 7000 mi^2. 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.

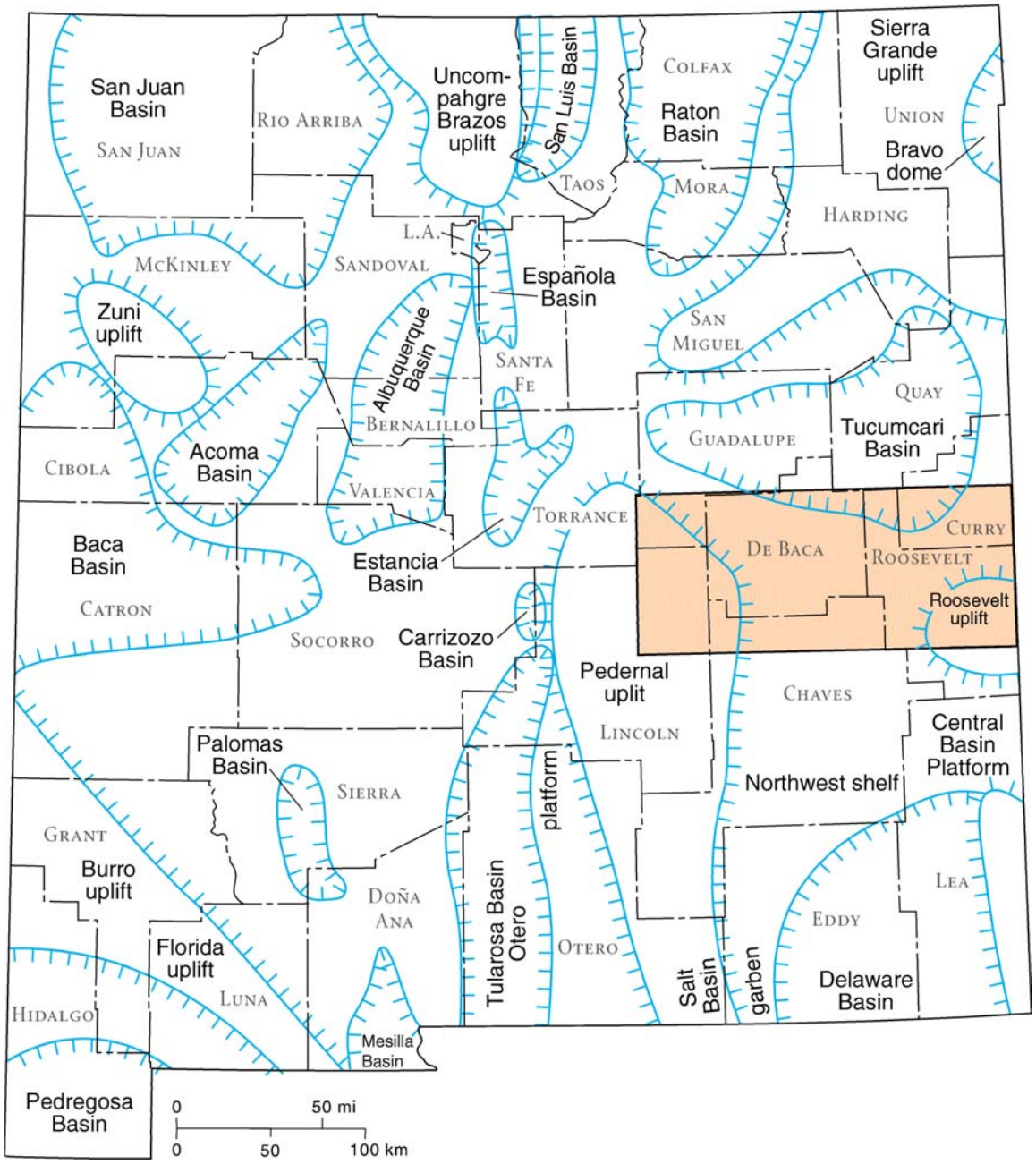

Figure 1. Location of Sin Nombre area (orange) and principal geologic basins of New Mexico.

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 Figure 2 for stratigraphic column). Oil and natural gas have been obtained from 17 oil and gas pools within Sin Nombre (Table 1). Approximately 100

BCF gas and 6 million bbls oil have been produced. 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.

Quaternary		undivided continental sediments
Tertiary		Ogallala Fm.
Triassic	Upper	Redonda Fm.
		Chinle Gp.
	Middle	Santa Rosa Ss.
Permian	Ochoan	Rustler Fm.
		Salado Fm.
	Guadalupian	Artesia Gp.
	Leonardian	San Andres Fm.
		Glorieta Ss.
		Yeso Fm.
	Wolfcampian	Abo Fm.
		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.

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.

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. From Broadhead and Jones (2002).

The area is sparsely drilled and explored. Outside of the productive oil and gas pools, only 94 wells have been drilled to Precambrian basement. This is approximately one well per every two townships. Most of these basement tests have been drilled in the southeast part of Sin Nombre. There are 106 townships with no wells drilled to basement.

Structure

Precambrian structure is dominated by a uniform eastward dip of approximately 1^o across the entire Sin Nombre area (Figure 3). 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. Towards the east, progressively older sedimentary strata overlie Precambrian basement. In the southeastern part of Sin Nombre, Ordovician dolostones rest on the Precambrian.

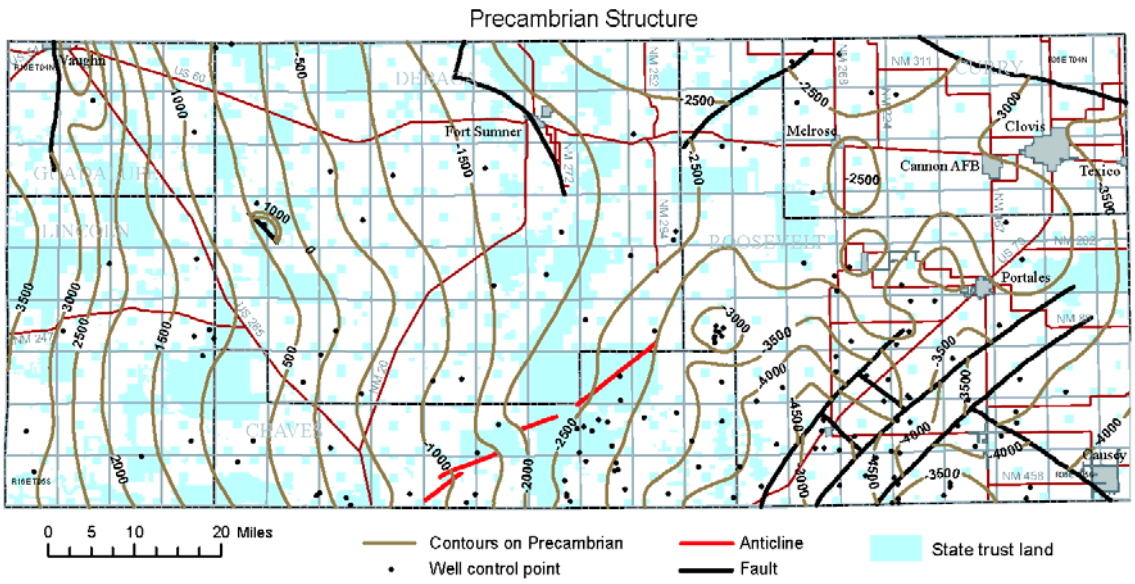

Figure 3. Structure contour map of the Precambrian surface, Sin Nombre area. From Broadhead and Jones (2002).

The central part of the Sin Nombre area is dominated by an east-plunging structural nose (the Sin Nombre arch) that separates the Northwest shelf of the Permian Basin on the south from the Tucumcari Basin on the north. This is a major east-west trending uplifted tectonic element that is parallel to other east-west trending tectonic uplifts in the area such as the Matador arch and the Wichita uplift in west Texas and parts of the Sierra Grande uplift in New Mexico. It is a late Paleozoic structure associated with the Ancestral Rocky Mountains. Examination of topographic maps and shaded relief maps (Figure 4) indicate that several major east-west oriented drainage features are present at the surface on the flanks of this structural nose. It is quite probable that this structural nose is bounded on its north and south flanks by east-west trending high-angle faults of late Paleozoic age that exhibit minimal displacement at the ground surface but have substantial displacement at the Precambrian surface. Incised drainage has been developed along the faults at the ground surface. Similar uplifted elements of the Ancestral Rocky Mountains such as the Sierra Grande arch, the Pedernal uplift, the Matador arch, and the Wichita uplift are bordered on their margins by deep grabens (elevator basins) that may be productive of oil and gas (Brister et al., 2001; Broadhead, 2001a, 2001b, 2001c; Montgomery, 1984).

The southeast part of the Sin Nombre area is a positive structural element formed by the north end of the Roosevelt uplift (Figure 3). 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 is cut by several high-angle faults (Figure 3). Many of the faults are 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. The largest faults in the area have maximum vertical offsets of only a few hundred feet.

Abo structure mimics the Precambrian structure but is more subdued (Broadhead and Jones, 2002). The tectonic movements that produced the Pedernal uplift, the Sin Nombre arch and the adjacent basinal areas were largely Pennsylvanian and Early Permian in age. Most tectonic movement ceased by the end of Abo deposition so most of the faults exhibit no major offset of post-Abo strata.

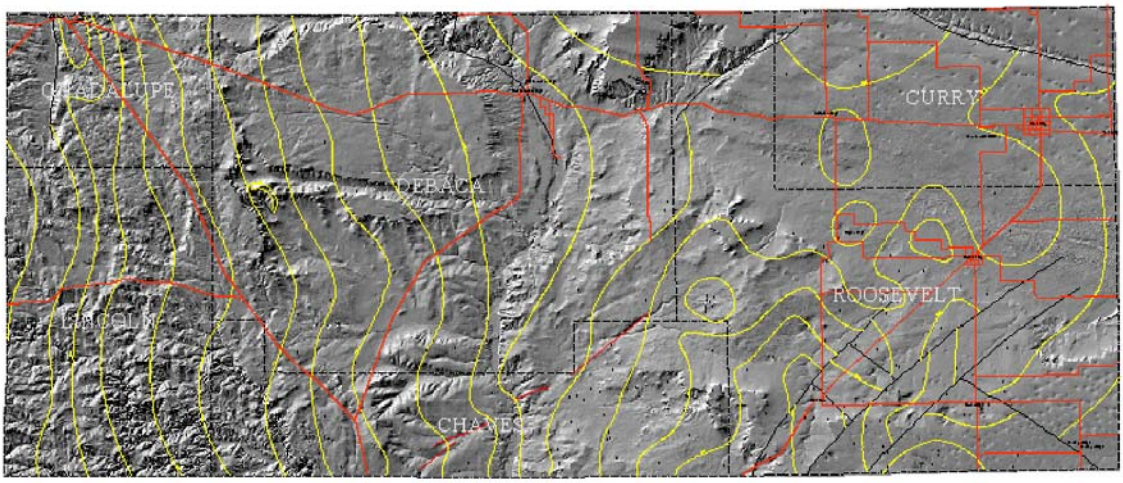

Figure 4. Structure contours on Precambrian basement and shaded topographic relief image of Sin Nombre area. Yellow lines are structure contours on Precambrian basement. Red lines are principal roads and highways.

Oil and Gas Production

Oil and natural gas have been produced from six stratigraphic units within the Sin Nombre area (Figure 2): 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 (Table 1).

The Abo produces from lenticular, low-permeability, fluvial-deltaic, red bed sandstone reservoirs that are interbedded with red, nonmarine mudstones (Broadhead, 1984; Bentz, 1992). Production has been almost entirely from the Pecos Slope and Pecos Slope West gas pools (Figure 5). These pools are situated on the southern flank of the Sin Nombre arch. The nonmarine clastics interfinger with marine dolostones in the southeastern part of the Sin Nombre area. The Abo Formation blankets the area and is 650 to 750 ft at the Pecos Slope and Pecos Slope West pools. The trapping mechanism at Pecos Slope and Pecos Slope West is poorly understood and appears to involve regional structure combined with either a northward loss of internal shale seals or a capillary pressure barrier on the north side of these pools.

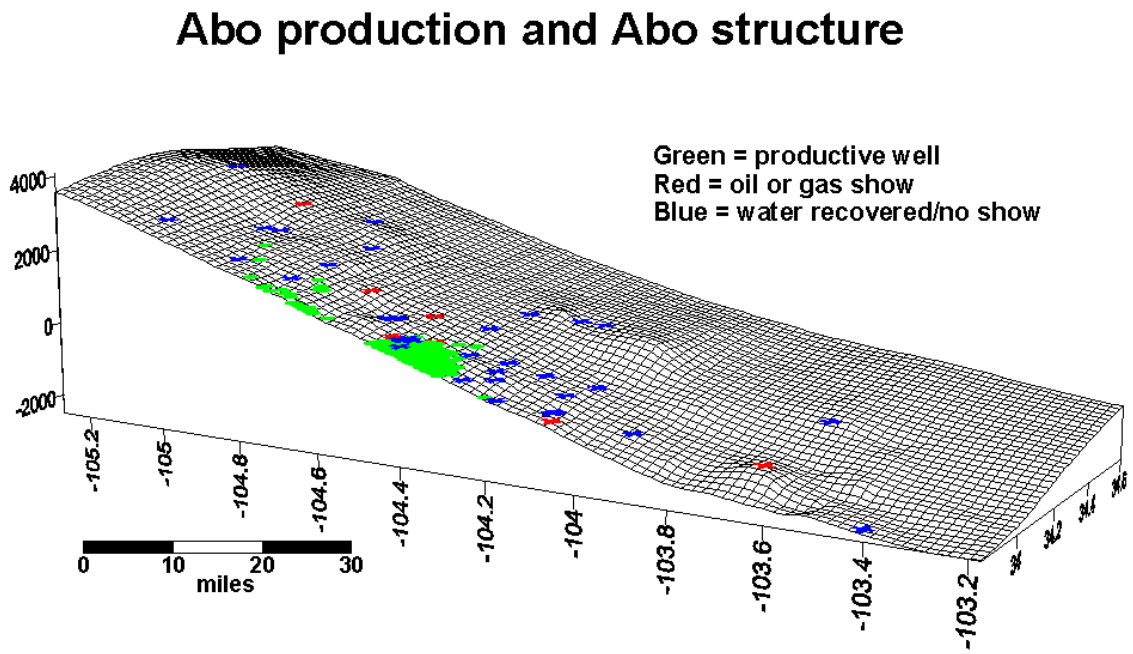

Figure 5. Wells productive from the Abo Formation (Permian), exploratory wells that have tested Abo strata, and structural relief on the Abo Formation.

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 (Figure 5; Broadhead and Jones, 2002). Most of the wells drilled in these 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 tests broadly outline areas of future potential and indicate that gas has migrated into the Abo north of the Pecos Slope and Pecos Slope West pools.

Pennsylvanian reservoirs are structural-stratigraphic traps in limestones formed by drape of Pennsylvanian limestones over Pennsylvanian-age structures (Figure 6; Green and Schlueter, 1988; Ahlen, 1988; Speer, 1993). Porosity is mostly vugular and results from leaching of phylloid algal plates and other skeletal material. Productive Pennsylvanian reservoirs have been correlated as Canyon (Upper Pennsylvanian: Missourian) and Strawn (Middle Pennsylvanian: Des Moinesian) in age. The Pennsylvanian accumulation at Tule, along with the underlying gas accumulation in the Montoya dolostones (Ordovician), marks the northernmost commercial production of hydrocarbons in the New Mexico part of the Permian Basin.

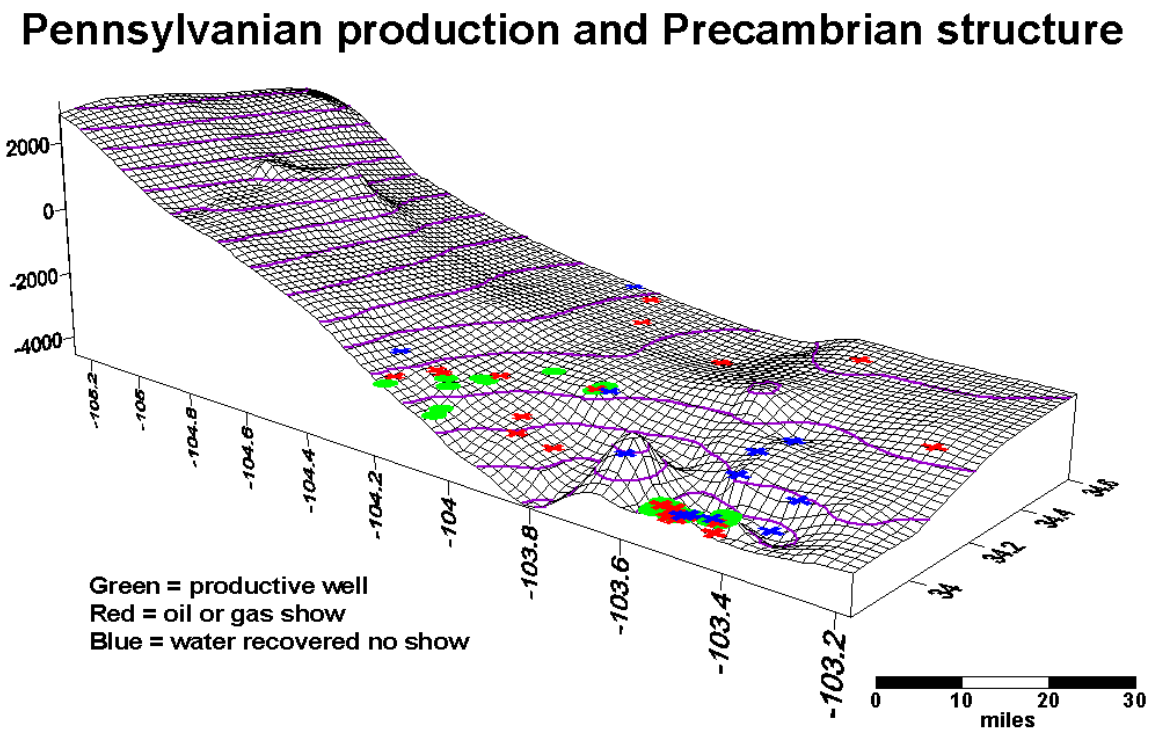

Figure 6. Wells productive from Pennsylvanian reservoirs, exploratory wells that have tested Pennsylvanian strata, and structural relief on Precambrian basement.

Fusselman (Silurian) and Montoya (Ordovician) carbonates are productive mostly on the flanks of Pennsylvanian-age structures in the southeast part of the Sin Nombre area (Figure 7). These early Paleozoic rocks have either been removed from the crests of these structures or have been thinned by erosion over the crests of these structures. Fusselman reservoirs are formed by dolomudstones with vugular porosity and by fine-grained sucrosic dolostones (Green and Schlueter, 1988). Traps are formed by truncated anticlines. Montoya reservoirs are finely crystalline sucrosic dolostones with vugular pores (Ahlen, 1988). The trap at the Tule pool is formed by a Pennsylvanian-age structure and is described as paleotopographic (Ahlen, 1988). The Montoya accumulation at Tule, along with overlying gas accumulations in the Pennsylvanian and in the San Andres Formation (Permian), marks the northernmost commercial production of hydrocarbons in the New Mexico part of the Permian Basin. Fusselman and Montoya strata pinchout to the northwest of Tule and are not present throughout most of the Sin Nombre area (Figure 7).

Several exploratory wells in the southeast part of Sin Nombre have been drilled into the Montoya and Fusselman and have encountered mostly salt water. This indicates that reservoir quality strata are widespread and that exploration might be concentrated in updip locations, whether on structures such as at Tule or along the northern and northwestern pinchouts of the Montoya and Fusselman. Several structures have not been adequately tested and there are probably numerous structures that have not been identified in the subsurface of this little explored and sparsely drilled area.

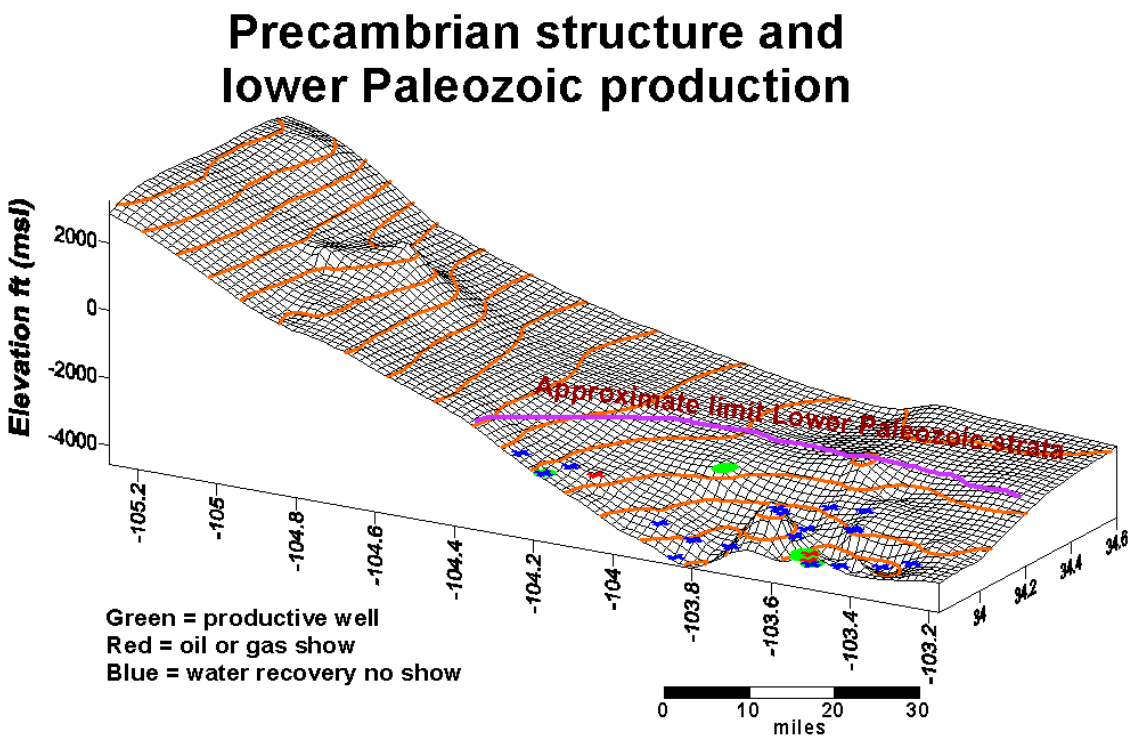

Figure 7. Wells productive from Ordovician and Silurian reservoirs, exploratory wells that have tested Ordovician and Silurian strata, and structural relief on Precambrian basement.

Relatively minor oil and gas production has been obtained from limestone reservoirs of Mississippian age. Although reservoirs and traps are poorly understood, Mississippian production is obtained from reservoirs preserved on the flanks of Pennsylvanian-age structures. 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.

Minor gas production has been obtained from carbonate reservoirs in the San Andres Formation (Permian). Significant volumes of oil and gas have been produced from the San Andres 4 to 10 miles south of the Sin Nombre area along a trend formed by more than 30 oil pools, including the Chaveroo, Tom Tom, and Cato, which have a cumulative production exceeding 37 million bbls oil. Traps along the trend are formed by porosity zones that pinchout updip to the north (Gratton and Lemay, 1969; Yedlosky and McNeal, 1969; Cowan and Harris, 1986; Ward et al., 19886, and Keller, 1992). Numerous exploratory wells have tested the San Andres within the Sin Nombre area (Broadhead and Jones, 2002). 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 wells have yielded oil and gas shows from the San Andres. 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 (see Pitt and Scott, 1981). Alternatively, oil and gas in the San Andres within the northern part of the Sin Nombre area may have a source within the Tucumcari Basin (see Broadhead et al., 2002).

Hydrocarbon shows have also been reported from the Triassic, the Artesia Group (Permian), the Glorieta sandstone (Permian), the Yeso Formation (Permian), and from fractured Precambrian basement. These shows are a further indication that permeable strata have been widely charged by hydrocarbons in the Sin Nombre area. Hydrocarbons in the southern part of the Sin Nombre area migrated northward from the Permian Basin. Hydrocarbons on the northern part of Sin Nombre migrated southward from source rocks in the Tucumcari Basin.

Also of exploratory interest are the east-west trending drainage lineaments on the flanks of the Sin Nombre arch that are seen on the shaded relief map (Figure 4). If these lineaments reflect deeper, late Paleozoic age faults then they may be important considerations in exploration. These faults may not only define potential traps but may also control facies distribution within the Pennsylvanian and lower Permian sections and may also exhibit partial control on the location of northern pinchouts of pre-Pennsylvanian strata.

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 premier 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. Production from discoveries of gas in the Abo and Pennsylvanian sections north of present gas pools may be commercial with the extension of existing pipelines to the north. The petroleum geology and petroleum potential of the Sin Nombre area is summarized in Broadhead and Jones (2002).

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Acknowledgments

This paper is an abstraction of a more comprehensive report (Broadhead and Jones, 2002). The research in this report was sponsored by the New Mexico State Land Office

under contract 02-24 to the New Mexico Bureau of Geology and Mineral Resources. Jami Bailey, Larry Kehoe, Eleanore Nestlerode, and Joe Mraz of the New Mexico State Land Office provided helpful input into the design and purpose of this project. Glen Jones of the New Mexico Bureau of Geology and Mineral Resources provided GIS work. Kathy Glesener and Leo Gabaldon drafted the illustrations.