New Mexico Geological Society

Downloaded from: http://nmgs.nmt.edu/publications/guidebooks/66

Petroleum geology of the Las Vegas Basin, an overview

R. F. Broadhead, 2015, pp. 253-260

in:

Guidebook 66 - Geology of the Las Vegas Area, Lindline, Jennifer; Petronis, Michael; Zebrowski, Joseph, New Mexico Geological Society 66th Annual Fall Field Conference Guidebook, 312 p.

This is one of many related papers that were included in the 2015 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. Non-members will have access to guidebook papers two years after publication. Members have access to all papers. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, *maps*, *stratigraphic charts*, and other selected content are available only in the printed guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

New Mexico Geological Society Guidebook, 66th Field Conference, Geology of the Meadowlands, Las Vegas Region, 2015, p. 253–260

PETROLEUM GEOLOGY OF THE LAS VEGAS BASIN, AN OVERVIEW

RONALD F. BROADHEAD
New Mexico Bureau of Geology & Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM, ron@nmbg.nmt.edu

ABSTRACT—The Las Vegas Basin occupies approximately 2000 mi^2 (5180 km^2) in north-central New Mexico. Although present basin geometry originated during Laramide compressive tectonism, most of the more than 10,000 ft (3048 m) of sedimentary fill is Pennsylvanian in age and was deposited in the Rainesville trough, the Pennsylvanian precursor of the Las Vegas Basin.

Commercial gas production has been obtained from the Dakota Sandstone and sandstones of the Morrison Formation (Jurassic) at the Wagon Mound field in east-central Mora County. The eight wells in the field produced a total of 97 million ft^3 gas from 1976 until field abandonment in 1979. The Graneros Shale (Upper Cretaceous), which overlies the Dakota Sandstone, is the probable source rock.

Shows of hydrocarbon gas have also been encountered in Pennsylvanian strata. The Pennsylvanian consists of up to 6500 ft (1981 m) of dark-gray and red shales, sandstones, minor conglomerate and minor marine limestones. The dark-gray shales constitute thermally mature petroleum source rocks with up to 9.5% total organic carbon (TOC). Kerogens are primarily gas prone. The Pennsylvanian section is within the thermogenic window in the deeper parts of the basin. Sandstones interbedded with the source rocks are the primary reservoir targets. Reservoirs domed upward by the Turkey Mountains uplift have trapped CO_2 gas that was transported into the basin by magmas that formed the laccolith at the core of the uplift.

The Sangre de Cristo Formation (Lower Permian) may hold petroleum potential in any areas where dark-gray shales are present. These dark-gray shales may contain sufficient organic matter to act as source rocks where thermally mature. Post-Sangre de Cristo Permian strata, Triassic strata, and the Entrada Sandstone (Jurassic) are devoid of petroleum source rocks. Gases in these units are CO_2-rich.

INTRODUCTION

The Las Vegas Basin occupies approximately 2000 mi^2 (5180 km^2) in north-central New Mexico (Fig. 1). On the west, the basin is bounded by the Sangre de Cristo uplift. On the east and south, the basin floor rises gradually and merges with the Sierra Grande uplift. On the north, the Cimarron arch separates the Las Vegas Basin from the Raton Basin. During the Pennsylvanian, the tectonic elements in the region were different (Fig. 2) and reflected Ancestral Rocky Mountain tectonics rather than the Laramide tectonics that produced the modern tectonic setting.

During the Pennsylvanian, a large part of the Las Vegas region was occupied by the Rainesville trough (see Baltz and Myers, 1999). The eastern and southern boundaries of the basin were similar to the present-day boundaries with a ramp-like transition to the Sierra Grande uplift. The Sierra Grande uplift is an Ancestral Rocky Mountain structure that was first formed during the Pennsylvanian. The northern boundary was formed by the Cimarron arch, a fault-bounded uplift that had an exposed Precambrian core during the Pennsylvanian. The Cimarron arch separated the Rainesville trough from the Central Colorado Basin, the Pennsylvanian precursor of the Raton Basin. On the west, the exposed Precambrian core of the El-Oro Rincon uplift separated the Rainesville trough from the Taos trough (Baltz and Myers, 1999). The Brazos uplift was located to the west of the Taos trough.

The sedimentary fill of the Las Vegas Basin is dominated by Pennsylvanian and Early Permian sediments (Figs. 3–6), which largely infilled the Rainesville trough. These sediments obtain a maximum thickness of 9000 ft (2743 m) in the central parts of the basin. Pennsylvanian strata have a maximum thickness of 6500 ft (1981 m). These strata pinch out to the east on the Sierra Grande uplift and to the north on the Cimarron arch. A part of the thickness of the Pennsylvanian section is caused by east-directed thrust faults that repeat the section and appear to be Pennsylvanian in age (see Baltz and Myers, 1999; Broadhead, 2008). However, the non-repeated section in wells is more than the thickness of these strata in all nearby tectonic elements, except possibly to the west in the Taos trough. The Pennsylvanian and

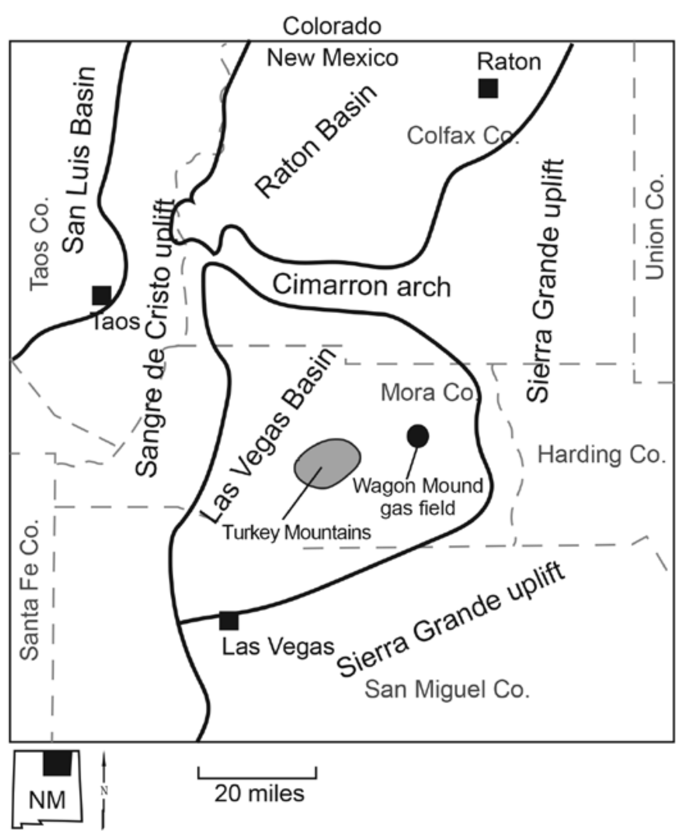

FIGURE 1. Major Cenozoic tectonic elements in the Las Vegas Basin area.

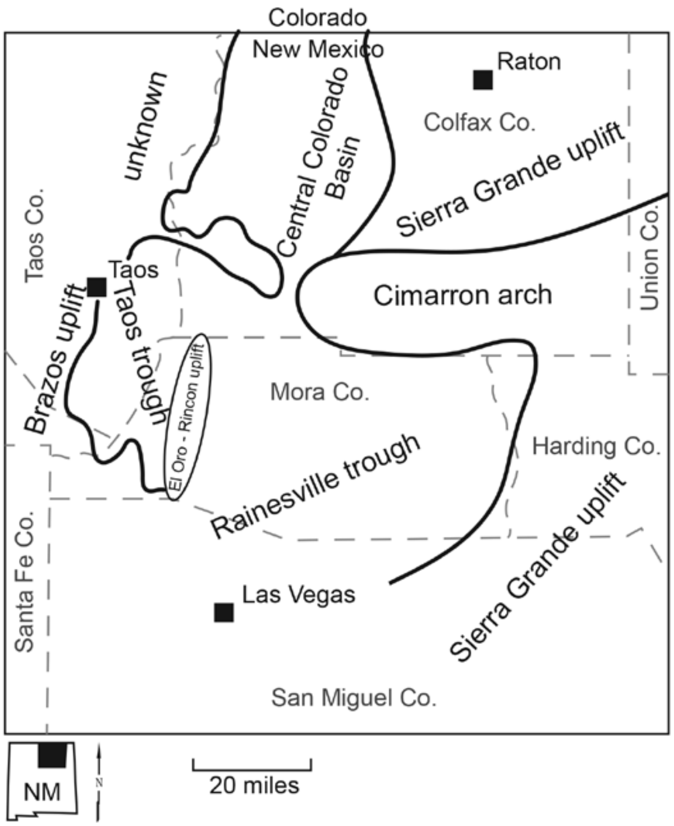

FIGURE 2. Major Pennsylvanian-age tectonic elements. Modified from Baltz and Myers (1999).

Early Permian sedimentary fill is dominated by marine shales. Fine- to coarse-grained arkosic sandstones are interbedded with the shales and minor beds of marine limestone are also present. Shales in the upper part of the Pennsylvanian-Early Permian section are mostly red and organic poor, but substantial amounts of organic-rich, dark-gray shales are present in the Sandia Formation and Madera Group (Pennsylvanian).

From the Permian through Early Cretaceous, the topography of the Las Vegas Basin was subdued. Strata are relatively thin when compared to the Pennsylvanian section (Fig. 3). Leonardian and Guadalupian (Permian) strata were deposited in shallow, restricted marine shelf and shoreline environments. Triassic and Jurassic strata were deposited in fluvial and lacustrine environments, except for the Entrada Sandstone which was formed by eolian dunes in an inland desert. With the Cretaceous came a major marine transgression and the Western Interior Cretaceous Seaway covered the area (Kauffman, 1977). Although a full Cretaceous section is preserved to the north in the Raton Basin (Broadhead, 2008), most of the Cretaceous in the Las Vegas Basin has been removed by Cenozoic erosion, leaving only a thin remnant of what had been deposited in the Western Interior Cretaceous Seaway.

The western boundary of the Las Vegas Basin is defined by east-directed, west-dipping Laramide (latest Cretaceous to Early Tertiary) reverse faults. These faults bring older Precambrian and Pennsylvanian rocks of the Sangre de Cristo uplift into a suprapositional relationship with younger Mesozoic strata on the east (Baltz and Myers, 1999; O'Neill and Mehnert, 1988; New Mexico Bureau of Geology and Mineral Resources, 2003).

Local structural features are also apparent at the surface in the Las Vegas Basin. These post-date the Mesozoic strata that crop out at the surface over most of the basin. The most prominent of these features is the Turkey Mountains uplift which is located in the central deep part of the basin. This uplift forms an isolated mountain range in the central, deep part of the basin. Hayes (1957) postulated that the Turkey Mountain dome was formed by doming over an intrusive Tertiary laccolith. Subsequent to Hayes' publication, the Union Oil Co. No. 1 Fort Union well was drilled within the interior of the Turkey Mountains and proved Hayes's hypothesis correct. The well penetrated a series of intrusive rocks described on the scout card as porphyries from a depth of 2800 ft (853 m) to total depth of 4070 ft (1240 m). The intrusive rocks are apparently a part of a laccolith-sill complex (Mann et al., 2015), the intrusion of which formed a dome that resulted in the Turkey Mountains. Northerly-trending intrusive mafic dikes are exposed in the interior of the Turkey Mountains (Boyd, 1983). Boyd described these dikes as alkali lamprophyres and gave a date of 15.0 ±0.7 million years.

PETROLEUM OCCURRENCES

Commercial production of natural gas in the Las Vegas basin has been obtained from the Dakota Sandstone (Cretaceous) and the Morrison Formation (Jurassic) at the Wagon Mound field in east-central Mora County (Fig. 1; Brooks and Clark, 1978). Wagon Mound constitutes the only commercially productive reservoir that has been thus far discovered in the basin. Exploratory wells elsewhere in the basin have encountered gas shows in the Greenhorn Limestone and Dakota Sandstone (Cretaceous), the Santa Rosa Sandstone (Triassic), the Glorieta Sandstone (Permian), the Sangre de Cristo Formation (Upper Pennsylvanian-Lower Permian), and the Madera Group and Sandia Formation (Pennsylvanian). Broadhead (2008) compiled a list of exploratory test wells in the basin and descriptions of shows encountered by those wells.

Gas shows in the Santa Rosa Sandstone and the Glorieta Sandstone are nonflammable CO_2-rich gases. Gas shows in Cretaceous strata, the Sangre de Cristo Formation, the Madera Group, and the Sandia Formation are hydrocarbons, except for one well drilled on the Turkey Mountains uplift which encountered CO_2 in the Sangre de Cristo Formation.

The Wagon Mound gas field is located in T21N R21E in east-central Mora County (Fig. 1). The field was discovered in 1973. Gas production began in 1976 and continued until field abandonment in 1979. Cumulative production was 97,281,000 ft^3 gas. Production from the field was obtained from eight wells completed in the Dakota Sandstone (Cretaceous). The Morrison Formation (Jurassic) contributed to production in three of the eight wells. The geology of the Wagon Mound field has been summarized by Brooks and Clark (1978) and most of the following section has been extracted from their work.

Age		Stratigraphic units	Thickness (feet)	Description
Cretaceous	Upper	Niobrara Shale	0 - 300*	Dark-gray marine shales, minor micritic ls, thin fine-grained ss
		Fort Hays Limestone	0 - 60*	Medium to dark-gray lime mudstones & wackestones, dark-gray marine shale
		Carlile Shale	0 - 220*	Very dark-gray marine shale, minor siltstone & micritic limestones
		Greenhorn Limestone	50 - 60*	Medium to dark-gray lime mudstones and calcareous shales
		Graneros Shale	170 - 200*	dark-gray marine shales, minor thin siltstones & micritic limestones
	Lower	Dakota Sandstone	170 - 200*	Fine to medium quartzose ss, carbonaceous shale
Jurassic	Upper	Morrison Fm.	350 - 435*	Red, brown, blue-gray, dark-gray nonmarine shales; fine to medium white to green ss
	Middle	Entrada Ss.	60 - 150*	Fine to medium, white, quartzose ss
Triassic	Upper	Chinle Group	450 - 800	Red nonmarine shales, minor dark-gray shale, minor fine to medium nonmarine ss
		Santa Rosa Sandstone	100 - 200	Gray, fine to coarse nonmarine ss and red shale
	Middle	Moenkopi Fm.	100 - 240	Red shales, fine to medium quartzose lenticular ss
Permian	Guadalupian	Bernal Fm.	120 - 160	Red-maroon shale, fine -medium lenticular quartzose ss
	Leonardian	Glorieta Ss.	200 - 400	Fine-medium white quartzose ss
		Yeso Fm.	200 - 500	Red silty shale, orange to white fine-medium ss
	Wolfcampian	Sangre de Cristo Fm.	2000 - 9000	Coarse-grained conglomeratic arkosic ss. Red shales. Possible dark-gray shales in some areas.
Pennsylvanian	Virgilian, Missourian, Des -moinesian	Madera Group		Fine to coarse ss, many arkosic dark-gray to black shale & red shale. Marine limestone.
	Atokan, Morrowan	Sandia Formation		Fine to coarse ss, many arkosic dark-gray to black shale & red shale. Marine limestone.
Mississippian		Arroyo Penasco Formation	0 - 160	Marine limestone, minor fine-coarse quartzose ss
Precambrian				quartzite, schist, gneiss, granite, granodiorite, amphibolite, gabbro, tonalite

* absent from central part of Turkey Mountains uplift

FIGURE 3. Stratigraphic column of the Las Vegas Basin. Modified from Broadhead (2008).

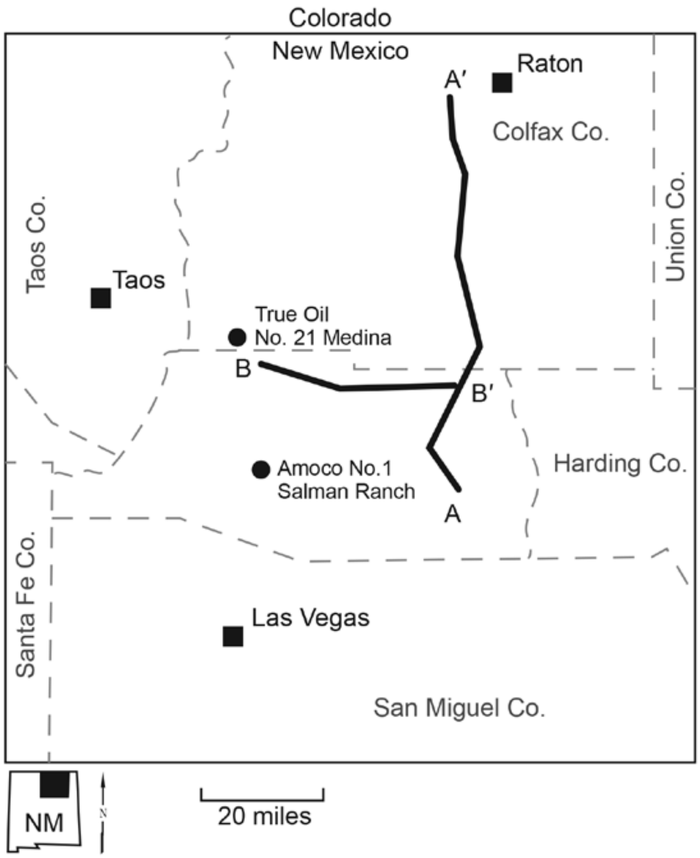

FIGURE 4. Locations of cross sections A-A' (Fig. 5) and B-B' (Fig. 6).

The trapping mechanism at Wagon Mound is formed by a northeast-trending doubly-plunging anticline with a structural relief of approximately 150 ft (46 m). Length of the structure is approximately 7 miles (11 km) and width is 4.5 miles (7.2 km). The main pay zone at the Wagon Mound field is formed by shallow marine, lenticular sandstones in the upper part of the Dakota Sandstone. Secondary pays are present within conglomeratic sandstone in the lower part of the Dakota Sandstone, but in most places this part of the section is below the gas-water contact and is therefore water bearing. Approximately 5000 acres of producible land have been proven by drilling. The trap has not been filled to the spill point. Relatively minor pay zones are present in the lenticular, fluvial sandstones of the Morrison Formation. Presumably the lenticular nature of the Dakota Sandstone and Morrison Formation reservoirs lends a stratigraphic component to trapping. Depth to production varied from 300–700 ft (91–213 m), depending on the position of the well on the structure and whether the pay is within the Dakota Sandstone or within the Morrison Formation. Initial reservoir pressures were low, only 5.5 psi. Porosities of productive sandstones range from 15–25 percent. The Dakota Sandstone and Morrison Formations have different gas-water contacts and, therefore, are hydraulically isolated from each other. Produced gas is 81–83% methane, 15–18% nitrogen, and contains only trace amounts of CO_2.

PETROLEUM SOURCE ROCKS

Determination of the presence or absence of petroleum source rocks is essential when assessing the petroleum potential of a frontier basin such as the Las Vegas Basin. Without source rocks, no oil or natural gas can be present in the basin. Major accumulations can occur only if significant volumes of source rocks are present and only if those source rocks are thermally mature. The type of organic matter (kerogen) in the source rock determines whether oil or gas will have been generated upon maturation. The thermal maturity will determine if generated oil has been naturally refined into wet gas, or upon sufficient maturation, dry gas.

The primary petroleum source rocks in the Las Vegas Basin are dark-gray marine shales in the Pennsylvanian section. Total organic carbon (TOC) content of these shales ranges from 0.16–9.55% and is more than 1% in most samples (Figs. 7–9). Higher values of TOC are present in the Sandia Formation (Lower Pennsylvanian) than in the Madera Group (Middle and Upper Pennsylvanian) but TOC values in excess of 1%, which are adequate for petroleum generation, are present throughout the Pennsylvanian section. In the True Oil No. 21 Medina well (Fig. 8), the Pennsylvanian section appears to have been repeated by thrust faulting. In the upper thrust plate the shales in the Sandia Formation have a maximum TOC content of 1.01%. In the lower thrust plate, most Sandia Formation shales have a TOC content of more than 2% and several of the shales have TOC in excess of 4 with a maximum value of 9.55%. This is suggestive that TOC varies laterally in the shales as well as vertically, presumably as a result of aerial variations in depositional environment. Kerogens appear to be dominated by woody and herbaceous types with a secondary population of inertinite and only minor amorphous types (Broadhead, 2008), indicating that gas with some associated oil would have been generated upon thermal maturation. In the deeper parts of the basin, the Pennsylvanian section is within the thermogenic gas window (Figs. 8, 9). Therefore, any generated oil in the deeper parts of the basin has been has been naturally refined into gas.

Limited data indicate that shales in the Sangre de Cristo Formation (Upper Pennsylvanian—Lower Permian) are too organically lean to generate petroleum in the Las Vegas Basin. TOC data are available from only one well, the Continental No. 1 Mares-Duran (Bayliss and Schwarzer, 1987) which is located in the northeastern part of the basin. In that well, TOC values for the Sangre de Cristo Formation range from 0.7–0.12%. These values represent the dominant Sangre de Cristo Formation red shale facies. However, to the north in the Raton Basin, poorly defined facies belts of dark-gray shales are present within the Sangre de Cristo Formation (Broadhead, 2008). The dark-gray color is suggestive of enhanced organic carbon content when compared to the dominant red shale facies. If dark-gray shales are also present in the subsurface of the Las Vegas Basin, then limited volumes of petroleum source rocks may be present within the Sangre de Cristo Formation. The available maturation data indicate that the Sangre de Cristo Formation is thermally immature or is within the upper part of

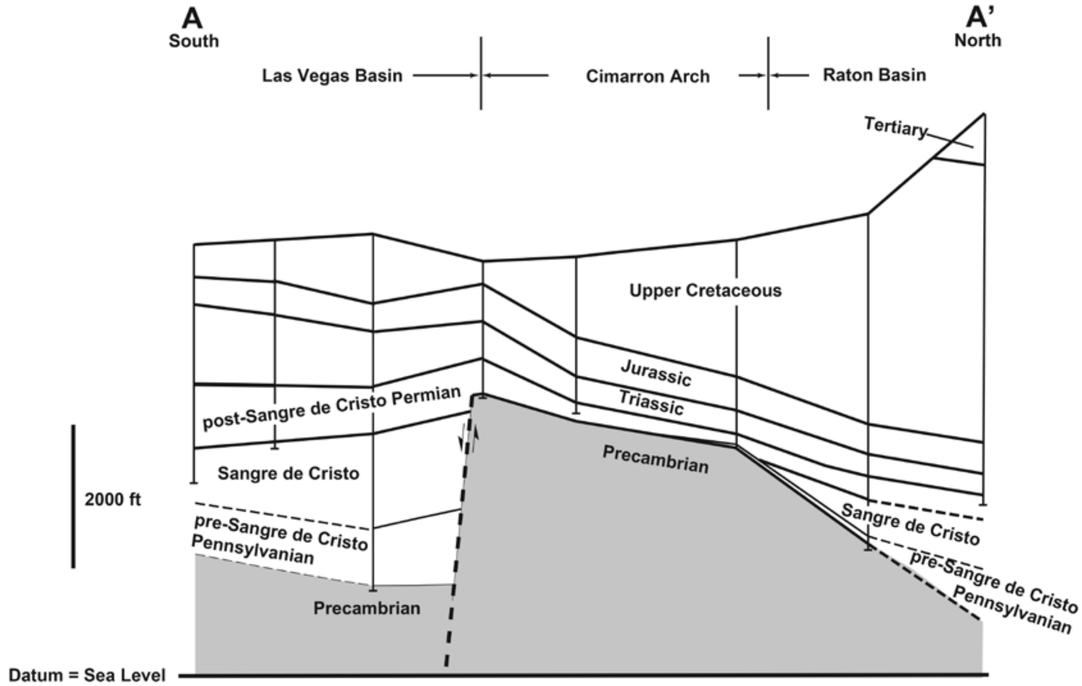

FIGURE 5. Structural cross section A-A'. Datum is sea level. See Figure 4 for location. Simplified from Broadhead (2012).

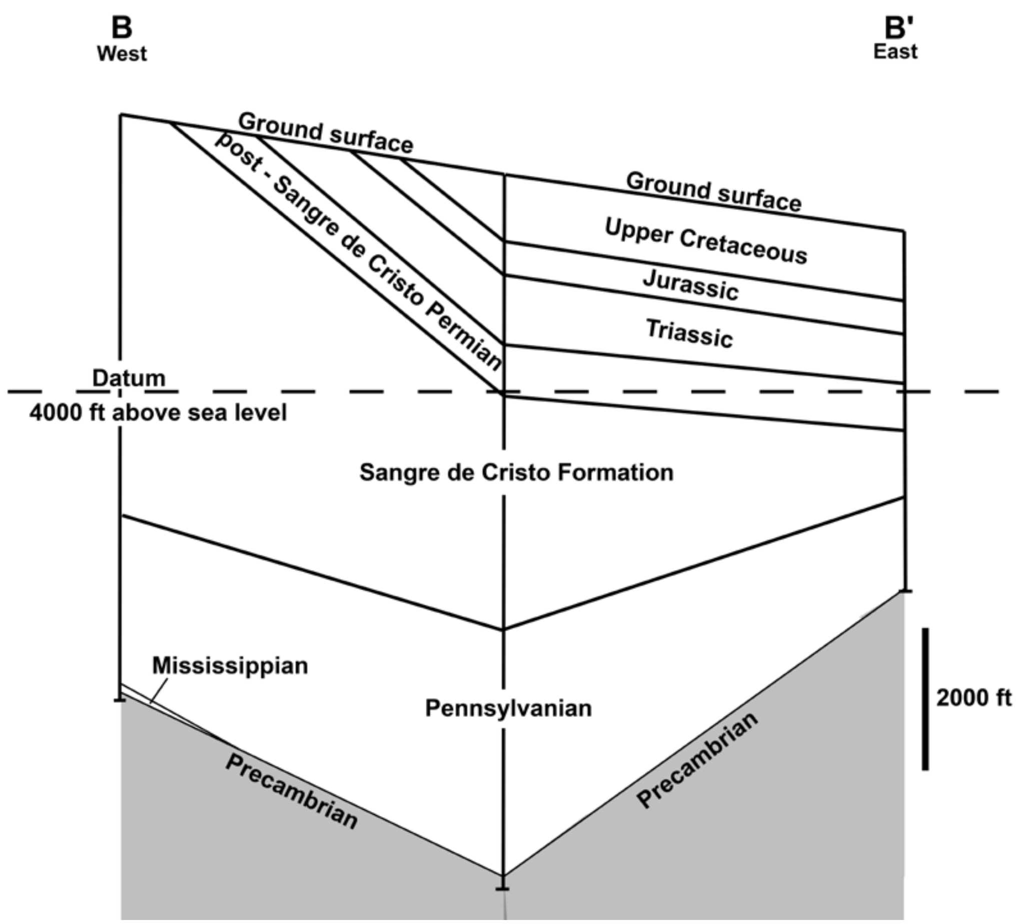

FIGURE 6. Structural cross section B-B'. Datum is 4000 ft above sea level. See Figure 4 for location.

Age		Stratigraphic units	TOC (percent)	Thermal maturity
Cretaceous	Upper	Niobrara Shale	0.95*	oil window
Cretaceous	Upper	Fort Hays Limestone	no data	
Cretaceous	Upper	Carlile Shale	1.04*	oil window
Cretaceous	Upper	Greenhorn Limestone	no data	
Cretaceous	Upper	Graneros Shale	1.56*	oil window
Cretaceous	Lower	Dakota Sandstone	reservoir facies	
Jurassic	Upper	Morrison Fm.	no data	oil window?
Jurassic	Middle	Entrada Ss.	reservoir facies	
Triassic	Upper	Chinle Group	no major source facies	
Triassic	Upper	Santa Rosa Sandstone	reservoir facies	
Triassic	Middle	Moenkopi Fm.	no source facies	
Permian	Guadalupian	Bernal Fm.	no source facies	
Permian	Leonardian	Glorieta Ss.	reservoir facies	
Permian	Wolfcampian	Yeso Fm.	reservoir facies	
Permian	Wolfcampian	Sangre de Cristo Fm.	0.08 - 0.12	biogenic gas window to oil window
Pennsylvanian	Virgilian, Missourian, Des-moinesian	Madera Group	0.16 - 9.55	oil window to dry gas window
Pennsylvanian	Atokan, Morrowan	Sandia Formation		
Mississippian		Arroyo Penasco Formation	no source facies	
Precambrian			no source facies	

* only 1 sample available

FIGURE 7. Stratigraphic chart of petroleum source rock parameters. Modified from Broadhead (2008).

the oil window in the basin, depending on depth and location (see Broadhead, 2008).

Most of the stratigraphic section above the Sangre de Cristo Formation is devoid of petroleum source facies (Fig. 7). Significant thicknesses of shales are present in the Chinle Group (Triassic) and the Morrison Formation (Jurassic). The Chinle Group shales are red and the Morrison Formation shales are variegated in color with neither containing an organic-rich source facies. The Graneros Shale, Carlile Shale, and Niobrara Group (Upper Cretaceous) are dark-gray shales that contain sufficient TOC for petroleum generation. Limited data indicate TOC ranges from 1 to 2 in these strata. The kerogens are a mixture of oil-prone and gas-prone types (Broadhead, 2008). In the northeastern part of the Las Vegas Basin, data from the Shell No. 1 Shell State well indicate the Upper Cretaceous shales are mature and within the oil window (Broadhead, 2008). To the southeast in the vicinity of the Wagon Mound gas field, stratigraphic position relative to the Dakota Sandstone and Morrison Formation reservoirs suggests that the Graneros Shale may be the source rock for the gas trapped in the Wagon Mound field. The high nitrogen content of the gas at Wagon Mound indicates that the source rock has low maturity and is either within the biogenic gas window or the uppermost part of the oil window.

PETROLEUM POTENTIAL

The Las Vegas Basin has considerable petroleum potential. Primary potential is for hydrocarbon gas within the deeply buried Pennsylvanian section. The Dakota and Morrison Formations have lesser potential for low-pressure hydrocarbon gas accumulations. Pennsylvanian reservoirs domed upward on the Turkey Mountains uplift may contain CO_2 reserves. Other strata in the basin, the post-Sangre de Cristo Permian section, Triassic strata, and the Entrada Sandstone are devoid of source facies and are likely characterized by CO_2-water systems rather than petroleum-water systems.

The thick, marine Pennsylvanian section is the primary target for petroleum exploration in the Las Vegas Basin (Broadhead, 2008). The thick sections of organic-rich shales provide the source rocks. They are thermally mature throughout most of the basin and are in the thermogenic gas window in the deeper parts of the basin. Kerogen composition indicates that gas with perhaps some associated oil was generated upon maturation. This conclusion is supported by the gas shows encountered in the Pennsylvanian section by wells drilled in the basin. One well, the Hancock No. 1 Sedberry located in sec. 25 T17N R16E in the southwestern part of the basin, flowed noncommercial volumes of gas with a methane content of 98.6% (Broadhead, 2008). This indicates dry gas is present in that part of the basin. Other wells drilled in the basin have recovered gas on drill-stem tests or have cross-over of the neutron-porosity and density-porosity logs in porous sandstones (gas effect). Sandstones and minor conglomerates interbedded with the shale source rocks are the major reservoir targets in the Pennsylvanian section. Pennsylvanian sandstones with gas shows have porosities ranging from 5–12% (Broadhead, 2008). The shales may also have

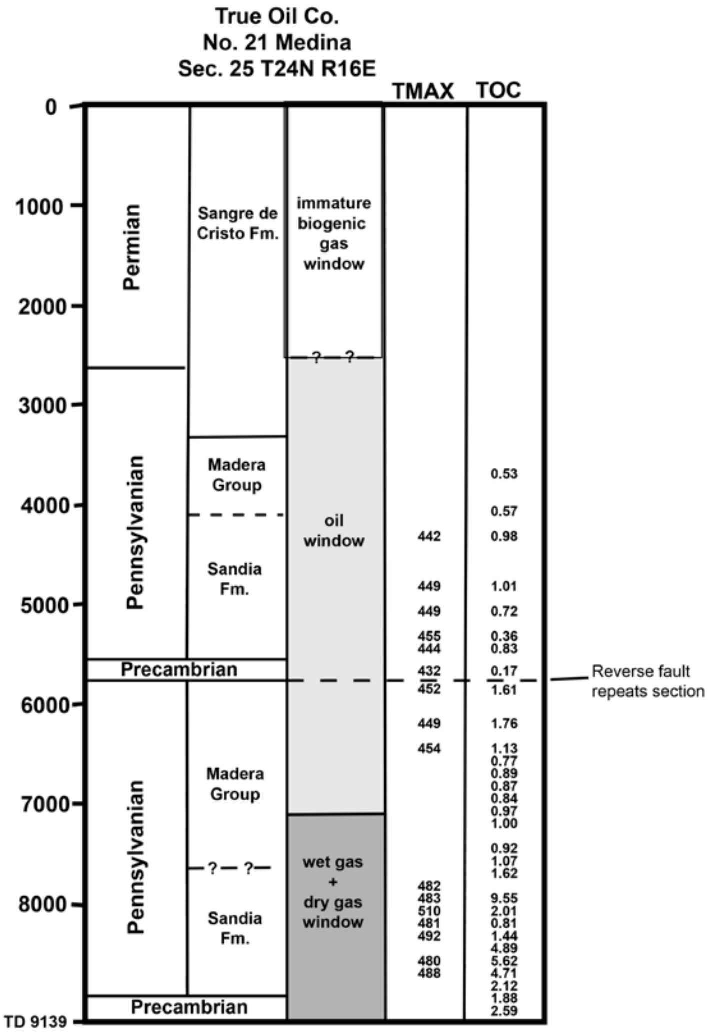

FIGURE 8. Petroleum source rock profile for True Oil Co. No. 21 Medina well. TMAX, Rock-eval TMAX value. TOC, Total organic carbon. Data from Core Laboratories, Inc. and Chevron U.S.A., Inc. (1987). See Figure 4 for location of well. Modified from Broadhead (2008).

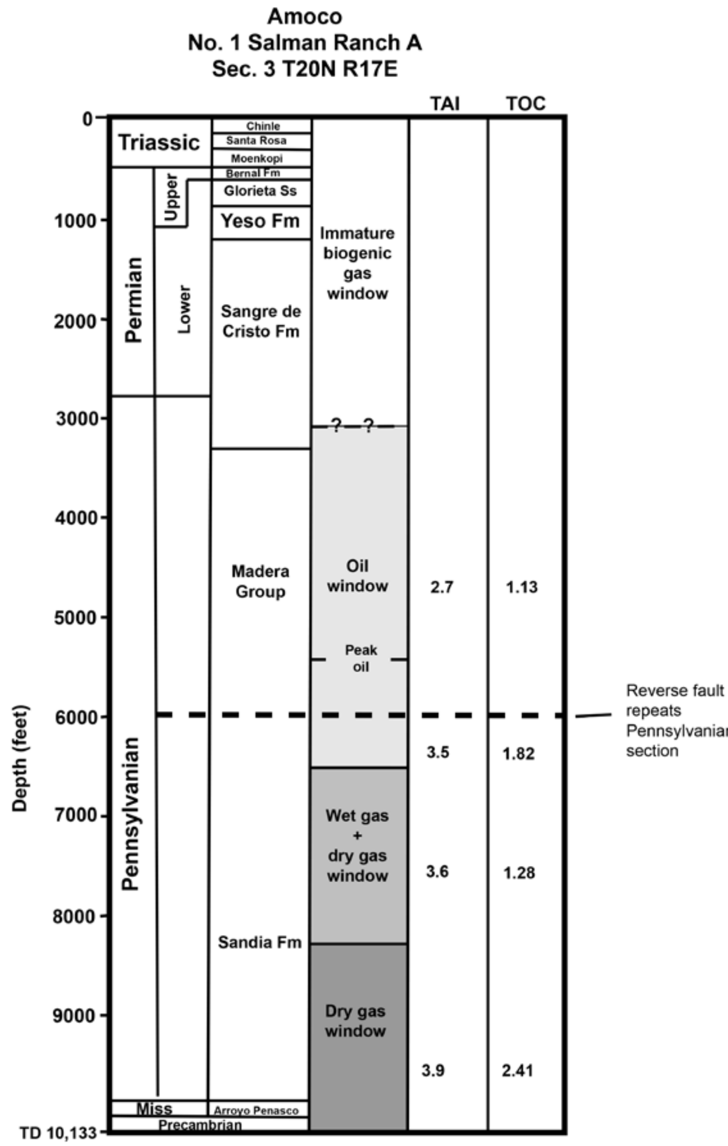

FIGURE 9. Petroleum source rock profile for Amoco No. 1 Salman Ranch A well. TAI, Thermal Alteration Index. TOC, Total organic carbon. Data from Bayliss and Schwarzer (1988). See Figure 4 for location of well. Modified from Broadhead (2008).

potential for shale gas. The Sangre de Cristo Formation may have moderate petroleum potential in any areas that may contain dark-gray kerogen-rich shales but the low levels of thermal maturity will have resulted in incomplete petroleum generation.

An exploratory well drilled on the Turkey Mountains uplift, the Union Land and Grazing No. 1 Fort Union well, recovered gas from a depth of 2343 ft (714 m) in the lower part of the Sangre de Cristo Formation that flowed at a rate of 923,000 ft^3 gas per day. The gas was 97% CO_2. It is probable that the Tertiary-age intrusive rocks that form the core of the mountain range were the source of the CO_2, which was exsolved from the rock-forming magmas as they rose through the crust (Broadhead, 2008). Entrapment is within the domal structure formed by intrusion of the laccolith. Thus, in an elegant act of natural processes, the laccolith not only formed the trap but also supplied the gas that was trapped. However, the presence of hydrocarbon gases in wells drilled elsewhere in the basin is strong evidence that CO_2 associated with the Turkey Mountains laccolith has not migrated pervasively throughout the Pennsylvanian section in other parts of the basin.

The presence of the Wagon Mound gas field indicates that there is potential for natural gas in the Dakota Sandstone and Morrison Formation in the Las Vegas Basin. These stratigraphic units have been eroded from the Turkey Mountains uplift, the northwestern part of the basin, and along the mountain front at the southwestern edge of the basin. They have also been eroded from the larger drainages east of the basin and the Dakota is extensively exposed along the eastern flank of the basin. These erosional areas define areas of recharge responsible for the fresh water that is present in the Dakota Sandstone throughout the basin. Where the Dakota Sandstone is present, it occurs at shallow depths of only a few hundred feet. The widespread entry of fresh water into the Dakota Sandstone indicates that gas potential is low except on structures such as the Wagon Mound anticline that may remain unflushed. The Graneros Shale, which is the postulated source rock for the gas at Wagon Mound, is present in most places where the Dakota Sandstone is present and forms a geographically continuous gas source. It will have low maturity. Because the Dakota Sandstone is present at shallow depths, reservoir pressures will be low.

The remainder of the stratigraphic section, the Yeso Formation, Glorieta Sandstone and Bernal Formation (Permian), the Moenkopi Formation, Santa Rosa Sandstone, and Chinle Group (Triassic), and the Entrada Sandstone (Jurassic) are devoid of petroleum source facies. This limits petroleum potential in these units to gas that may have migrated vertically upward from Pennsylvanian source rocks. Because known faults in the Pennsylvanian section are Pennsylvanian-age thrust faults that do not continue upward into younger strata, it seems improbable that major migration pathways exist. Gas shows in these units are CO_2, which was probably derived from the exsolution of gas from rising magmas that formed the extensive Tertiary volcanic rocks that crop out in the basin. It is unlikely that the CO_2 was formed by thermal decomposition of carbonate rocks that came into contact with the magmas because the strata associated with the CO_2-rich gases contain few if any carbonate rocks. In this regard, the Las Vegas Basin is similar to the Raton Basin where there are dual hydrocarbon-water and CO_2-water systems with the hydrocarbon-water systems occurring in strata with petroleum source facies and the CO_2-water systems occurring in water devoid of petroleum source facies (Broadhead, 2012).

SUMMARY

Commercial gas production in the Las Vegas Basin has been obtained from the Dakota Sandstone (Cretaceous) and the Morrison Formation (Jurassic) at the Wagon Mound field, which produced 97 million cubic feet of gas from 1976 until field abandonment in 1979. Although limited potential exists for undiscovered low-pressure gas in the shallow Dakota Sandstone, primary potential is for gas in deep Pennsylvanian strata. Dark-gray Pennsylvanian shales are thermally mature petroleum source rocks that contain dominantly gas-prone kerogens. Pennsylvanian strata are in the thermogenic gas window in deeper parts of the basin. Primary reservoir targets are sandstones interbedded with the shale source rocks. Post-Sangre de Cristo Formation Permian strata, Triassic strata, and the Entrada Sandstone (Jurassic) low petroleum potential. Gas shows in these strata are CO_2 and reservoirs appear to be characterized by CO_2-water systems rather than hydrocarbon-water systems.

REFERENCES

Baltz, E.H., and Myers, D.A., 1999, Stratigraphic framework of upper Paleozoic rocks, southeastern Sangre de Cristo Mountains, New Mexico, with a section on speculations and implications for regional interpretation of Ancestral Rocky Mountain paleotectonics: New Mexico Bureau of Mines and Mineral Resources, Memoir 48, 269 p.

Bayliss, G.S., and Schwarzer, R.R., 1987, Hydrocarbon source rock evaluation of Continental Oil Co. No. 1 Mores-Duran Sec. 14, T23N, R17E, Mora County, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file report 284, 13 p. Available online at http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=284.

Bayliss, G.S., and Schwarzer, R.R., 1988, Hydrocarbon source rock evaluation of Amoco Production Co. No. 1 Salman Ranch A, Sec. 3, T20N, R17E, Mora County, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file report 320, 12 p. Available online at http://geoinfo.nmt.edu/publications/openfile/details.cfml? Volume=320.

Boyd, T.L., 1983, Geology and joint pattern study of the Turkey Mountains, Mora County, New Mexico: unpublished M.S. thesis, West Texas State University, Canyon Texas, 120 p.

Broadhead, R.F., 2008, The natural gas potential of north-central New Mexico: Colfax, Mora and Taos Counties; New Mexico Bureau of Geology and Mineral Resources, Open-file report 510, 145 p. plus 23 plates and 2 databases. Available online at http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=510.

Broadhead, R.F., 2012, Hydrocarbon-water and CO_2-water systems in the pre-Cretaceous section in the New Mexico part of the Raton Basin: The Mountain Geologist, v. 49, no. 2, p. 55–74.

Brooks, B.J., and Clark, W.R., 1978, Wagon Mound Dakota-Morrison (gas); *in* Fassett, J.E., ed., Oil and gas fields of the Four Corners area, v. II: Four Corners Geological Society, p. 553–555.

Core Laboratories, Inc. and Chevron U.S.A., Inc., 1987, Hydrocarbon source-rock analyses, True Oil Company No. 21 Medina well, Colfax County, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file report 272, 8 p. Available online at http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=272.

Hayes, P.T., 1957, Possible igneous origin of the Turkey Mountains dome, Mora County, New Mexico: American Association of Petroleum Geologists, Bulletin, v. 41, p. 953–956.

Kauffman, E.G., 1977, Geological and biological overview: Western Interior Cretaceous Basin: The Mountain Geologist, v. 14, nos. 3–4, p. 75–99.

Mann, R., Lindline, J., Heizler, M., and Heizler, L., 2015, Timing and Emplacement Setting of the Turkey Mountain laccolith, Mora County, New Mexico (abs.): New Mexico Geological Society Spring Meeting Proceedings, p. 40.

New Mexico Bureau of Geology and Mineral Resources, 2003, Geologic map of New Mexico: New Mexico Bureau of Geology and Mineral Resources, scale 1:500,000, 2 sheets.

O'Neill, J.M., and Mehnert, H.H., 1988, Petrology and physiographic evolution of the Ocate volcanic field, north-central New Mexico. A. The Ocate volcanic field—description of volcanic vents and the geochronology, petrography, and whole-rock chemistry of associated flows: U.S. Geological Survey, Professional Paper 1478-A, p. A1-A30.