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OIL AND GAS POTENTIAL OF THE RATON BASIN, NEW MEXICO

LEE A. WOODWARD
Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

Abstract—Minor amounts of natural gas were produced in the Raton Basin during the late 1970's from the Dakota Formation (Cretaceous) at the Wagon Mound field in New Mexico and during the 1930's from fractured Cretaceous shale at the Garcia field of southern Colorado. However, in general, limited exploration for hydrocarbons in the basin has met with only minor success. This is probably due in large part to lack of deep drilling and to the fact that permeable sandstones are less abundant in the Cretaceous System in the Raton Basin than in most of the productive basins of the Rocky Mountain region.

At the present time the Raton Basin is the only major Laramide basin of the Rocky Mountain region that does not have commercial hydrocarbon production; however, major undiscovered accumulations of oil and (or) gas could be present. Numerous shows have been recorded, mainly from the Cretaceous System and a few from the Pennsylvanian; dark marine shales are potential hydrocarbon source beds in these intervals. Possible traps include fracture systems in shaly Cretaceous units, truncated beds beneath thrust faults, up-dip pinchout of Pennsylvanian sandstones, a few untested anticlines and perhaps complex stratigraphic zones in the deeper parts of the basin.

INTRODUCTION

That part of the Raton Basin located in New Mexico, including the Las Vegas sub-basin, is about 160 km long and as much as 95 km wide. It is bounded on the west by the Sangre de Cristo uplift and on the east by the Sierra Grande arch (Fig. 1). Cretaceous and Tertiary strata (Fig. 2) form most of the surface exposures, and a few areas are covered by late Cenozoic volcanic rocks.

Hydrocarbons were produced for a short time during the late 1970's when minor, low-pressure gas was obtained from the Cretaceous Dakota Formation and the Jurassic Morrison Formation at the Wagon Mound field (Fig. 3). At least 52 hydrocarbon shows are recorded for this part of the Raton Basin (Table 1), with most of them from Cretaceous units.

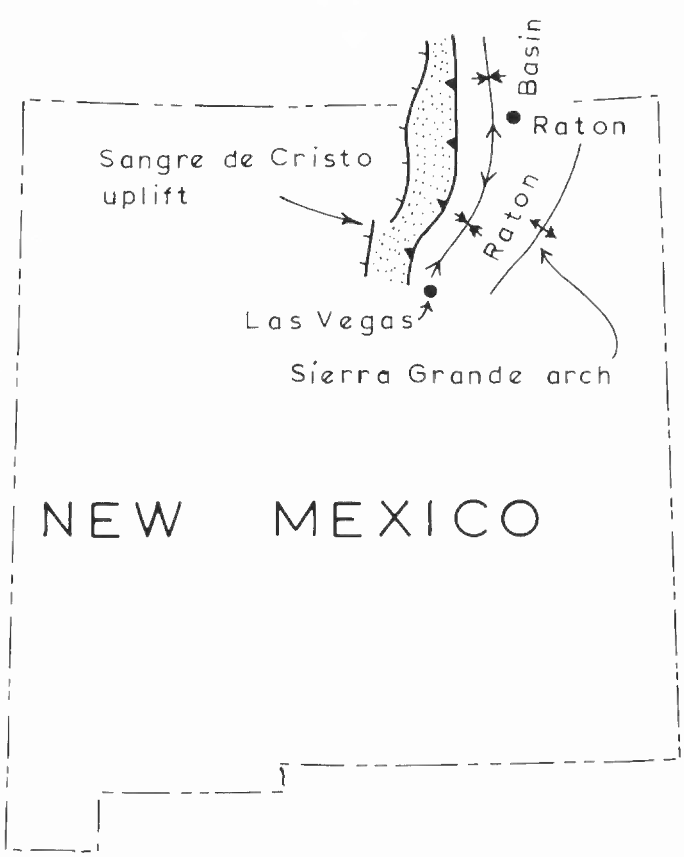

FIGURE 1. Index map showing Raton Basin and nearby tectonic elements.

Several low-volume gas wells are shut in because of the lack of pipelines and the current poor market for gas (Broadhead, 1986).

Drilling commenced in the New Mexico part of the basin in 1906 and has continued intermittently since then (Speer, 1976), with most of the wells testing Cretaceous strata. Although recent drilling activity has been at a moderate pace, a gas discovery in the Dakota Sandstone occurred in 1985 (Broadhead, 1986).

STRUCTURE

The Raton Basin is asymmetrical, having a steep western limb and a gently dipping eastern limb with the synclinal axis near the western part of the basin, and is divided into two parts by the Cimarron basement arch that extends westward from Maxwell (Fig. 3). Structural relief between the deepest part of the basin in New Mexico and the adjacent Sangre de Cristo uplift is at least 4,700 m; structural relief between the basin and the Sierra Grande arch to the east ranges from 1,200 to 2,100 m.

On the west the basin margin is marked by thrust and reverse faults that have pushed Precambrian and Paleozoic rocks over Paleozoic and, locally, over Mesozoic rocks. On the east the basin gradually merges through low dips with the western limb of the Sierra Grande arch. South of Las Vegas the axis of the Raton Basin dies out in gently dipping Permian and Triassic rocks.

There are at least 18 anticlines that range in size from small domes to elongate folds 24 km in length in the New Mexico portion of the Raton Basin. Different kinds of anticlines occur: some caused by compression of strata, uparching of the Precambrian rocks or draping of strata over basement faults and others formed by injection of laccolithic igneous bodies. Folds formed by laccoliths usually can be recognized by the presence of igneous rocks.

In some cases the distinction between structures of laccolithic and non-laccolithic origin may be difficult, but the difference has important implications; laccolithic domes are younger (middle to late Tertiary) and less likely to be traps for hydrocarbons whereas the other folds are usually older (early Tertiary) and are more likely to contain hydrocarbons. However, areas of igneous intrusions should not be totally discounted, as Creely and Saterdal (1956) reported oil in fractures in an igneous sill at Ojo anticline in the northern part of the Raton Basin. The dome along the anticlinal axis north of Vermejo Park (T31 and 32N, R18 and 19E) probably was formed by injection of igneous rocks (Speer, 1976), but some of the potential reservoir rocks may be above the igneous injections and could provide traps for hydrocarbons. The Turkey Mountains (T20N, R19E) also appear to have been domed by an igneous intrusion (Hayes, 1957).

STRATIGRAPHY

Stratigraphic units are described from oldest to youngest (Fig. 2) with emphasis on those rocks that are potential source or reservoir beds. For detailed discussions of the strata the reader is referred to articles by Johnson and Wood (1956) and Baltz (1965). Roberts et al. (1976) presented isopach and lithofacies maps of Paleozoic units in northeastern New Mexico. The following descriptions are taken mainly from these reports. Marine and continental sedimentary strata range in total thickness from at least 2,900 m in the western part of the Raton Basin in New Mexico to approximately 670 m on the Sierra Grande arch.

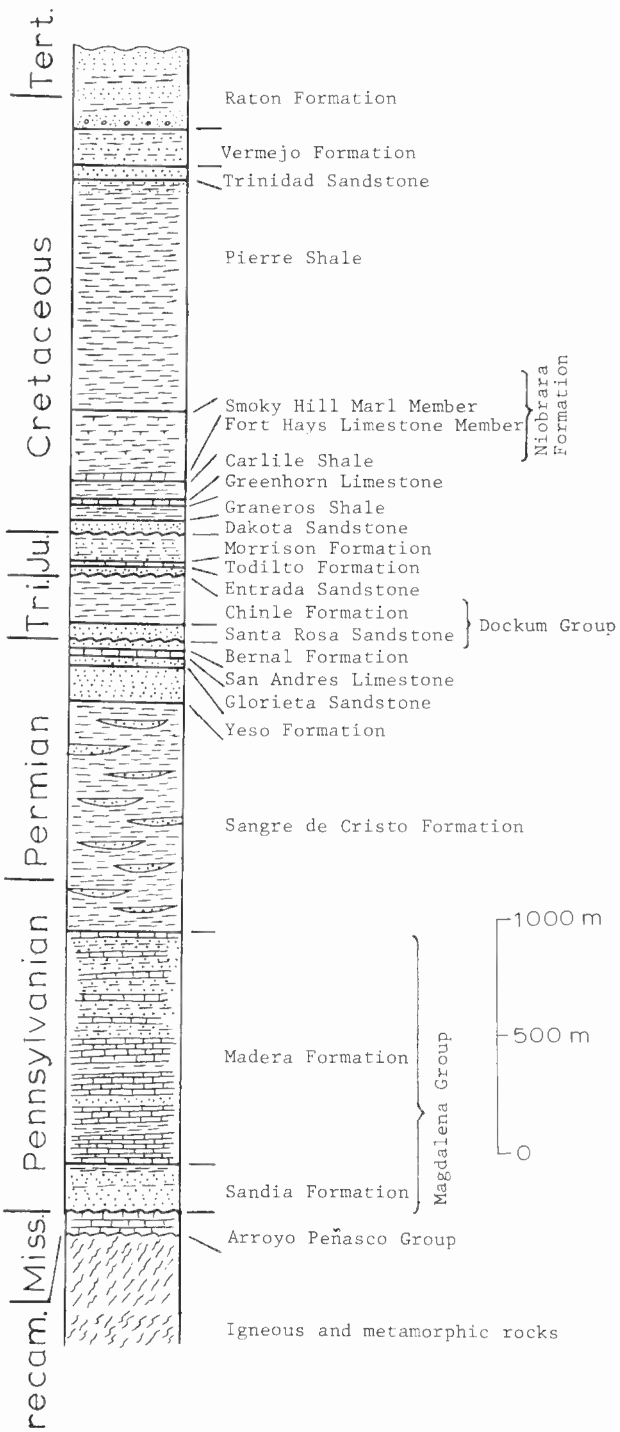

FIGURE 2. Graphic columnar section of Paleozoic, Mesozoic, and lower Tertiary strata in the Raton Basin, New Mexico.

Precambrian

Precambrian igneous and metamorphic rocks are exposed along the eastern margin of the Sangre de Cristo uplift which forms the western boundary of the Raton Basin and have been reached in about 23 wells drilled in the New Mexico part of the Raton Basin. Weathered material from the top of Precambrian granitic rock that is encountered in drill holes is commonly referred to as "granite wash" on completion cards and drillers logs, inferring that basement rocks are immediately beneath; however, arkose beds within the Permian and Pennsylvanian units may have been misidentified on some logs as "granite wash," leading to problems in determining the configuration of the top of the Precambrian rocks.

Mississippian

A thin Mississippian sequence of carbonates occurs in the Sangre de Cristo Mountains, but it seems likely that Mississippian strata are not present in the subsurface in the eastern part of the Raton Basin (Roberts et al., 1976; Armstrong and Mamet, 1979). Baltz and Read (1960) reported that Mississippian strata are about 10.5 m thick in the Continental No. 1 Leatherwood-Reed well near Las Vegas (sec. 15, T16N, R17E). Mississippian beds are assigned to the Arroyo Peñasco Group and consist of the basal Del Padre Sandstone Member overlain by dolomite and limestone of the Espiritu Santo Formation which in turn is overlain by carbonate collapse breccia of the Tererro Formation (Armstrong and Mamet, 1979). Baltz (1965, p. 2045) noted that the Tererro may be as much as 30 m thick in the subsurface in the southern part of the basin and is present at the Continental No. 1 Mares-Duran well (sec. 14, T23N, R17E).

Pennsylvanian

Pennsylvanian strata are included in the Magdalena Group that consists of the Sandia Formation and the Madera Formation, in ascending order. The Magdalena Group ranges in thickness from more than 2,400 m in the Sangre de Cristo Mountains to a wedge out along the Sierra Grande arch.

The Sandia Formation rests unconformbly on Precambrian and Mississippian rocks, and in the southern Raton Basin ranges in thickness from 90 to 490 m (Baltz, 1965, p. 2045). At the Shell No. 1 Mora Ranch well (sec. 5, T22N, R19E) the Sandia is 207 m thick and consists of coarse-grained to conglomeratic sandstone, dark-gray shale and a few minor limestone beds.

The Madera Formation rests conformably on the Sandia and is comprised of a lower gray limestone member and an upper arkosic limestone member. The lower member is composed of interbedded fossiliferous gray limestone, dark-gray shale and sandstone; this member is 210 to 365 m thick in the southern part of the basin (Baltz, 1965, p. 2049). The arkosic limestone is up to 845 m thick in the southern Raton Basin (Baltz, 1965, p. 2049) and consists of interbedded clastic and crystalline limestone, red, green and gray shale and conglomeratic arkose and feldspathic sandstone.

Pennsylvanian strata are absent from the Cimarron arch, probably as a result of nondeposition, and onlap eastward onto Precambrian rocks of the Sierra Grande arch. Near the crest of the arch the Pennsylvanian rocks are absent, and Permian units rest on the Precambrian. The subsurface distribution of Pennsylvanian rocks in the northern part of the Raton Basin in New Mexico is poorly known, but it is likely that they are present only in the western part of the basin (Baltz, 1965, p. 2052; Roberts et al., 1976). The eastward pinchout of Pennsylvanian strata provides potential hydrocarbon traps that are discussed later.

Permo-Pennsylvanian

The Sangre de Cristo Formation overlies the Magdalena Formation and consists of brownish-red arkose alternating with siltstone, mudstone and shale. Minor marine limestone is present in the lower part of the formation (Zeller and Baltz, 1954), but most of the unit appears to be of continental origin. The basal part of the formation interfingers southward with and is laterally equivalent to the upper part of the Madera Formation, and the upper part of the formation intertongues with the overlying Yeso Formation. The Sangre de Cristo Formation is as much as 1,605 m thick in the southern Raton Basin (Baltz, 1965, p. 2054) and appears to thicken rapidly toward the northwest, attaining about 2,900 m in the northern Sangre de Cristo Mountains (Brill, 1952, p. 821).

Permian

Permian units are, in ascending order, the Yeso Formation, Glorieta Sandstone, San Andres Limestone and Bernal Formation. The Yeso consists mainly of fine-grained, light orange to red sandstone and siltstone, although near the top of the formation some thin dolomitic limestone and gypsum beds occur. The Yeso is conformable on the Sangre de Cristo at most localities, but to the east on the Sierra Grande arch the Yeso overlaps older strata and rests unconformably upon Precambrian rocks. The Yeso is up to 150 m in thickness in the southern part of the Raton Basin, thinning northward toward the Cimarron arch where it is absent (Brill, 1952, p. 827). It also intertongues northward with the upper part of the Sangre de Cristo Formation.

The Glorieta Sandstone consists of gray, fine- to medium-grained, well-sorted, well-cemented marine sandstone that is as much as 84 m thick in the southern part of the basin (Baltz, 1965, p. 2055). This unit becomes coarser grained northward, and is absent from the Cimarron arch (Brill, 1952).

The San Andres Limestone consists of dense, dark-gray, petroliferous, marine limestone with a few sandy layers. This unit is about 45 m thick in the southern part of the basin, but thins northward and is absent in the northern part of the basin (Baltz, 1965, p. 2055).

The Bernal Formation is composed of reddish siltstone, shale and fine- to coarse-grained sandstone with a few thin limestone and gypsum beds. This unit is as much as 45 m thick in the southern part of the basin, but may be locally absent because of an erosional unconformity at its top (Baltz, 1965).

Triassic

Upper Triassic strata are assigned to the Dockum Group and unconformably overlie Permian beds at most localities although they locally rest on older units. In the southern Raton Basin the thickness is 300 to 365 m (Baltz, 1965), but on the north edge of the basin the Dockum thins and wedges out in the subsurface (Oriel and Mudge, 1956). The Dockum Group consists of the Santa Rosa Sandstone overlain by the Chinle Formation. The Santa Rosa Sandstone is probably fluvial and was deposited on an alluvial plain; it is composed of thin to thick, brown, gray and red sandstone intercalated with red shale and ranges in thickness from 76 to 137 m because of lenticularity of the upper sandstone beds (Baltz, 1965, p. 2058). Traces of asphaltic residue occur in the lower part of the Santa Rosa Sandstone and are probably derived from the Permian San Andres Limestone (Baltz, 1965, p. 2058).

The Chinle Formation is as much as 275 m thick in the central part of the basin, becoming thinner toward the crest of the Sierra Grande arch. This unit consists of red, purple and greenish shale with interbedded red, brown and gray sandstone near the middle. The Chinle probably accumulated in stream channels and adjacent floodplains.

Jurassic

The basal unit of the Jurassic System is the Entrada Sandstone which is 6 to 36 m thick (Baltz, 1965, p. 2059) and unconformably overlies Triassic rocks at most places. This unit has been called Wingate, Exeter or Ocate, but is referred to here as the Entrada. It is white to pink or red, fine- to coarse-grained, sub-rounded to well-rounded, well-sorted eolian sandstone, cemented with calcite and minor gypsum.

Conformably overlying the Entrada is a unit referred to as the Todilto Limestone and Ralston Creek (?) Formation by Baltz (1965, p. 2060); it is composed of limestone, shale, gypsum and sandstone totaling 15 to 30 m in thickness, with the Todilto pinching out northward and eastward into shale and sandstone (Baltz, 1965, p. 2060). This unit is conformably overlain by the Morrison Formation that is composed of fluvial, green and gray shale with interbedded reddish to brown sandstone and minor conglomerate and limestone totaling 45 to 122 m in thickness (Baltz, 1965, p. 2060).

Cretaceous

Cretaceous strata have a maximum thickness of about 1,430 m in the Raton Basin near the New Mexico-Colorado border. The following units, in ascending order, are present: Purgatoire Formation, Dakota Sandstone, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Formation, Pierre Shale, Trinidad Sandstone, Vermejo Formation and the basal part of the Raton Formation. For a detailed discussion of the strata from the Pierre Shale through the Poison Canyon Formation (Paleocene) the reader is referred to an article by Johnson and Wood (1956).

The Purgatoire Formation is not distinguished on most completion cards for wells in the New Mexico part of the basin, and Baltz (1965, p. 2061) noted that on the western margin of the basin the Purgatoire and the overlying Dakota Sandstone cannot be differentiated. Thus, in subsurface work the Purgatoire, where present, is commonly included with the Dakota Sandstone. Baltz (1965, p. 2061) reported that the Pugatoire is present in most of the Raton Basin, but Jacka and Brand (1972) suggested that it is not present in the southern part of the basin near Las Vegas. The Purgatoire consists of a lower conglomeratic sandstone and an upper unit of interbedded sandstone and carbonaceous shale. Baltz (1965, p. 2061) reported that in the southern part of the Raton Basin the lower sandstone is 15 to 43 m thick, and the upper unit is 6 to 12 m thick.

The Dakota Sandstone in the Raton Basin consists of three intervals (Jacka and Brand, 1972). Gilbert and Asquith (1976) reported that the lower interval is a braided alluvial sheet of fine- to medium-grained, crossbedded sandstone with conglomerate lenses; the middle interval contains interbedded fine- to very fine-grained lenticular sandstone and carbonaceous shale and coal deposited in a meander-belt environment; and the upper interval is composed of fine- to very fine-grained, horizontally stratified sandstone that is a transgressive marine unit. Total thickness of the Dakota Sandstone plus the Purgatoire Formation, where present, ranges from about 35 to 67 m.

The Graneros Shale is unconformable on the Dakota and consists of dark-gray, marine shale with minor interbeds of bentonite, limestone and fine-grained sandstone. The Graneros is 35 to 82 m thick, but most sections are about 52 m thick.

The Greenhorn Limestone is conformable on the Graneros and consists of thin-bedded marine limestone with intercalated gray calcareous shale. In the Raton Basin the Greenhorn is 6 to 27 m thick.

Resting conformably on the Greenhorn is the Carlile Shale which is composed of dark-gray, marine shale with minor, thin limestone interbeds, calcareous concretions and calcareous sandstone and sandy shale, mainly in the upper part of the formation. Where sandstone is present it is called the Codell Sandstone and attains thicknesses up to 6 m. The Carlile is about 34 to 98 m thick, with most localities having thicknesses of approximately 53 m.

The Niobrara Formation is marine, overlies the Carlile and consists of a lower member, the Fort Hays Limestone, which is composed of thin-bedded limestone and subordinate intercalated gray calcareous shale, and an upper member, the Smoky Hill Marl, which is made up of calcareous shale with subordinate thin interbeds of gray limestone and sandy shale. The Fort Hays Limestone Member is about 6 to 14 m thick, and the Niobrara as a whole is 76(?) to 270 m, but most reported thicknesses are about 180 to 245 m.

The marine Pierre Shale is conformable on the Niobrara and consists mainly of dark-gray to blackish shale with minor thin interbeds of sandy shale, sandstone and limestone. The upper 30 m is transitional with the overlying Trinidad Sandstone and is composed of shale and thin interbeds of sandstone. The Pierre Shale is mostly 730 to 880 m thick, although one well has a reported thickness of only 520 m.

The Trinidad Sandstone consists of very fine- to fine-grained, light-gray argillaceous sandstone that is thin bedded in the lower part, but becomes thick bedded and massive in the middle and upper parts. This formation has a maximum thickness of about 60 m in the New Mexico part of the Raton Basin and a minimum subsurface thickness of 30 m. Matuszczak (1969) interpreted the Trinidad Sandstone as beach, near-shore and offshore deposits formed by a regressive sea retreating toward the northeast; occasional pauses in regression or transgressions toward

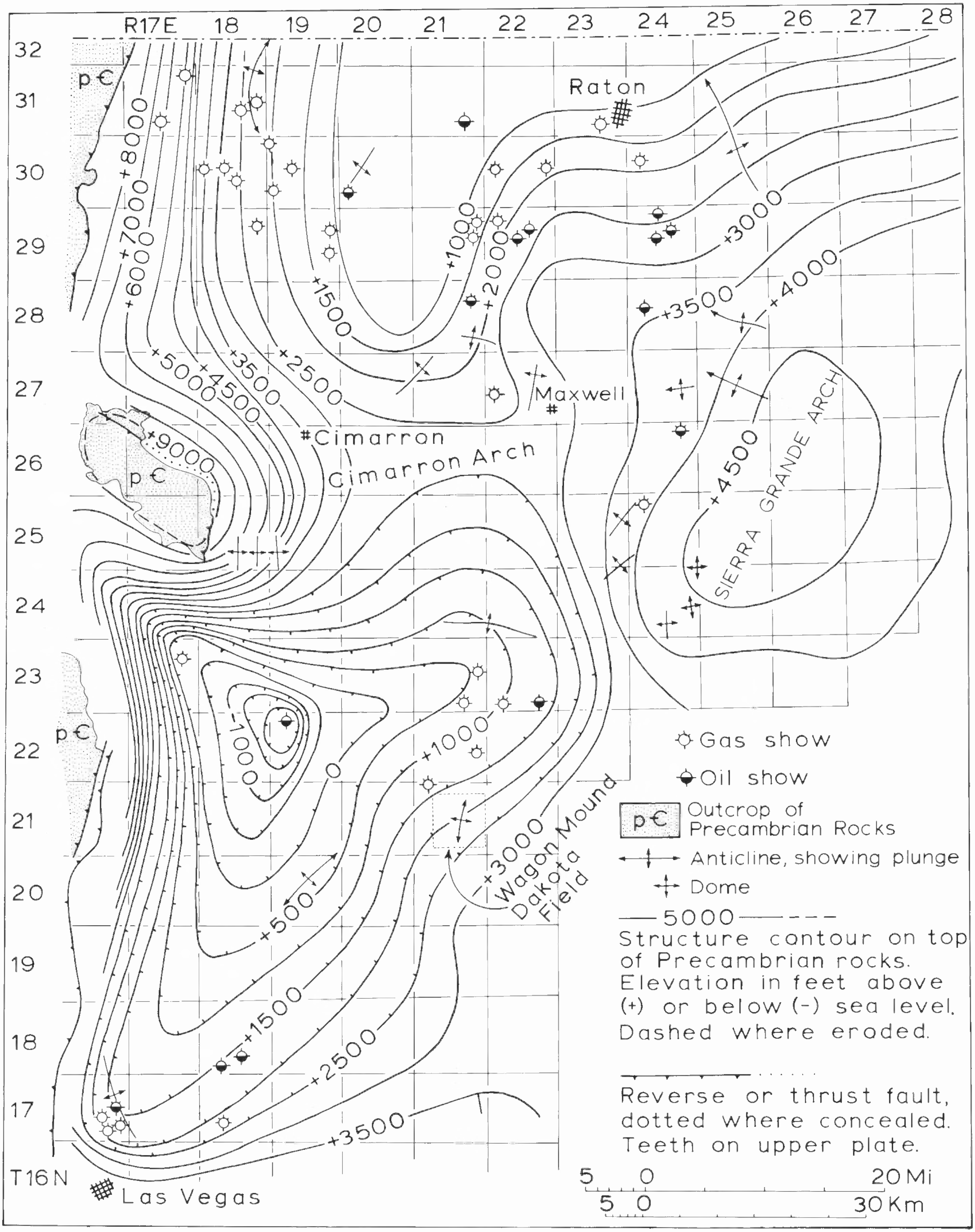

FIGURE 3. Structure contour map of Raton Basin, New Mexico on top of Precambrian basement rocks (modified from Woodward and Snyder, 1976). Contour interval 500 and 1,000 ft.

the southwest resulted in thickening and winnowing of the sands, leading to northwest-trending thick areas with high porosities. He reported maximum porosity of 21 percent and permeability greater than 200 millidarcies; however, the samples outside the thick areas commonly have low porosities and permeabilities less than 1.0 millidarcy. Speer (1976) questioned the northwest depositional trends reported by Matuszczak (1969) and suggested that the evidence favors northeast trends.

The Vermejo Formation ranges in thickness from a maximum of about 120 m in the subsurface to a wedge edge on the east side of the basin near Raton. It is composed of fine- to medium-grained sandstone, gray carbonaceous shale and coal and is interpreted as floodplain and swamp deposits.

Upper Cretaceous and Lower Tertiary

The Raton Formation is of Cretaceous and Paleocene age (Johnson and Wood, 1956) and consists of very fine- to coarse-grained sandstone, arkose, graywacke and interbedded gray siltstone, shale and coal, with a thin conglomerate or conglomeratic sandstone at the base. This unit was deposited under floodplain and swamp conditions and ranges in thickness from a wedge edge in T27N, R17E to about 520 m in the Colorado part of the basin. Beds in the upper part of the Raton Formation intertongue with and grade into the lower beds of the overlying Poison Canyon Formation (Paleocene) toward the southwest (Johnson and Wood, 1956).

Tertiary

The lower part of the Poison Canyon Formation (Paleocene) consists of coarse, arkosic sandstone, conglomerate and thin yellow shale derived from a Precambrian source in the Sangre de Cristo uplift to the west. The Poison Canyon has a maximum thickness of about 760 m in the deepest part of the basin in Colorado (Johnson and Wood, 1956, pp. 714–716). This formation, the stratigraphically highest unit in the New Mexico part of the Raton Basin, has been extensively eroded and is not shown on Figure 2.

Tertiary-Quaternary

Widespread basalt flows that rarely exceed 60 m in thickness rest unconformably on older rocks in the southern part of the Raton Basin and southeast of Raton, New Mexico and range in age from 8 m.y. to Holocene (Stormer, 1972). Some of the volcanic centers have associated shallow intrusions, but there is little metamorphic effect on nearby sedimentary strata.

TECTONIC DEVELOPMENT

In early Paleozoic time the area of the present Raton Basin was tectonically stable, being located on the south flank of the transcontinental arch, a mildly positive feature. There are no Cambrian, Ordovician, Silurian or Devonian strata here (Armstrong and Mamet, 1979). During Mississippian time, which was also quiescent, a thin sequence of shelf carbonates accumulated but was dissected and beveled prior to deposition of Pennsylvanian strata (Armstrong and Mamet, 1979).

In the late Paleozoic the present southern Sangre de Cristo uplift and southwestern Raton Basin was the site of the Rowe-Mora depositional basin (Read and Wood, 1947). In Early Pennsylvanian time delta, delta front and nearshore clastic facies that were derived from the Uncompahgre uplift in central-northern New Mexico and southwestern Colorado were deposited in the Rowe-Mora basin; these sediments thin eastward by non-deposition or erosional truncation onto the Sierra Grande arch (Roberts et al., 1976, p. 143). This pattern of sedimentation changed markedly in Late Pennsylvanian time as the Sierra Grande arch became a major source area for marine sediments being deposited in the basin (Roberts et al., 1976). Continental deposits accumulated during much of Permian time, but toward the end of the period there was a marine transgression resulting in deposition of the San Andres Limestone and a succeeding regression. A major erosional unconformity separates Permian rocks from overlying Upper Triassic strata.

Triassic and Jurassic strata of continental origin were deposited throughout much of the area of the future Raton Basin, except in the northern part of the basin where the Triassic is missing. Epeirogenic uplift resulted in regional unconformities between the Triassic and Jurassic strata and between the Jurassic and Cretaceous rocks. In Cretaceous time a thick sequence of marine shale with subordinate sandstone and minor limestone accumulated in a shallow sea that was related to a foredeep located to the east of the Cordilleran foldbelt of Utah and Nevada.

Structural evolution of the Raton Basin during Laramide (latest Cretaceous-early Teritary) time was described by Johnson and Wood (1956) and is briefly summarized as follows. Rise of the Sangre de Cristo uplift to the west resulted in detritus being eroded and deposited in the Raton Basin as sand in the upper part of the Pierre Shale, in the Trinidad Sandstone and in the Vermejo Formation. Toward the end of the Cretaceous, uplift to the west provided sediment for the Raton Formation and the lower part of the Poison Canyon Formation. There was rejuvenation of the uplift in the Paleocene, and the upper part of the Poison Canyon was deposited. In late Paleocene and Eocene time the area was tilted and folded as uplift continued to the west; some of the Poison Canyon Formation was eroded at this time. Thrusting and folding occurred twice during the Eocene, and the present structural outlines of the Raton Basin and Sangre de Cristo uplift were attained. Normal faulting accompanied further rise of the Sangre de Cristo uplift during Neogene time (Lindsey et al., 1983).

Intrusive igneous rocks were injected during mid- to late Tertiary time, forming extensive sills and laccoliths along the western margin of the Raton Basin and near Vermejo Park. Dikes and sills are widely scattered south of Raton. Volcanic rocks were extruded from vents within the Raton Basin from Ocate to Wagon Mound, and to the south and east of Raton on the eastern margin of the basin in the late Cenozoic.

HYDROCARBON OCCURRENCES

Minor gas was produced from a low-pressure Dakota Sandstone reservoir in a shallow dome at the Wagon Mound field during the late 1970's, and fracture reservoirs in the Niobrara, Carlile and Greenhorn formations produced minor gas at the Garcia field in the Raton Basin of southern Colorado in the 1930's and early 1940's (Clair and Bradish, 1956). Three wells in T29N, R21 and 22E (Fig. 3, Table 1), drilled in 1984 and 1985, reported 50 to 550 MCFGPD from the Dakota Sandstone; these wells are shut in because of lack of pipelines and the low price of gas (Broadhead, 1986).

There are six recorded shows of hydrocarbons from Pennsylvanian strata and one show from the Sangre de Cristo Formation (Permian and Pennsylvanian) in the Raton Basin in New Mexico (Table 1). In addition there are at least 40 shows of oil and (or) gas from Cretaceous rocks of the Raton Basin in New Mexico (Table 1), with 29 of the shows probably from shales or limestones.

Shows in the Paleozoic rocks came mainly from sandstone and arkosic sandstones. Fifteen shows are recorded for the Dakota Sandstone as well. Most of the hydrocarbon shows in the Raton Basin are from rocks lacking indigenous porosity (i.e., carbonate- and silica-cemented siltstones and carbonate beds in the Cretaceous). This led me (Woodward, 1984) to discuss the possibilities for fracture reservoirs in Cretaceous rocks in the Raton Basin; the reader is referred to this paper for a detailed discussion of the hydrocarbon occurrences as related to fracture reservoirs. A few of the more significant occurrences include the Odessa Natural Corporation-No. 4 W. S. Ranch well (sec. 12, T29N, R19E) that yielded 70 MCFGPD from the Fort Hays Limestone Member of the Niobrara Formation (Speer, 1976) and the Pennzoil-No. 2 Vermejo Ranch well (sec. 1, T31N, R17E) that yielded 691 MCFGPD from the Pierre Shale (Broadhead, 1982).

DISCUSSION

Dark marine shales of the Cretaceous and Pennsylvanian Systems are likely source rocks for generation of hydrocarbons. The San Andres Limestone (Permian) and Todilto Limestone (Jurassic) are also possible source rocks, but most other pre-Cretaceous units are not likely to have generated hydrocarbons. Potential reservoir rocks, mainly sandstones, are present in the Pennsylvanian, Permian, Triassic, Jurassic and Cre-

TABLE 1. Wells with oil and gas shows, Raton Basin, New Mexico.

WELL	LOCATION	T.D. (FEET)	SHOW	DEPTH (FEET)	FORMATION	SOURCE OF INFORMATION
PIONEER-#1 FARMER	15-15N-16E	2215	GAS, OIL	?	?	FOSTER AND CHAVEZ (1986)
HOOVER-#1 SAN GUIJILLA	13-17N-16E	2073	OIL	?	?	FOSTER AND CHAVEZ (1986)
McGREGOR-#1 AZUL	22-17N-16E	1239	GAS	?	?	FOSTER AND CHAVEZ (1986)
STARR-#3 ADAMS	23-17N-16E	5200	GAS	?	MADERA	BALTZ (1965)
HANCOCK-#1 SEDBERRY	25-17N-16E	5135	GAS	?	MADERA	BALTZ (1965)
MONUMENT-#2 SEDBERRY	25-17N-16E	4718	GAS	4620-4718	PENNSYLVANIAN	COMPLETION CARD
CHEBEAUGE-AZUL	26-17N-16E	340	GAS, OIL	?	CRETACEOUS?	FOSTER AND CHAVEZ (1986)
PATTERSON-#1 ADAMS	26-17N-16E	705	GAS	?	?	FOSTER AND CHAVEZ (1986)
PATTERSON-#2 ADAMS	26-17N-16E	808	GAS	?	?	FOSTER AND CHAVEZ (1986)
CONTINENTAL- #2 SHOEMAKER	28-17N-18E	4519	GAS	2700	SANGRE DE CRISTO	COMPLETION CARD
NEW MEXICO-#1 KRONIG	27-18N-18E	1680	OIL	?	?	FOSTER AND CHAVEZ (1986)
NEW MEXICO-SHELLABERGER	33-18N-18E	1625	OIL	820	DAKOTA?	COMPLETION CARD
CORONADO-#4 MORA RANCH	5-21N-21E	1068	GAS	?	FORT HAYS LS.	ORAL REPORT
WOOD-#1 SIMMS	9-21N-21E	632	GAS	587-632	DAKOTA	COMPLETION CARD
SHELL-#1 MORA RANCH	5-22N-19E	9690	DEAD OIL STAIN, GAS	750, 8029-8135	DAKOTA, PENNSYLVANIAN	EXAMINATION OF CUTTINGS
BAKKE-#1 H. DANIELS	24-22N-21E	1034	GAS FLARE	989	GRANEROS	COMPLETION CARD
CONTINENTAL- #1 MARES DURAN	14-23N-17E	7765	GAS	6729-6754	PENNSYLVANIAN	COMPLETION CARD
COLUMBINE-#1 GEORGE	13-23N-21E	1600	GAS	?	DAKOTA	COMPLETION CARD
BROOKS-#1 FERNANDEZ	34-23N-21E	1485	GAS	140	CARLILE?	COMPLETION CARD
FRANKS-#1 JEOFFRAY	32-23N-22E	1048	GAS	935	GRANEROS?	COMPLETION CARD
SHELL-#1 STATE	35-23N-22E	5040	DEAD OIL STAIN	810, 4400-4600	DAKOTA, PENNSYLVANIAN	EXAMINATION OF CUTTINGS
WINSTON MARKS-#1 STATE	5-25N-24E	1740	GAS	1535-1543	?	COMPLETION CARD
YORK DENTON-#1 TEX-MEX	2-26N-24E	1525	OIL, GAS	327, 387, 415, 432	GRANEROS, GREENHORN, CARLILE	COMPLETION CARD
FRANKS-#1 LAROE	19-27N-22E	1825	GAS	1200	NIOBRARA?	COMPLETION CARD
CONTINENTAL-#1 SPRINGER	11-28N-21E	2900	OIL STAIN, GAS ODOR	2855-2874	GRANEROS, DAKOTA	COMPLETION CARD
HOWARD & O'HERN- #1 MOORE	8-28N-24E	1478	OIL	1421-29, 1434-53	DAKOTA	COMPLETION CARD
ODESSA-#4 W.S. RANCH	12-29N-18E	6196	GAS	?	PIERRE, FT. HAYS	SPEER (1976)
AMERICAN FUELS- #1 W.S. RANCH	6-29N-19E	4330	GAS	?	PIERRE	SPEER (1976)
ODESSA-#3 W.S. RANCH	24-29N-19E	5084	GAS	?	PIERRE	SPEER (1976)
PERMA-#1 KAISER-EDSON	13-29N-21E	3510	GAS	3230-3276	DAKOTA	COMPLETION CARD
PERMA-#1-Y CHALFONT-KAISER	13-29N-21E	3448	GAS	3293-3338	DAKOTA	COMPLETION CARD
CONTINENTAL- #5 ST. LOUIS	16-29N-22E	2882	OIL STAIN, ODOR, FLUORESCENCE	2679-2709	DAKOTA	COMPLETION CARD
CONTINENTAL- #4 ST. LOUIS	17-29N-22E	4709	OIL, GAS, ODOR	2775-2782	DAKOTA	COMPLETION CARD

TABLE 1 (continued).

WELL	LOCATION	T.D. (FEET)	SHOW	DEPTH (FEET)	FORMATION	SOURCE OF INFORMATION
PERMA-#1 RUSHTON	18-29N-22E	3374	GAS, 100MCFGPD	2984-3023	DAKOTA	BROADHEAD (1986)
INFLOW-#1 BROWN	3-29N-24E	260	OIL	240-260	NIOBRARA?	COMPLETION CARD
EUREKA-#1 C. MOORE	10-29N-24E	4083	GAS	180	NIOBRARA	COMPLETION CARD
CONDRON-#1 MOORE	10-29N-24E	4075	OIL STAIN	1471-1501	DAKOTA	COMPLETION CARD
ODESSA-#1 W.S. RANCH	16-30N-18E	2281	GAS	1634-37, 1755-61	RATON, VERMEJO	COMPLETION CARD
AMERICAN FUELS-#3 W.S. RANCH	22-30N-18E	3950	GAS	?	PIERRE	SPEER (1976)
ODESSA-#5 W.S. RANCH	22-30N-18E	6388	GAS	?	PIERRE	SPEER (1976)
ODESSA-#2 VERMEJO	16-30N-19E	5402	GAS	?	PIERRE	SPEER (1976)
ODESSA-#2 W.S. RANCH	30-30N-20E	5160	GAS	?	PIERRE	SPEER (1976)
ODESSA-#1-X W.S. RANCH	30-30N-20E	5063	GAS, OIL	4910-5026	DAKOTA	COMPLETION CARD
CONTINENTAL-#1 ST. LOUIS	13-30N-22E	5185	GAS	310-325, 3090	PIERRE, GREENHORN	COMPLETION CARD
CONTINENTAL-#8 ST. LOUIS	18-30N-22E	5500	GAS	4474	DAKOTA	COMPLETION CARD
BROOKS-#1 McAULIFFE	17-30N-24E	1165	GAS	640	NIOBRARA	COMPLETION CARD
PENNZOIL-#2 VERMEJO	1-31N-17E	3737	GAS	1340-3737	PIERRE, NIOBRARA	COMPLETION CARD
PENNZOIL-#1 VERMEJO	34-31N-17E	4380	GAS	?	TRINIDAD	BROADHEAD (1982)
UNION-#2 BARTLETT	23-31N-18E	3265	GAS	2000	PIERRE?	COMPLETION CARD
UNION-#1 BARTLETT	23-31N-18E	4411	GAS	115	PIERRE?	COMPLETION CARD
CONTINENTAL-#2 ST. LOUIS	26-31N-21E	7268	OIL STAIN IN FRACTURES	1668-1696	PIERRE	COMPLETION CARD
CONSOLIDATED-#1 DeLISIO	26-31N-23E	708	GAS	550	PIERRE?	COMPLETION CARD

taceous Systems. Most of the sandstones in the Permian, Triassic and Jurassic have no nearby source-beds; however, faults and unconformities could have allowed oil migration into these excellent reservoir rocks.

Structural traps include anticlines or domes and steeply dipping permeable beds truncated by thrust faults along the western side of the Raton Basin. A dome at Wagon Mound (Fig. 3) produced minor gas from the Dakota Formation, but it is likely that a north-trending fault may have enhanced the permeability there. Most of the obvious domes have been drilled, but in some cases they may not have been adequately tested (Speer, 1976). No wells have been drilled through the thrusts on the west side of the basin to test the underlying section. It is likely that only Paleozoic rocks will be present beneath the thrusts at most localities, and many of these units are not attractive targets. Thrusts may truncate strata as young as Cretaceous (T28, 29 and 30N, R16E), but this area is complicated by abundant igneous intrusions.

Permeable sandstones of the Magdalena Group (Pennsylvanian) are present in the southern part of the Raton Basin and could provide good reservoir rocks; these beds pinch out eastward and updip onto the Sierra Grande arch, providing stratigraphic-structural traps. The area east of the Shell-No. 1 Mora Ranch well (sec. 5, T22N, R19E) and west of the Sierra Grande arch has been tectonically stable since the time of deposition of the Magdalena Group, as the depositional slope was toward the northwest during the Late Pennsylvanian (Roberts et al., 1976), and the present-day structural dip is in the same direction. This suggests that any hydrocarbon accumulations may have remained intact. A major uncertainty concerning such traps is the precise location of the wedge-edge of the Magdalena because there is little well control.

Carbonate-rich beds of the Greenhorn Limestone, the Niobrara Formation and the Codell Sandstone Member of the Carlile Formation are the most widespread and thickest intervals of the Cretaceous that might develop fracture reservoirs. Silica-rich siltstone and orthoquartzite interbeds in the Graneros, Carlile and Pierre Shales may provide additional zones capable of fracturing. In general, areas favorable for the development of fracture reservoirs within the Cretaceous shales of the Raton Basin are where there are abrupt changes in dip and (or) strike, along the hinges of folds within the basin and at the synclinal bend at the foot of the western limb of the basin. By analogy, there is hydrocarbon production from fracture reservoirs in correlative Cretaceous beds in similar geologic settings in the San Juan Basin of northwestern New Mexico. Detailed structure contour maps are needed to more precisely define areas favorable for fracture reservoirs in the Raton Basin. Although brittle interbeds capable of fracturing appear to be fairly widespread in the Cretaceous System in the Raton Basin, additional data are needed to construct more precise lithofacies maps.

Other rocks having low indigenous porosities include the Vermejo Formation sandstones and parts of the Trinidad Sandstone. A gas show in the Trinidad from the Pennzoil-No. 1 Vermejo Ranch (sec. 34, T31N, R17E) occurs along the steep western flank of the Raton Basin; fractures due to folding may be significant in enhancing the reservoir characteristics of the Trinidad here. Dolly and Meissner (1977) suggested that a gas accumulation may be present in a basin-bottom hydrodynamic trap in the Trinidad Sandstone in the Colorado part of the basin, a potential which should be evaluated in the New Mexico part of the basin.

Fracturing may serve to release methane from coal beds in the Vermejo and Raton Formations. Gas-bearing reservoirs are reported for complex channel sandstones with low permeabilities in the Raton and Vermejo Formations in the northern part of the basin (Dolly and Meissner, 1977), suggesting that these units may also contain gas in the New Mexico part of the basin.

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REFERENCES

Armstrong, A. K. and Mamet, B. L., 1979, The Mississippian System of north-central New Mexico: New Mexico Geological Society, Guidebook 30, pp. 201–210.

Baltz, E. H., 1965, Stratigraphy and history of Raton Basin and notes on San Luis Basin, Colorado-New Mexico: American Association of Petroleum Geologists Bulletin, v. 49, pp. 2041–2075.

Baltz, E. H. and Read, C. B., 1960, Rocks of Mississippian and probable Devonian age in Sangre de Cristo Mountains, New Mexico: American Association of Petroleum Geologists Bulletin, v. 44, pp. 1749–1774.

Brill, K. G., 1952, Stratigraphy in the Permo-Pennsylvanian zeugogeosyncline of Colorado and northern New Mexico: Geological Society of America Bulletin, v. 63, pp. 809–880.

Broadhead, R. F., 1982, Oil and gas discovery wells drilled in New Mexico in 1981: New Mexico Geology, v. 4, pp. 17–19.

Broadhead, R. F., 1986, Oil and gas discovery wells drilled in New Mexico in 1985: New Mexico Geology, v. 8, pp. 36–40.

Clair, J. R. and Bradish, B. B., 1956, Garcia gas field, Las Animas County, Colorado: Rocky Mountain Association of Geologists, Guidebook to Raton Basin, pp. 75–78.

Creely, R. S. and Saterdal, A. O., 1956, Ojo anticline, Huerfano County, Colorado: Rocky Mountain Association of Geologists, Guidebook to Raton Basin, pp. 68–70.

Dolly, E. D. and Meissner, F. F., 1977, Geology and gas exploration potential, Upper Cretaceous and lower Tertiary strata, northern Raton Basin, Colorado: Rocky Mountain Association of Geologists Symposium, Exploration Frontiers of the Central and Southern Rockies, pp. 247–270.

Foster, R. W. and Chavez, R. R., 1986, Petroleum exploration map of San Miguel County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Petroleum Exploration Map 11, scale 1:126,720.

Gilbert, J. L. and Asquith, G. B., 1976, Sedimentology of braided alluvial interval of Dakota Sandstone, northeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 150, 16 pp.

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

Jacka, A. D. and Brand, J. P., 1972, An analysis of the Dakota Sandstone in the vicinity of Las Vegas, New Mexico, and eastward to the Canadian River Valley: New Mexico Geological Society, Guidebook 23, pp. 105–107.

Johnson, R. B. and Wood, G. H., Jr., 1956, Stratigraphy of Upper Cretaceous and Tertiary rocks of Raton Basin, Colorado and New Mexico: American Association of Petroleum Geologists, Bulletin, v. 40, pp. 707–721.

Lindsey, D. A., Johnson, B. R. and Andriessen, P. A. M., 1983, Laramide and Neogene structure of the northern Sangre de Cristo Range, south-central Colorado: Rocky Mountain Association of Geologists, Rocky Mountain Foreland Basins and Uplifts, pp. 219–228.

Matuszczak, R. A., 1969, Trinidad Sandstone, interpreted, evaluated, in Raton Basin, Colorado-New Mexico: Mountain Geologist, v. 6, pp. 119–124.

Oriel, S. S. and Mudge, M. R., 1956, Problems of lower Mesozoic stratigraphy in southeastern Colorado: Rocky Mountain Association of Geologists, Guidebook to Raton Basin, pp. 19–24.

Read, C. B. and Wood, G. H., Jr., 1947, Distribution and correlation of Pennsylvanian rocks in late Paleozoic sedimentary basins of northern New Mexico: Journal of Geology, v. 55, pp. 220–236.

Roberts, J. W., Barnes, J. J. and Wacker, H. J., 1976, Subsurface Paleozoic stratigraphy of the northeastern New Mexico basin and arch complex: New Mexico Geological Society, Guidebook 27, pp. 141–152.

Speer, W. R., 1976, Oil and gas exploration in the Raton Basin: New Mexico Geological Society, Guidebook 27, pp. 217–226.

Stormer, J. C., 1972, Ages and nature of volcanic activity on the southern High Plains, New Mexico and Colorado: Geological Society of America Bulletin, v. 83, pp. 2443–2448.

Woodward, L. A., 1984, Potential for significant oil and gas fracture reservoirs in Cretaceous rocks of the Raton Basin, New Mexico: American Association of Petroleum Geologists, v. 68, pp. 628–636.

Woodward, L. A. and Snyder, D. O., 1976, Tectonic map of the southern Raton Basin, New Mexico: New Mexico Geological Society, Guidebook 27, map in pocket.

Zeller, H. D. and Baltz, E. H., 1954, Uranium-bearing copper deposits in the Coyote district, Mora County, New Mexico: U.S. Geological Survey, Circular 334, 11 pp.