RATON BASIN–SIERRA GRANDE UPLIFT PROVINCE (041)

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With a section on coalbed gas by Dudley D. Rice and Thomas M. Finn

INTRODUCTION

The Raton Basin is an elongate, asymmetric basin in southeastern Colorado and northeastern New Mexico, analogous to other Rocky Mountain structural-stratigraphic basins associated with the Rocky Mountain Laramide orogenic belt. It is bounded on the west by the Sangre de Cristo Uplift, on the north by the Wet Mountains and the Apishipa Arch, and on the southeast by the Sierra Grande uplift. The basin is approximately 175 mi long and up to 65 mi wide; it encompasses approximately 18,800 sq mi; sedimentary rocks may be 15,000-20,000 ft thick in the deepest part of the basin. The western flank of the basin dips steeply to the east and has been affected by substantial transcurrent and thrust faulting. In the Miocene, the basin was intruded by the Spanish Peaks igneous complex, which was accompanied by extensive fracturing and intrusion of numerous dikes and sills. Intrusion of the Spanish Peaks complex does not appear to have significantly elevated the general geothermal level of the entire basin.

Post-Precambrian stratigraphy in the Raton Basin is typical of the southern Rocky Mountains. A thin carbonate succession (Devonian / Mississippian) overlies the Precambrian basement. Overlying this sequence are 5,000-10,000 ft of terrigenous Permian-Pennsylvanian strata, largely sandstones and redbeds. Triassic redbeds (approximately 1,000 ft) and about 500 ft of terrigenous Jurassic follow. The Cretaceous section includes 200 ft of the basal sequence of clastic Purgatoire / Dakota, followed by 1,000 - 2,000 ft of marine chalks, marls, and organic-rich shales of the Benton and Niobrara Groups. This sequence is overlain by approximately 2,500 ft of Pierre Shale. The marginal marine, partly deltaic Trinidad Sandstone overlies the Pierre, and is in turn overlain by the coal-bearing Vermejo Formation. The Upper Cretaceous / Paleocene coal-bearing Raton Formation overlies the Vermejo. Tertiary sediments of the Poison Canyon Formation overlying these strata are highly variable, and represent continental terrigenous sedimentation during the end of the Laramide orogeny. Perhaps 10,000 ft of Tertiary sediments were originally deposited, but erosion has removed much of the sediment, especially around the basin margins. A generalized stratigraphic section showing the hydrocarbon-bearing strata is shown as figure 2.

In the Colorado portion of the Raton Basin, gas wells have produced measurable quantities from Permian, Upper Triassic, and Cretaceous strata in Las Animas County, and from Cretaceous age rocks in Huerfano County. Approximately 4,000 bbl oil were produced from the Codell Formation (Cretaceous) at the Gardner field (now plugged and abandoned) in Huerfano County. The Cretaceous Greenhorn limestone is being tested near the Apache Canyon field in Las Animas County. The Garcia field, now abandoned, in Las Animas County, Colorado, produced 1.5 BCFG from the Cretaceous Pierre Formation and Apishipa Member of the Niobrara Formation between 1896 and 1943. Natural gas was produced from the Dakota and Morrison Formations in the now-abandoned Wagon Mound field in Mora County, New Mexico.

Carbon dioxide is produced from the Sheep Mountain field, Huerfano County, Colorado. Drilling began in the early 1970's, when the target was oil and (or) gas. Production of CO_2 is from the Cretaceous Dakota and Jurassic Entrada Formations at depths between 3,500 and 6,000 ft. The field has produced approximately 481 BCF of CO_2. The Bravo Dome [Bueyeros field], located in parts of Harding, Union and Quay Counties, New Mexico, also produces CO_2, in part from the Permian Glorieta and Yeso Formations, and has produced [through 1990] 118 BCF of CO_2. This field is estimated to contain more than 16 TCF of CO_2 reserves; approximately one-half is estimated to be recoverable with existing technology.

No commercial oil or gas fields are now active in the basin area, although the coal-bearing Raton and Vermejo Formations yield significant quantities of methane. Two hypothetical conventional gas plays are defined. These are: Upper Cretaceous - Lower Tertiary (4101), and Jurassic-Lower Cretaceous (4102). Three unconventional coalbed gas plays are also defined and described herein by Dudley D. Rice and Thomas M. Finn. They are Northern Raton Basin Play (4150), Raton Basin–Purgatoire River Play (4151), and Southern Raton Basin Play (4152). Further discussion of coalbed gas plays, with references, may be found in the chapter by Rice, "Geologic framework and description of coalbed gas plays" elsewhere in this CD-ROM.

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CONVENTIONAL PLAYS

4101. UPPER CRETACEOUS–LOWER TERTIARY PLAY (HYPOTHETICAL)

This hypothetical, continuous-type “tight gas” play is largely restricted to the marginal marine, partly deltaic Trinidad Sandstone, although stratigraphic traps could occur in the Vermejo and Raton Formations. Dolly and Meissner (1977) estimated the uppermost Cretaceous / lowermost Tertiary section may have *generated* approximately 23 TCFG and that approximately 6 TCFG may be recoverable. Rose and others (1986) calculated that as much as 750 BCF of recoverable gas reserves exists in basin-centered gas in the northern portion of the Raton Basin.

Reservoirs: Cretaceous Trinidad Sandstone, marginal marine, partly deltaic is the potential reservoir rock; general thickness probably varies between 100 and 250 ft; reservoir sands may be as much as 50 ft thick; reservoir porosity is probably 10-14 percent, but porosity varies between 2 and 18 percent. Other potential clastic reservoirs include the Cretaceous Vermejo and Cretaceous / Paleocene Raton Formations.

Source rocks, timing, and migration: Pierre Shale and coal / carbonaceous beds are potential sources in the Vermejo, Raton, and Poison Canyon Formations. Generation and migration probably began no earlier than Eocene.

Traps: Trinidad sandstones, in a basin-center environment, may lack a conventional seal. Depth to production is rather shallow, ranging between approximately 4,000 and 6,000 ft.

Exploration status and resource potential: The play is poorly explored. It is possible that a few new discoveries will exceed 6 BCFG. Probably a number of small gas fields could be found.

4102. JURASSIC-LOWER CRETACEOUS PLAY (HYPOTHETICAL)

This is a high-risk play, and potential reservoirs are restricted to Jurassic Morrison and Cretaceous Dakota sandstones deposited as highly lenticular marine bars and fluvial channels. Sandstones may be fine to coarse grained, 10-40 ft thick; log-derived porosity may reach 15-25 percent. Field pressure, determined from the now-abandoned Wagon Mound field (Mora County, New Mexico) is low.

Reservoirs: Jurassic Morrison and Cretaceous Dakota sandstones, deposited as highly lenticular marine bars and fluvial channels, are the potential reservoirs. Sandstones are fine to coarse grained, 10-40 ft thick; porosity, determined from logs, varies between 15 and 25 percent, permeability appears high. Field pressure was low (5.5 psi). Most of the gas was found in the upper Dakota sands.

Source rocks, timing, and migration: Shale and coal are possible sources within the Purgatoire-Dakota sequence, and overlying shales include potential source beds for oil and gas. Generation probably began in early Tertiary (Eocene) when overlying strata were at least 10,000 ft thick. Migration probably began in the Eocene.

Traps: Gas was structurally trapped in the Dakota sands in a low-relief, northeast-trending Laramide anticline; some gas was trapped in lenticular, fluvial Jurassic Morrison sandstones. Interbedded shales probably act as traps. Depth to known occurrences is 500-5,000 ft.

Exploration status: The play is poorly explored. It is unlikely that new discoveries will exceed 6 BCFG or 1 MMBO. A number of small gas fields could probably be found.

Resource potential: This is a high risk play; undiscovered resources are estimated to be of small size.

UNCONVENTIONAL PLAYS

Coal-Bed Gas Plays

by Dudley D. Rice and Thomas M. Finn

Three coalbed gas plays are identified in the Raton Basin Province (041). They are the Northern Raton Basin Play (4150), the Raton Basin–Purgatoire River Play (4151), and the Southern Raton Basin Play (4152).

Tyler and others (1991), Stevens and others (1992), and Close and Dutcher (1993) have described the geologic controls and potential of coalbed gas in the Raton Basin, southeastern Colorado and northeastern New Mexico.

In the Raton Basin, coal beds with potential for coalbed gas are contained within the Upper Cretaceous Vermejo and Upper Cretaceous-Paleocene Raton Formations. The Vermejo Formation is as much as 350 ft thick and individual coal seams are as much as 14 ft thick. The cumulative coal thickness for the formation ranges from 5 to 35 ft. The overlying Raton Formation is as much as 1,600 ft thick and has a net coal thickness in the range from 10 to 120 ft. Although the Raton Formation contains more coal, individual coal seams are thinner, more discontinuous, and distributed over 1,200 ft of section. The nature of the coal seams in the two formations is controlled by depositional environment; the Vermejo was deposited in a lagoonal environment; whereas, the Raton was deposited in a fluvial setting. Although coal beds are as much as 4,100 ft deep in the northern part of the basin along the LaVeta Syncline, they are generally less than 1,200 ft over a large part of the basin.

The rank of coals in the Vermejo Formation ranges from high-volatile C bituminous along the margins of the basin to low-volatile bituminous in the central part of the basin. The rank generally coincides with present-day depth of burial and structural configuration, and probably resulted from maximum depth of burial that occurred in early Tertiary time. However, the highest ranks (low-volatile bituminous) occur along the eastward-flowing Purgatoire River where the present-day depths of burial are less than about 1,200 ft. These high ranks are interpreted to be the result of high heat flow from the crust, upper mantle, and (or) deep igneous intrusions which was transferred laterally by groundwater flow in middle Tertiary time. During this time, Vermejo and Raton coal beds commonly served as planes of weakness for igneous intrusions. However, the thermal maturity of the coal beds is only locally affected (one-dike width) by the intrusions.

Coal-bed gases from production tests in the Raton Basin are composed mostly of methane with minor amounts of ethane, carbon dioxide, and nitrogen (each less than 1 percent). Isotopic analyses indicate that the gases are predominantly of thermogenic origin and were probably generated during time of maximum burial and (or) heat flow. Some mixing of relatively recent biogenic gas may occur in areas of groundwater flow.

The Raton Basin is a strongly asymmetric basin with a gently dipping eastern flank and a steeply dipping western flank that is thrust-faulted. Several major folds are located along the western margin of the basin. Minor normal faulting occurs within the basin with displacements generally less than 50 ft. The primary fracture permeability system in both the coals and adjoining rocks is oriented east-west.

Regional groundwater flow in the basin is eastward. Recharge is along the elevated, western outcrops which are characterized by higher rainfall. Discharge is at outcrops along the lower eastern margin and also along the Purgatoire River Valley. Reservoir pressures for coal beds are generally underpressured in relation to hydrostatic pressure (less than 0.43 psi/ft). TDS concentrations are relatively low (less than 5,000 ppm) for coalbed waters, indicating a short residence time and continuous recharge from adjacent sandstones, dikes, sills, and (or) the coals themselves. Because of the low TDS contents, produced coalbed waters might be utilized for irrigation or stock, which would keep development costs lower.

Gas contents of coal beds in the basin are highly variable and range from 4 to 810 Scf/t. These contents seem to correlate more closely with depth below the hydrologic potentiometric surface than with depth below the ground surface. On the basis of coal thickness, coal density, drillable area, and gas content, in-place coalbed gas resources of the Raton Basin are estimated to be as much as 12 TCF.

Some coal is produced by both underground and surface methods in the Colorado and New Mexico parts of the basin. Mine-related emissions are minor. A recent explosion in an underground mine near Trinidad, Colorado, indicates that the coal beds are gassy.

Since the late 1970's, more than 110 exploration wells have been drilled for coalbed gas in the Raton Basin, both in Colorado and New Mexico. Production tests have been variable, but gas rates more than 300 MCF/D have been reported. At present, all wells are shut-in because of the absence of gas pipelines in the basin. However, a pipeline is currently under construction and a pilot nitrogren injection project for coalbed gas wells has been approved.

4150. NORTHERN RATON BASIN PLAY,

4151. RATON BASIN–PURGATOIRE RIVER PLAY,

4152. SOUTHERN RATON BASIN PLAY

The target area for coalbed gas is where coal beds of the Vermejo and Raton Formations are greater than 500 ft deep. The thicker, more continuous seams of the Vermejo Formation are probably better targets for coalbed gas production. The target area is divided into 3 plays based on depth, coal rank, and concentration of gas in place: (1) Northern Raton Basin Play, (2) Raton Basin–Purgatoire River Play, and

(3) Southern Raton Basin Play. Exploration wells have been drilled for coalbed gas in all three plays, but, as stated before, production has not been established. The reserve potential of coalbed gas from all three plays is considered to be very good, but production will depend on infrastructure development, particularly pipeline construction.

In the Northern Raton Basin Play (4150), coal rank is as much as medium-volatile bituminous and depths of burial are as much as 4,100 ft, the deepest in the basin. Because of the increased depths, there is a large amount of gas in-place (as much as 24 BCF/sq mi). The potential for reserves from this play is considered to be good, with low permeability resulting from burial depth considered as a possible negative factor.

The Raton Basin–Purgatoire River play (4151) occurs in the central part of basin where coal ranks (medium- to low-volatile bituminous) and gas contents (more than 300 Scf/t) are high, and drilling depths are relatively shallow (less than 1,200 ft). These factors result in a good potential for reserves of coalbed gas from this play.

In the Southern Raton Basin Play (4152), coal ranks are as much as medium-volatile bituminous, but depths of burial are less than 1,400 ft. Because of these relatively shallow depths, concentrations of gas in-place are about 8 BCF/sq mi or less. The reserve potential of this play is also regarded as good.

REFERENCES

(References for coalbed gas are shown in Rice, D.D., Geologic framework and description of coalbed gas plays, this CD-ROM)

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Rose, P.R., Everett, J.R., and Merin, I.S., 1986, Potential basin-centered gas accumulations in Cretaceous Trinidad Sandstone, Raton basin, Colorado, *in* Spencer, C.W., and Mast, R.F., eds., Geology of tight gas reservoirs: American Association of Petroleum Geologist Studies in Geology 42, p. 111-128.

AGE		STRATIGRAPHIC UNITS		THICKNESS (FT)
CENOZOIC	PALEOCENE	Poison Canyon Formation		0 – 2500
CENOZOIC / MESOZOIC	PALEOCENE / CRETACEOUS	Raton Formation		0 – 2075
MESOZOIC	CRETACEOUS	Vermejo Formation		0 – 360
MESOZOIC	CRETACEOUS	Trinidad Sandstone		0 – 255
MESOZOIC	CRETACEOUS	Pierre Shale		1300 – 2900
MESOZOIC	CRETACEOUS	Niobrara	Smokey Hill Marl	900
MESOZOIC	CRETACEOUS	Niobrara	Fort Hayes Limestone	0 – 55
MESOZOIC	CRETACEOUS	Benton	Codell Sandstone	0 – 30
MESOZOIC	CRETACEOUS	Benton	Carlile Shale	165 – 225
MESOZOIC	CRETACEOUS	Benton	Greenhorn Ls.	20 – 70
MESOZOIC	CRETACEOUS	Benton	Graneros Shale	175 – 400
MESOZOIC	CRETACEOUS	Dakota Sandstone		140 – 200
MESOZOIC	CRETACEOUS	Purgatoire Formation		100 – 150
MESOZOIC	JURASSIC	Morrison		150 – 400
MESOZOIC	JURASSIC	Wanakah		30 – 100
MESOZOIC	JURASSIC	Entrada		40 – 100
MESOZOIC	TRIASSIC	Dockum Group		0 – 1200
PALEOZOIC UNDIVIDED				5000 – 10,000

Primary gas reservoir

Source rocks for gas

Primary oil reservoir

Source rocks for oil

Secondary gas reservoir

Secondary oil reservoir