

# ALBUQUERQUE-SANTA FE RIFT (023)

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## INTRODUCTION

This province is part of the Rio Grande rift system and consists of segmented or offset basins that formed as a result of middle Tertiary to Quaternary rifting. The province extends from Socorro, New Mexico, on the south to the northern end of the San Luis Valley in Colorado, a distance of about 280 mi. The east-west width of the province ranges from 15 to 65 mi and the eastern and western boundaries are mostly uplifted mountain blocks exposing Precambrian to Mesozoic rocks generally dipping away from the rifted basins. The primary objectives in the province are pre-rift Cretaceous and older strata, which in most of the province are covered by continental Tertiary-Quaternary fill. This fill, which is greater than 20,000 ft thick in some places, has largely masked Laramide and older structures, thereby necessitating seismic data to delineate structure. As is common in rift basins, the geothermal gradient is above normal. Bottom-hole temperatures of wells indicate the present gradient to average slightly over 2°F/100 ft.

About 120 wells have been drilled in the province, but only about 50 wells penetrated Cretaceous or older rocks. Most of these latter wells were drilled in the 1970's and early 1980's. There is no production in the province, although there was marginal oil production for a short time from two wells in different areas of the province. Except for the drilling of five or six dry holes in the northwestern part of the province, there has been little exploration in the province in the last 6 or 8 years. Refer to Molenaar (1988) for a more detailed discussion of the petroleum geology and hydrocarbon plays of this rift basin area.

On the basis of expected reservoirs, reservoir depth, type of hydrocarbon expected, drilling history, and geography, five hypothetical plays are recognized. These are Albuquerque Basin Play (2301), Hagan-Santa Fe Embayment Play (2302), Espanola Basin Play (2303), San Luis Valley Biogenic Gas Play (2304), and San Juan Sag Play (2305).

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## CONVENTIONAL PLAYS

### 2301. ALBUQUERQUE BASIN PLAY (HYPOTHETICAL)

This is a hypothetical structural play related to down-dropped blocks of Mesozoic and Paleozoic rocks that have been buried sufficiently for the generation of hydrocarbons, or structures that are along migration paths of downdip-generated hydrocarbons (Black, 1982). The play is in the large, generally flat or low-relief area of the Albuquerque Trough and is bounded on the east by the Sandia, Manzano, and Los Pinos Mountains, which are composed of Paleozoic and older rocks. The west side is bounded by the Puerco Platform, composed of Cretaceous rocks, and the Lucero Uplift and Ladron Mountains, both of which consist of Paleozoic and older rocks. The northern boundary is a volcanic-covered area where the rift is offset to the east, and the southern boundary is marked by the converging of the flanking uplifts in the vicinity of Socorro.

**Reservoirs:** The primary objectives of the play are coastal and marine Cretaceous sandstones, which are along depositional strike with the San Juan Basin where these rocks are major producers of oil and gas. Secondary objectives are the Jurassic, sheetlike, eolian Entrada Sandstone and Paleozoic shelf sandstones and carbonates. All these potential reservoirs range in thickness from about 25 to 100 ft. Recoveries on drill-stem and production tests of Cretaceous sandstones in wells in the play area indicate fairly low permeabilities for these potential reservoirs.

**Source rocks:** Oil-prone source rocks are in the basal marine part of the Cretaceous section (Greenhorn interval) and, in the northern part of the play area, the Niobrara-equivalent, middle part of the Mancos Shale. On the basis of analogies of these source rocks with those in the San Juan Basin, the source rocks would be expected to be type II and the total organic carbon content (TOC) would be 1 to 2 or 3 percent. Although not documented, additional oil-prone source rocks may be the interbedded marine shales in the cyclic Pennsylvanian and Permian section. Good gas-prone, type III source rocks are in Cretaceous carbonaceous shales and coals. The maturation ranges from immature to marginally mature along the shallower basin margins to overmature or gas-prone in the deeper parts. Most of the play is considered a gas play because of the predominance of gas shows in the drilled wells, the gas-prone nature of most of the source rocks, and the generally high maturations.

**Timing and migration:** Data are lacking on the timing and migration of hydrocarbons, but it seems likely that the amount of burial by Tertiary sediments and the degree of tilting of individual fault blocks was a controlling factor.

**Traps:** Although the structure of underlying rocks is obscured by the late Tertiary fill, normal faulting seems to be a predominant structural feature of the Albuquerque Basin. At least three of the nine Cretaceous test wells encountered normal faults that cut out significant parts of the section. Traps are anticipated closures within different fault blocks, and many probably would be fault traps. Drilling depths to the Dakota Sandstone would be 6,000-20,000 ft, and the size of possible traps is unknown. Seals would be dependent on fault seals and overlying impermeable shales, either within the Cretaceous section or overlying Tertiary fill. The abundance of gas shows in the Tertiary continental section, which probably was sourced from Cretaceous rocks, suggests that sealing of Cretaceous or older reservoirs may be a problem.

**Exploration status:** Of 46 tests in the play area, only 9 penetrated the Cretaceous section and 4 penetrated all or parts of the Paleozoic section. The Tertiary and Quaternary fill, which is greater than 20,000 ft in some places, has masked Laramide and older structures, thereby necessitating seismic data to delineate structure. Published data on pre-Tertiary structure are not available, but the Shell Oil Company conducted seismic surveys throughout the basin in the 1970's and drilled, or caused to be drilled, nine deep tests. The seismic data must have been difficult to interpret in places, judging by the differences between the prognosticated formational depths and the actual drilled depths. Gas and some oil shows were reported in Cretaceous rocks. Unsuccessful attempts were made in one well to complete for gas production in the Point Lookout Sandstone at a depth of about 17,000 ft. A follow-up well, presumably a Shell farmout, was drilled in 1984 3 or 4 mi to the south and found the Point Lookout 400 ft structurally higher than the Shell well, but no tests were run. This was the last well drilled in the Albuquerque Basin. Geothermal gradients, as calculated from bottom-hole temperatures of 10 deep tests, range from 1.74 to 2.17°F/100 ft and average about 2°F/100 ft.

**Resource potential:** In summary, the Albuquerque Basin Play covers a large area and has the potential for large amounts of hydrocarbons, probably gas. Little is known about the subsurface structure. Seismic data collected in the recent past seem to have been of only mediocre quality at best. The few deep tests indicate that the area is broken by large normal faults.

### **2302. HAGAN-SANTA FE EMBAYMENT PLAY (HYPOTHETICAL)**

The Hagan-Santa Fe Embayment is in the southern part of the Espa-ola Basin, but because of the different play attributes, this hypothetical play is split off from the Espa-ola Basin Play and is considered separately. The play area is tear-drop shaped and about 25 mi in diameter. It is bound on the west by the northern volcanic-covered end of the Albuquerque Basin, on the east by the southern plunge of the Sangre de Cristo Mountains, and on the south by the Sandia Mountains and their broad eastern flank. To the north, the play is separated from the Espa-ola Basin along the line of truncation of Cretaceous rocks, which is controlled by wells in one area.

**Reservoirs:** The play is a structural-stratigraphic play for oil and gas in relatively shallow (<4,000 ft) Cretaceous objectives (Black, 1979, 1984). The primary reservoir objectives are the Dakota Sandstone, 25–100 ft thick, and the Tocito and Semilla Sandstone Members of the Mancos Shale, 10–25 ft thick. The Jurassic Entrada Sandstone, about 50 ft thick, and possibly Pennsylvanian carbonates are secondary objectives.

**Source rocks, timing and migration:** The primary oil-source rocks are of moderate quality and are in the lower part of the Mancos Shale and, where preserved, the Niobrara-equivalent part of the Mancos. Shales at the base of the Todilto Limestone are also potential source rocks. In addition, carbonaceous shales in the Dakota and above the Mancos Shale are potential gas source rocks. All of these rocks are mostly in the oil-generating range, although maturation levels range widely owing to Oligocene intrusions in the area (Molenaar, 1988).

**Timing and migration:** Unlike the other plays in this province, the Hagan-Santa Fe Embayment Play area is only partially covered by late Tertiary synrift fill. The structural history of the Hagan-Santa Fe Embayment is poorly understood, but it apparently it is complex (Black, 1979). At least 6,000 ft of Eocene Galisteo Formation and Oligocene Espinaso Formation was tilted eastward 20° to 25° degrees in middle or late Tertiary time. It seems likely that the time of maximum maturation was prior to this deformation or in the Oligocene, when the intrusive rocks were emplaced and there was sufficient overburden of the Eocene Galisteo Formation and Oligocene Espinaso Formation.

**Traps:** Traps of probable small to moderate size are both structural and stratigraphic, the latter in the case of the lenticular Semilla and Tocito Sandstone Members. Seals

would be overlying Mancos Shale for Cretaceous reservoirs, Todilto anhydrite for the Entrada Sandstone, and interbedded shales for Pennsylvanian carbonate reservoirs.

**Exploration status:** About 34 wells have been drilled in the play area, most since 1974, and all but 2 of 3 wells were drilled into or through the Cretaceous section. Several wells were drilled to the Entrada Sandstone. Oil or gas shows were reported in most or all the wells. A small amount of oil has been produced in one well from the Tocito Sandstone Lenticle of the Mancos Shale at a depth of 2,740 ft. In addition, two or three wells might have been completed as gas wells if a gas pipeline had been present. The calculated geothermal gradient, based on bottom-hole temperatures of many wells, ranges from 1.9 to 2.7°F/100 ft and averages about 2.2°F/100 ft.

**Resource potential:** In summary, the Hagan-Santa Fe Embayment Play covers a relatively small area, and the individual trap sizes are probably small. Although gas has been encountered, the main potential is oil. Relatively shallow drilling depths and outcrop and well control make delineation of structure easier than in the Albuquerque Basin.

### **2303. ESPA-OLA BASIN PLAY (HYPOTHETICAL)**

This is a hypothetical play that covers the major part of the Espa-ola Basin north of the Hagan-Santa Fe Embayment. The southern boundary, which separates this play from the Hagan-Santa Fe Embayment Play, is the projected northern truncation edge of Cretaceous rocks. The eastern boundary is the uplifted Sangre de Cristo Mountains, the northern boundary is the narrowing and eastward offset of the rift system, and the western boundary is the volcanic Jemez Mountains. The entire play area is covered by late Tertiary synrift deposits, and little is known about the subsurface structure and stratigraphy.

**Reservoirs:** Potential reservoirs are Pennsylvanian carbonate rocks and possibly the Jurassic Entrada Sandstone along the southern margin, where it hasn't been removed by pre-Galisteo erosion. Reservoir thickness is estimated to range from 25 to 100 ft.

**Source rocks, timing and migration:** Postulated source rocks would be marine shales within the cyclic Pennsylvanian system and, where preserved, the basal shale of the Todilto Limestone Member. Sparse data indicate the maturation levels in Pennsylvanian rocks and Tertiary (?) rocks to be in the oil-generating window. The data on Tertiary (?) rocks are from depths of 6,000-7,000 ft.

**Traps:** The play is an oil play for structural traps.

**Exploration status:** Only about four exploration tests have been drilled in the Espa-ola Basin Play area. Two wells east of the city of Espa-ola , drilled in 1931 and 1961, bottomed in Pennsylvanian rocks at depths of about 1,700 and 2,730 ft, respectively. Minor oil shows were reported in both wells. These wells were probably drilled on an intermediate fault block adjacent to the Sangre de Cristo Mountains. A well west of Santa Fe, drilled in 1985, was either in Tertiary granite wash or Precambrian granite at a total depth of 7,710 ft.

**Resource potential:** In summary, the Espa-ola Basin Play is very speculative and risky. Although oil shows have been reported, good source rocks and reservoirs have not been documented. Seismic data and additional well control are necessary to further evaluate the play.

#### **2304. SAN LUIS VALLEY BIOGENIC GAS PLAY (HYPOTHETICAL)**

This hypothetical play covers an elongate area about 70 mi long and 20 mi wide in the east-central part of the San Luis Valley, which is a rifted valley filled with continental Tertiary deposits. The boundaries are arbitrary, and the play is based on the many gas shows in shallow water wells in the area north and east of Alamosa, Colorado. Gas has been produced from about 35 of these wells and used by farmers for heating purposes for many years. Analytical data indicate that the gas is of biogenic origin. The reservoirs for gas in this play are sands or sandstones in lacustrine, clay-rich beds of Pliocene age. Whether or not a commercial accumulation of gas exists in this play is speculative. Certainly at such shallow depths, the reservoir pressure would be low.

Limited geophysical and well data indicate that a basement high or horst block underlies the play area. Depth to Precambrian basement is as shallow as 6,000 ft. The deepest part of the greater San Luis Basin, which is bound by the foothills of the San Juan Mountains on the west, and by the Sangre de Cristo Mountains on the east, is near the east margin. According to gravity calculations, the top of the Precambrian surface is at a depth of about 22,500 ft in the structurally low area northeast of Alamosa. A slightly greater depth was calculated for the area a few miles west of Taos, New Mexico.

In addition to the shallow wells that were drilled for gas, or water wells that were converted to gas wells, about 23 wells were drilled in the greater San Luis Valley area. Three wells in the northern third of the San Luis Valley that penetrated the entire section found Tertiary on Precambrian. The other wells were still in Tertiary rocks at total depth. The hydrocarbon potential of this large area is very low.

### 2305. SAN JUAN SAG PLAY (HYPOTHETICAL)

The San Juan Sag Play is based on the presence of hydrocarbon traps, primarily in Cretaceous rocks, below a thick section of volcanic rocks along the foothills of the San Juan Mountains on the west side of the San Luis Valley (Gries, 1985). Oil seeps or staining in surface igneous rocks and subsurface oil and gas shows in Cretaceous and igneous rocks indicate that there are mature oil-source rocks in the system and, hence, enhance the viability of the play. The play area is about 70 mi long and 30 mi wide at the widest point and extends from the line of easternmost truncation of Cretaceous rocks as indicated by seismic and well control along the foothills of the San Juan Mountains, westward to an arc that extends from the western margin of the San Juan volcanic field east of Pagosa Springs, Colorado, to the north end of the San Luis Valley. The play area is actually not part of the rift system, but some of the marginal rift faults probably extend into the play area.

**Reservoirs:** The play is primarily an oil play for Cretaceous and Jurassic sandstone and possibly Oligocene igneous reservoirs in structural and stratigraphic traps underlying a thick Oligocene volcanic cover. The Dakota Sandstone is the primary objective reservoir, and the Codell Sandstone Member of the Carlile Shale (eastern Colorado terminology) and Jurassic Junction Creek Sandstone, as well as fractured igneous dikes or sills, are secondary objectives (fig. 2, right side). The thicknesses of the sandstone reservoirs range from 20 to 100 ft.

**Source rocks:** The lower part of the Mancos Shale and the Niobrara-equivalent, middle part of the Mancos are the primary oil-source rocks, and the remainder of the Cretaceous section could provide adequate gas-prone source rocks. Total organic carbon content of the oil source-rocks is as much as 3 weight percent and averages about 1.4 percent. Except for overcooking in the proximity of Oligocene igneous intrusive rocks, most of the lower part of the Cretaceous section is in the oil-generating window.

**Traps:** Traps in this play would be structural, probably anticlinal as well as fault traps. Delineation of the structure under the thick volcanic cover (2,500–8,000 ft or more) with seismic surveys is difficult and costly, but not impossible. The area seems to be highly faulted under the volcanic cover as indicated by abrupt changes between wells in the depths of subsurface units. Based on wells drilled, depths to objectives range from about 6,000 to 13,000 ft. An analog for the type of accumulation in this play is the Price Gramps oil field located near the southwest boundary of the play area southeast of

Pagosa Springs, Colorado. This field has produced about 6 million barrels of oil from the Dakota Sandstone in a small faulted anticlinal trap at a depth of around 1,200 ft.

**Exploration status:** Since 1982, when the play commenced, 14 wells have been drilled and 11 penetrated Cretaceous objectives. Several wells had good oil or gas shows. One well was completed for 30 barrels of oil per day from a Tertiary sill and produced about 4,000 barrels before it was abandoned (Gries, 1985). Numerous igneous sills or dikes, some as thick as 600 ft, were encountered in the Cretaceous section in many of the wells. The thicker sills had a destructional effect on both the maturation (overcooking) and the reservoirs. The last well was drilled in 1990. The calculated geothermal gradient, based on bottom-hole temperatures of 12 wells, ranges from 1.87 to 3.30°F/100 ft and averages about 2.29°F/100 ft.

**Resource potential:** In summary, the San Juan Sag Play has a fair to good potential for containing hydrocarbon accumulations, but it is a very high-risk play. Mature, oil-prone source rocks are present and oil has been generated as indicated by surface and subsurface shows and seeps. Small- to medium-size traps are probably present, but delineating them under the thick volcanic cover and, in many places, rugged terrain by seismic methods is difficult and costly.

## **NCONVENTIONAL PLAYS**

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

## REFERENCES

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