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PENNSYLVANIAN ROCKS IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO

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INTRODUCTION

Pennsylvanian rocks do not crop out in the San Juan Basin, New Mexico, but are exposed in the Nacimiento Mountains and San Pedro Mountains to the east, the San Juan Mountains to the north and the Zuni Mountains to the south. Therefore, all studies of Pennsylvanian rocks in the basin are based on extrapolation of data from widely spaced outcrops outside the basin and from drill-hole data in the basin. Despite extensive drilling during the past 40 years, very few holes have penetrated Pennsylvanian rocks, leaving a considerable information gap below the thoroughly explored and studied Cretaceous rocks. This paper summarizes reports on Pennsylvanian rocks in areas adjacent to the basin; the illustrations are freely generalized from several subsurface studies.

STRATIGRAPHY OF THE NORTHWEST AND CENTRAL SAN JUAN BASIN

Molas Formation

The Molas Formation is the oldest Pennsylvanian formation in the San Juan Basin and it ranges in age from Morrowan in the southeast, to Atokan in the northwest. It contains a clastic red-bed sequence representing a paleosol developed on a karst terrain of the underlying Mississippian limestone (Peterson and Ohlen, 1963). It was subdivided by Merrill and Winar (1958) into three members, including a limestone conglomerate member at the base that grades upward to a poorly stratified claystone and siltstone member overlain by a member composed of well-stratified calcareous shale and siltstone containing in the upper 36 ft (11 m) some sandstone beds that bear marine fossils.

Thicknesses of the Molas range from over 200 ft (61 m) near the Colorado-New Mexico state line in the central part of the basin, to 0 ft on the Penasco and Zuni uplifts in the east and southwest. The Molas may correlate with part of the Sandia Formation in the southeastern part of the basin (fig. 1).

Hermosa Formation

The Hermosa Formation conformably overlies the Molas Formation and is recognized in the north, west and central parts of the basin. Thicknesses range from 3,000 ft (914 m) to 0 ft where the Hermosa wedges out against the Penasco and Zuni-Defiance highs. The age of the Hermosa ranges from Atokan to Virgilian, or Middle and Late Pennsylvanian. On their redefinition of the upper contact, Wengerd and Strickland (1954) consider the uppermost part of their Hermosa to be Wolfcampian. Three members of the Hermosa are recognized: the lower member, the Paradox Member and the upper member. Wengerd and Matheny (1958), however, raised the Hermosa to group status, and divided it into the Pinkerton Trail, Paradox and Honaker Trail formations, respectively.

The lower member (Pinkerton Trail Formation of Wengerd and Matheny, 1958) consists of massive to thin beds of gray siliceous limestone, gray calcareous shale and siltstone, thin arkosic sandstone lentils, and fragments reworked from the underlying Molas. These units contain fossils of marine origin typical of a shallow neritic shelf assemblage, and grade from mostly clastic in the lower portion to mostly carbonates in the upper portion. The lower member ranges in age from Atokan to early Des Moinesian, and is the time equivalent of part of the Sandia Formation in the southeastern San Juan Basin (fig. 1).

The Paradox Member contains complex lateral facies changes, from thick interbedded evaporites and black shale in the northwestern San Juan Basin and the southeasternmost

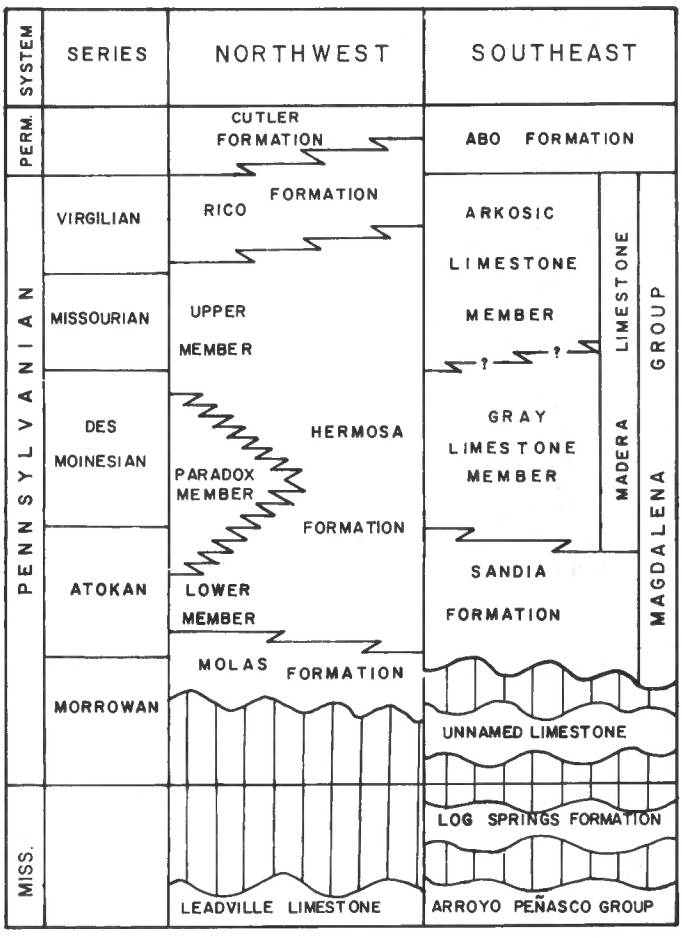

Figure 1. Probable correlations of Pennsylvanian rocks in the San Juan Basin, New Mexico.

Paradox basin, to thinner conglomeratic and cherty limestone, sandy siltstone and arkosic rocks in the central San Juan Basin. Evaporites in the Paradox wedge out abruptly in places against carbonate buildups.

In the Four Corners region, there are several hydrocarbon producing zones in the Paradox Member which have been given informal names. These zones are correlated on the basis of black shale layers between salt cycles (Hite, 1960). In ascending order, they are: the Alkali Gulch zone between cycles 30 and 34; the Barker Creek zone between cycles 11 and 19; the Akah zone between cycles 6 and 10; the Desert Creek zone between cycles 4 and 5; and the Ismay zone between cycles 1 and 3. These zones are also recognizable in carbonates of the Paradox Member of the northern and western San Juan Basin, but gradually become less distinct toward the central part of the basin; there, the Paradox Member becomes indistinguishable from the upper and lower members as suggested by subsurface logs. The Paradox may correlate with the gray limestone member of the Madera Formation, although the loss of identifiable Paradox characteristics in the southeastern part of the basin makes this correlation uncertain (fig. 1).

The upper member (Honaker Trail of Wengerd and Matheny, 1958) includes thin to massive gray cherty limestone and dolomite, gray calcareous shale, buff-gray siltstone, arkosic sandstone, and arkose. It is of Des Moinesian, Missourian and Virgilian ages; the upper part is younger owing to regression of the Pennsylvanian sea to the southeast. The upper member probably correlates with the arkosic limestone member of the Madera Formation (fig. 1).

Rico Formation

Rico Formation is the name for rocks of the transition zone above the Hermosa Formation, and consists of deposits formed during regression of the sea during Virgilian to Wolfcampian time. Lithologies grade from mostly carbonate at the base to mostly clastic red beds at the top. There is considerable disagreement over the boundaries and age of the Rico (Wengerd and Strickland, 1954). Baars (1961) proposed extending the Honaker Trail of Wengerd and Matheny (1958) to include the transition zone, entirely eliminating the use of the Rico. Wengerd and Szabo (1968) proposed including the red beds of the transition zone in the overlying Cutler Formation in southwestern Colorado, locally eliminating the upper member, inasmuch as this is the area of thick-clastic-material influx from the Uncompahgre highland to the east. The Rico Formation may correlate with the upper part of the Madera and the lower part of the Abo in the southeastern San Juan Basin (fig. 1).

STRATIGRAPHY OF THE SOUTHEAST SAN JUAN BASIN

Log Springs Formation

The Log Springs Formation of Chesterian age (Armstrong and Mamet, 1974), once thought to be the Pennsylvanian equivalent of the Molas Formation (Wengerd and Matheny, 1958), unconformably overlies the Mississippian Arroyo Penasco Group. The Log Springs is approximately 38-50 ft (11.6-15.2 m) thick and consists of 8-10 ft (2.4-3.0 m) of red silty hematitic shale, overlain by 30-40 ft (9.1-12.2 m) of red arkosic to conglomeratic, crossbedded, argillaceous dusty red sandstone. The Log Springs thins to 0 ft near the Penasco uplift. Armstrong and Mamet (1974) also recognized unnamed Morrowan carbonate rocks between the Log Springs and the overlying Sandia.

Sandia Formation

Wood and Northrop (1946) recognized two unnamed members of the Sandia Formation in the Magdalena Group. The lower limestone member called Osha Canyon by DuChene (1974), lies on the Log Springs Formation. The contact may be unconformable (Armstrong, 1955). The lower limestone member grades from a gray fossiliferous, arenaceous limestone at the base to a purple-gray shale containing limestone nodules at the top. The upper clastic member is a dark-brown, brown-gray, and brown-green sandstone and very arenaceous limestone. The thickness of the Sandia ranges from 280 ft (85 m) in the southern Nacimiento Mountains adjacent to the San Juan Basin, to 0 ft less than 10 mi (16 km) to the north on the Pennsylvanian Penasco uplift. The Sandia may be equivalent to the Molas and to the lower member of the Hermosa in the central basin, but the differing lithologies make correlation difficult (fig. 1).

Madera Limestone

The Madera Limestone of the Magdalena Group conformably overlies the Sandia Formation, except near the Penasco uplift, where pulses of uplift caused local unconformities. Read and Andrews (1944) divided the Madera into a lower gray limestone member and an upper arkosic member. The lower member contains gray cherty limestone and calcareous shale, and contrasts sharply with the overlying member's alternating red or brown arkosic sandstone, arkosic limestone and light-gray limestone. The gray limestone member is Atokan to Des Moinesian in age; the arkosic member ranges from Des Moinesian through Missourian to Virgilian in age. The Madera is conformably overlain by the Wolfcampian Abo Formation. It ranges in thickness from approximately 2,000 ft (610 m) in the Cabezon accessway (fig. 2) to 0 ft on the Penasco uplift. The gray limestone member is equivalent to part of the Paradox Member of the Hermosa Formation, and the arkosic member probably correlates with the upper member of the Hermosa (fig. 1).

PENNSYLVANIAN HISTORY

Early Pennsylvanian time throughout most of the present San Juan Basin was a period of erosion, solution and development of a paleosol in the Molas formed upon the Mississippian Leadville Limestone. In late Morrowan time, the sea entered through a trough in what is now the southeastern San Juan Basin, south of present-day Cuba, New Mexico, an area Wengerd and Strickland (1954) labeled the Cabezon accessway. By early Atokan time, the sea had extended across northwestern New Mexico and into the Paradox basin. As the sea moved northwestward, it also spread laterally, lapping onto the Penasco uplift to the east, and against the Zuni and Defiance uplifts to the south and west. The Penasco uplift was a southern spur of the San Luis and Uncompahgre uplifts of the ancestral Rocky Mountains (Wood and Northrop, 1946), all of which shed clastics into the Pennsylvanian seaway following pulses of uplift. The Zuni and Defiance uplifts were apparently much less active, as the sediments in the trough are thickest

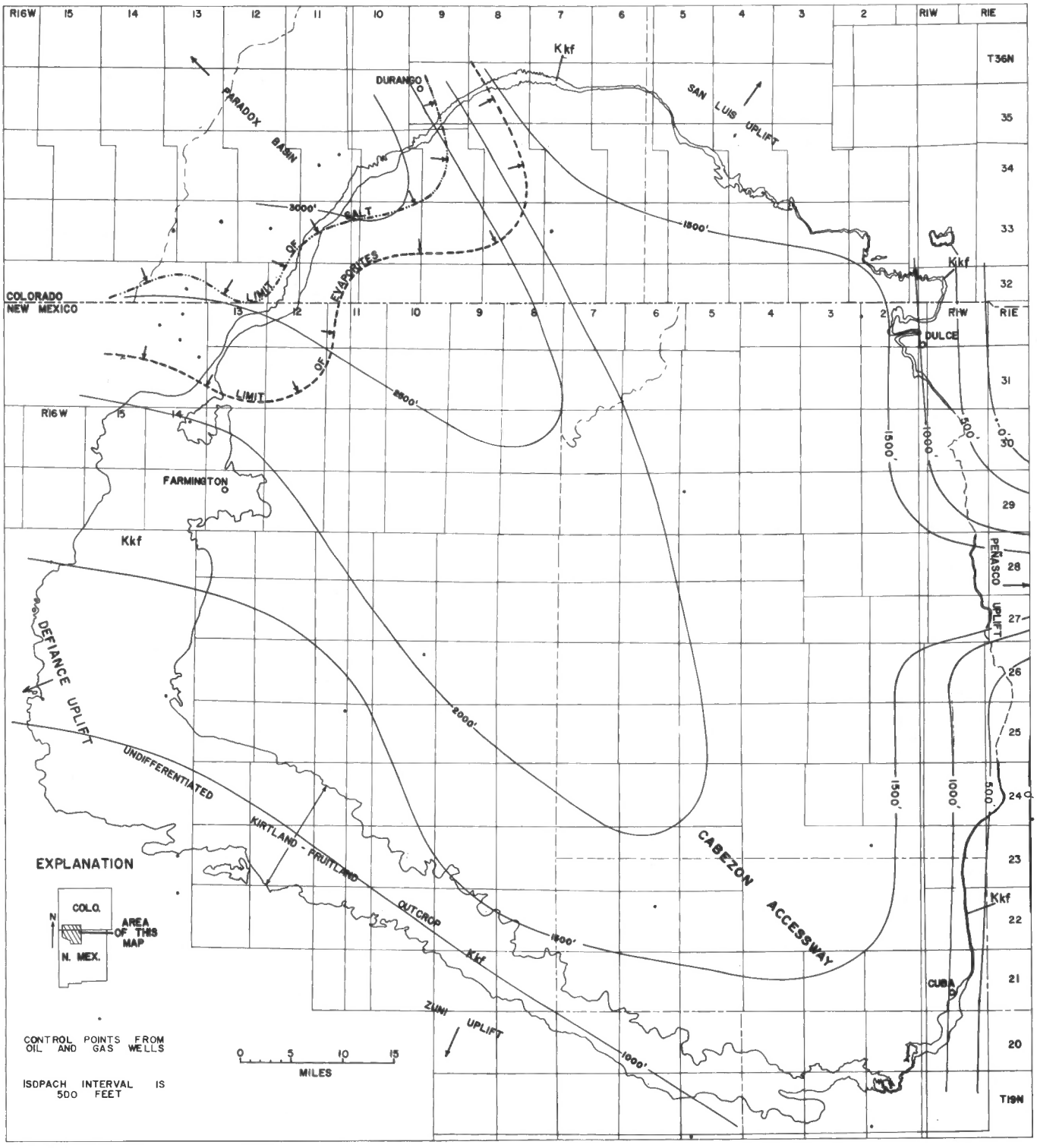

Figure 2. Isopach map of Pennsylvanian rocks in the San Juan Basin, with the limits of salt and evaporite depositions in the Paradox Member of the Hermosa Formation. The outcrop shown here is the undifferentiated Cretaceous Kirtland and Fruitland formations. (Base map is from Fassett and Hinds, 1971.)

near the Penasco axis, thinning gradually toward these lesser uplifts to the south and west (fig. 2).

The southern edges of the Paradox basin salt and evaporite facies in the Paradox Member of the Hermosa Formation are just inside the northwest edge of the present San Juan Basin (fig. 2). Laterally, each evaporite sequence seems to end abruptly against a carbonate buildup, indicating the development of a confining barrier prior to the deposition of the cycle (Wengerd and Matheny, 1958). Beyond the barrier, during late Atokan and early Des Moinesian time, cyclic neritic limestone deposition of the Hermosa Formation was occurring. Increased amounts of clastics thickened the section to the east, adjacent to the Uncompahgre and Penasco uplifts. The cycles are decreasingly identifiable in subsurface logs toward the southeast in the San Juan Basin, becoming indistinguishable in the center of the basin, and eventually giving way to the Madera Limestone in the southeastern basin. Therefore, the seas apparently received fresh sea water from the southeast (Wengerd and Strickland, 1954). An accessway, to the northwest in central Utah, similarly and simultaneously affected the Paradox basin (Wengerd and Matheny, 1958).

During late Des Moinesian time, strong uplift of the Uncompahgre, San Luis and Penasco highlands resulted in a great influx of clastic material and arkose, driving the sea out of the Paradox basin through the Cabezon accessway during Missourian and Virgilian time. Thus, by Early Permian time, the sea was nearly gone from the area of the San Juan Basin.

PENNSYLVANIAN OIL AND GAS IN THE SAN JUAN BASIN

There have been fewer than 20 Pennsylvanian oil-and-gas tests in the San Juan Basin within the Cretaceous Pictured Cliffs Sandstone outcrop, and only the Tenneco PAH well in sec. 3, T. 25 N., R. 11 W., had commercial shows. The majority of Pennsylvanian or deeper drilling has been in the northwestern part of the basin, testing the carbonate buildups bordering the salt facies, of the Paradox Member, as these are the producing zones in the Aneth and other fields. Some Pennsylvanian fields close to the San Juan Basin which seem to produce from carbonate complexes are: Tocito dome, 3 mi (4.8 km) west of the hogback edge (Cretaceous Cliff House Sandstone) of the basin and 20 mi (32 km) south of Shiprock, New Mexico; Table Mesa, also 3 mi (4.8 km) from the basin edge and 12 mi (19 km) south of Shiprock; Rattlesnake field, 12 mi (19 km) west of the basin and 6 mi (9.7 km) west of Shiprock; Hogback anticline, adjacent to the west side of the basin and 6 mi (9.7 km) east of Shiprock; and Barker dome, on the Colorado-New Mexico state line 5 mi (8 km) northwest of the basin rim. Except for Barker dome, which produces gas, these fields are primarily oil producers. The Rattlesnake field also produced helium, and the Hogback field produced "nonflammable gas"; neither field has any currently active Pennsylvanian wells.

The most recent well to penetrate the Pennsylvanian in the basin is the Mountain Fuel Supply No. 1 Fruitland in sec. 28, T. 30 N., R. 14 W. There were noncommercial shows in Pennsylvanian rocks, and the hole was being plugged back to the Cretaceous Dakota Sandstone. In light of shows in Pennsylvanian rocks of the San Juan Basin and significant Pennsylvanian oil-and-gas fields near the basin, the chance of economic production from Pennsylvanian rocks in the San Juan Basin cannot be discounted.

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