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WESTERN GAS SANDS PROJECT
→ ✓ AN APPROXIMATION OF CONTINUITY OF
LENTICULAR MESAVERDE SANDSTONE LENSES,
UTILIZING CLOSE-WELL CORRELATIONS,
PICEANCE BASIN, NORTHWEST COLORADO 34

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Abstract

Mesaverde Group sandstone units in 13 closely-spaced wells in the central and southern Piceance Basin of Colorado were correlated utilizing wireline log response quantitatively and qualitatively. Based on these correlations, the environmental subdivisions of the Mesaverde Group were characterized as follows.

- Paralic (upper mixed-marine) zone, occurring in the uppermost Mesaverde, includes thick sandstone units which are interpreted to be regionally continuous.
- Fluvial zone, containing point-bars 20 to 30+ ft thick, is interpreted to be correlatable to a maximum of 6,800 ft.
- Paludal zone, which has insufficient data to adequately characterize the sand units. However, 63 percent of the units are correlatable across at least 139 ft.

An approximation of the dimensional characteristics of Mesaverde sandstone units has potential applications in designing hydraulic fracturing treatments and estimating gas reserves more accurately.

1.0 Introduction

Within the Piceance Basin of northwestern Colorado, as shown in Figure 1 with study well location areas, the Upper Cretaceous Mesaverde Group produces gas from multiple sandstone reservoirs. These Mesaverde reservoir units are believed to contain large volumes of gas — up to 40 trillion cubic ft — yet are often non-commercial because of low production rates. These low rates are a function of very low permeability and limited reservoir size due to discontinuous, lenticular sandstone bodies. An approximation of the continuity and dimensions of Mesaverde reservoirs should be useful in designing more efficient hydraulic fracturing treatments.

EXPLANATION

- OIL FIELD
- GAS FIELD
- TOP DAKOTA FORMATION STRUCTURE CONTOUR
- PRE-CAMBRIAN ROCKS
- TERTIARY OUTCROP

STUDY WELL LOCATION AREAS

- ① RIO BLANCO UNIT
- ② RULISON FIELD, MWX AREA
- ③ SOUTHWEST RULISON FIELD

From Dunn, 1974

Figure 1 Oil and Gas Fields and Major Structural Elements, Piceance Basin and Contiguous Areas

2.0 Geologic Setting

To assess adequately the continuity of Mesaverde sandstone bodies in the Piceance Basin, the style in which the sandstones were deposited was characterized. As outlined by Lorenz (1982), the Mesaverde deltaic sediments were deposited into an interior seaway, as shown in Figure 2 (after Mallory et al, 1972), during most of Late Cretaceous time. The Mesaverde Group can be subdivided into contemporaneous depositional systems which form a "systems tract" (Brown and Fisher, 1977), as illustrated by the example in Figure 3. In the Piceance Basin from west to east, the tract is composed of medial fan, upper delta plain, lower delta plain and shoreface facies. The medial fan facies is characterized by braided stream deposits. Seaward, on the lower energy environment of the upper delta plain, meander belts dominate with deposition of point bar sandstones and overbank mudstones. Lorenz has termed this the fluvial zone of the Mesaverde. Seaward, on the lower delta plain, swampy conditions prevailed with deposition of coals, mudstones and distributary channel fill sandstones and is termed the paludal zone of the Mesaverde. At or near the wave dominated shoreline, barrier-bar sequences developed and formed composite, blanket-like sandstone deposits. These shoreface sandstones of the lower marine zone are presently known as the Castlegate, Sego, Corcoran, Cozzette and Rollins Sandstones.

Continued seaward progradation of each of these facies resulted in a vertically stacked sequence, as shown in the stratigraphic column of Figure 4. In addition to this sequence and based on palynological, mineralogical and morphological evidence in outcrop, Lorenz (Personal Communication, 1982) stated that mixed-marine/shoreline sandstones were deposited over the fluvial Mesaverde. This new interpretation is substantiated by palynological analyses of samples from the MWX-1 well (13 miles southwest of the outcrop) from the top of the Mesaverde Group (Gupta and Jiang, 1982).

The areas studied in this report were the Rulison Field and Rio Blanco Unit, both of which were shown in Figure 1. The geologic setting in both of these areas is considered to be similar during deposition of the Mesaverde Group.

Only the paralic (upper mixed-marine), fluvial and paludal zones of the Mesaverde are examined in this report.

From Lorenz (1982)
After Mallory et al (1972)

Figure 2 Generalized Paleogeography of the Central Rocky Mountain Region During Late Cretaceous Time

From Fisher and McGowen (1969)

Figure 3 Diagrammatic Sand-Dispersal System in Various Depositional Systems of Lower Wilcox

Modified from Lorenz (1982)
After Horn and Gere, 1954

Figure 4 Measured Stratigraphic Column Through Mesaverde Rocks in Rifle Gap

3.0 Sand Body Morphology and Dimensional Characteristics

In the studied sections, sand bodies are blanket-like deposits in the paralic (mixed-marine) zone, point-bars (predominantly) in the fluvial zone and channel-fill sandstones (predominantly) in the paludal zone. With these basic assumptions, each "ideal" sand body type can be dimensionally characterized.

Delta/shoreline sand aprons in the paralic zone are anticipated to be extensive and blanket-like in overall geometry. There may be some discontinuity where distributary channels or muddy bars and marshes dominated the local environment.

Point-bar morphology is directly related to stream flow. Large discharge streams are deeper, wider and form larger point bars than smaller streams. Meander length also is related directly to stream discharge. As shown in Figures 5 and 6, meander length can be translated into an approximate dimension relationship based on actual streams. Swanson (undated) used the thicknesses of recognized point-bar facies to give an indication of stream size and meander length. An empirical relation results in a thickness:½ meander length ratio ranging from approximately 1:100 to 1:132 for thicknesses ranging from 10 to 50 feet.

From literature of outcrop studies in the Piceance Basin, Knutson (1974) postulated a typical length:width:thickness ratio of 190:180:1 for sickle shaped (chute cut-off) point-bar sands in the lower Fort Union Formation. Assuming similar hydrodynamics, this ratio may also be applied to the fluvial Mesaverde.

Lorenz (1982) made the observation at the Rifle Gap outcrop that lenses from the Mesaverde fluvial zone have apparent widths many times their thickness with sandstone bodies ranging from 600 to 3,000 ft minimum lateral extent.

As shown in Figure 5, active meander belt point-bars do not have their long dimensions in any preferential orientation. Also, it is unlikely that the dimensions of original point-bars in an active fluvial system will be preserved because of cut and fill processes. Thus, consistency of orientations and dimensions is not expected in the subsurface. Figure 7 is an example of the irregular spatial relationship of individual sandstone lenses found in the fluvial Mesaverde.

Channel-fill sandstone body morphology characteristically has a length much greater than its width (Stokes, 1961). Generally, the width of the channel in which it originated and its length are dependent on the local conditions of burial and subsequent erosion. Knutson (1974) estimated that the typical Mesaverde channel-fill sand body has a length:width:thickness ratio of 140:14:1 with the length:thickness ratio ranging from 87:1 to 208:1.

Figure 5 Diagrammatic Outline of Meander Patterns and Point-Bar Deposits of the Laramie River, Wyoming

Figure 6 Morphology of a Meandering Stream

From Lorenz (1982)

Figure 7 Outcrop of Lens Group in the Fluvial Mesaverde Section, West Side of Rifle Gap

4.0 Methods and Results

To approximate the continuity of subsurface Mesaverde sandstone units in the Piceance Basin, 13 closely-spaced wells, with significant penetration into the Mesaverde Group, were chosen in the Rulison Field and the Rio Blanco Unit. Based on wireline log responses, sandstone units were correlated in the wells which were spaced between 139 to 10,400 ft apart. Based on the distance between wells, an approximate dimension can be assigned to correlative sandstone units. In this study, correlative sand units are interpreted to also be continuous between wells. These correlated units were subdivided into genetic paralic (mixed-marine), fluvial and paludal groups where possible. The results of the close-well correlations are as follows.

4.1 RULISON FIELD CORRELATION ANALYSIS

4.1.1 MWX-1 and MWX-2 Analysis

The MWX-1 and MWX-2 wells, drilled as part of the Department of Energy's Western Gas Sands Project to develop and improve technologies for producing tight-sand gas, are spaced 139 feet apart, as shown in Figure 8. Both wells penetrated the entire Mesaverde section and were logged under strict quality control guidelines.

Because of the high quality of digitized data, the sand units were selectively chosen by computer analysis. The following discriminating criteria were applied:

- shale volume (V_{sh}) must be less than 35 percent from corrected gamma ray log measurements;
- corrected bulk density (ρ_b) must be between 2.60 and 1.80, which is approximately equivalent to porosities 5 percent or greater; and
- thickness of the sand must be at least 8 ft.

Because of the very close well spacing (139 feet), the sand units continuous across both wells were expected to maintain similar character and log responses. Likewise, discontinuous units were expected to have dissimilar log responses. Thus, to determine the degree of similarity of correlated sand units, the character of the resistivity, bulk density and gamma ray logs was examined. These log responses were chosen because they represent unique correlation parameters for an individual sand lens where bulk density (ρ_b) is related to porosity, resistivity (R_t) is related to reservoir fluid content, and gamma ray response is related to clay volume and reservoir quality.

T 6 S
R 95 W

T 6 S
R 94 W

-12-

Correlation Lines ———

Figure 8 Rulison Field Study Well Location Map

The log responses were related by a single equation.

$$\frac{(\rho_b * GR)}{R_t} = \begin{matrix} X_1 \text{ for MWX-1} \\ X_2 \text{ for MWX-2} \end{matrix}$$

Results (X_1 and X_2) of this equation for each foot of each sand unit in MWX-1 and MWX-2 were accumulated. The ratio of the cumulative $X_1:X_2$ for correlative sandstone units yields a quantitative estimate of degree of similarity. For example, correlated reservoir units having identical log responses for R_t , ρ_b , GR and the same thickness will equate to a perfect similarity of 1.0. Arbitrary, but relative labels of poor, fair, good and excellent can therefore be assigned to similarity of correlated sand units.

Additional analyses lend further support to similar sand units using the above method. By utilizing gamma ray spectral data, general correlation of sand units can be made. In particular, the ratio of thorium counts to potassium counts (Th:K) can be related to clay typing and other interpretations (Fertl, 1979). The ratio of the cumulative Th:K for similar sands in MWX-1 and MWX-2 can also be equated to a degree of similarity.

Paralic Zone

The sandstone units included in the paralic (mixed-marine) zone could not be quantitatively compared because of the lack of resistivity data in that portion of MWX-2 log. Qualitatively, however, the entire interval correlates well across the 139-ft distance between the wells. The sandstone zone in both wells is approximately 200 ft thick, has a low gamma ray value and has no significant shale breaks. The paralic sands are distinguished from the fluvial sands by the clean and "blocky" (sharp upper/lower contacts) character of the gamma ray curve.

Correlations of sandstone units in MWX-1 and MWX-2 are illustrated in the cross sections located in the pocket following this report.

Fluvial Zone

The fluvial zone in MWX-1 and MWX-2 can be further divided into upper, middle and lower zones based on the number of sand units and average unit thickness in the interval. Characteristics of each zone are summarized in Table 1. Quantitative correlations using the previously described method are summarized as follows:

Zone	Degree of Similarity			
	Excellent	Good	Fair	Poor
Upper Fluvial	4	3	2	2
Middle Fluvial	0	2	2	3
Lower Fluvial	4	4	2	4

These points are also shown in Figure 9. Overall, 23 of 32 of the correlated sand units (72 percent) have a fair to excellent degree of similarity. Comparison of thorium:potassium ratios of correlative sandstone units also supports a positive correlation. The Th:K crossplot is shown in Figure 10.

Paludal Zone

MWX-1 and MWX-2 each penetrated the entire paludal section of the Mesaverde. Based on the quantitative degree of similarity of correlated sandstones, this zone is summarized as follows:

Zone	<u>Degree of Similarity</u>			
	Excellent	Good	Fair	Poor or No Correlation
Paludal Zone	.2	7	6	9

These points are also shown in Figure 11. Overall, 15 of 24 sandstone units (83 percent) were correlative across the 139-ft well spacing. Thickness of the paludal zone sandstone units ranged from 5 to 47 ft and averaged 17 ft.

4.1.2 Close-Paired Wells

The following well pairs, which were shown in Figure 8 and are in the vicinity of the MWX wells, were also analyzed.

- Federal 3-94 and Hunter No. 1
- Hunter No. 1 and No. 1 Juhan Federal
- MWX-1 and Hunter No. 1
- No. 1 Juhan Federal and Juhan No. 1
- MWX-1 and Federal 3-94
- MWX-1 and No. 1 Juhan Federal

Qualitative correlations of sand units in these wells were based on visual character of resistivity and gamma ray log curves, if available. The correlations in these wells were also subdivided into paralic and upper, middle and lower fluvial zones. Other than MWX-1 and MWX-2, only the No. 1 Juhan Federal penetrated the entire paludal section.

Paralic Zone

The thick, cleaner sand units, characteristic of the paralic zone, are also present in the uppermost Mesaverde in each of the well pairs described above. The high sand to shale ratio and "blockly" (sharp upper and lower sand unit contacts) gamma ray character also distinguish the interval in these well pairs.

Table 1 Characteristics of Fluvial Zone Subdivisions, Rulison Field

	Well Spacing, ft	Correlative Sand Units	Thickness in ft of all units, min-max, avg.	Interval	
UPPER FLUVIAL ZONE				Feet	Well
MWX-1 & MWX-2	135	9/11 = 81%	9 - 35, 17	4,280 - 4,950	MWX-1
Hayward 25-95 & Hayward 25-95A	285	8/10 = 80%	12 - 38, 21	6,370 - 6,910	Hayward 25-95
Federal 3-94 & Hunter No. 1	3,498	5/12 = 42%	11 - 54, 24	4,250 - 4,950	Hunter No. 1
Hunter No. 1 & No. 1 Juhan Federal	4,191	5/17 = 29%	13 - 54, 27	4,250 - 5,000	Juhan Federal
MWX-1 & Hunter No. 1	4,224	5/14 = 36%	13 - 40, 24	4,250 - 4,950	MWX-1
No. 1 Juhan Federal & Juhan No. 1	4,257	9/13 = 69%	11 - 54, 23	4,250 - 4,916	Juhan Federal
MWX-1 & Federal 3-94	4,554	6/14 = 43%	12 - 40, 24	4,278 - 4,950	MWX-1
MWX-1 & No. 1 Juhan Federal	5,412	4/16 = 25%	8 - 54, 24	4,250 - 4,950	MWX-1
Federal 30-95 & Federal 28-95	10,400	1/7 = 14%	15 - 51, 33	4,040 - 4,450	Federal 30-95
MIDDLE FLUVIAL ZONE					
MWX-1 & MWX-2	135	4/7 = 57%	6 - 24, 14	4,959 - 5,460	MWX-1
Hayward 25-95 & Hayward 25-95A	285	1/1 = 100%	10 - 10, 10	6,910 - 7,410	Hayward 25-95
Federal 3-94 & Hunter No. 1	3,498	3/15 = 20%	11 - 34, 18	4,950 - 5,450	Hunter No. 1
Hunter No. 1 & No. 1 Juhan Federal	4,191	2/10 = 20%	9 - 36, 19	4,950 - 5,450	Hunter No. 1
MWX-1 & Hunter No. 1	4,224	3/12 = 25%	10 - 34, 19	4,950 - 5,450	Hunter No. 1
No. 1 Juhan Federal & Juhan No. 1	4,257	2/9 = 22%	9 - 23, 16	4,916 - 5,460	Juhan Federal
MWX-1 & Federal 3-94	4,554	1/12 = 8%	11 - 32, 18	4,850 - 5,350	MWX-1
MWX-1 & No. 1 Juhan Federal	5,412	2/8 = 25%	9 - 36, 19	4,950 - 5,450	MWX-1
Federal 30-95 & Federal 28-95	10,400	0/4 = 0%	14 - 32, 21	4,450 - 4,790	Federal 30-95

Continued

Table 1 Continued

	Well Spacing, ft	Correlative Sand Units	Thickness in ft of all units, min-max, avg.	Interval	
LOWER FLUVIAL ZONE				Feet	Well
MWX-1 & MWX-2	135	10/14 = 71%	5 - 37, 19	5,460 - 6,595	MWX-1
Hayward 25-95 & Hayward 25-95A (7,410 - 8,420 ft)	285	12/16 = 75%	10 - 40, 28	7,410 - 8,420*	Hayward 25-95
Federal 3-94 & Hunter No. 1	3,498	4/13 = 31%	9 - 58, 27	5,450 - 6,020*	Hunter No. 1
Hunter No. 1 & No. 1 Juhan Federal	4,191	6/19 = 32%	8 - 52, 26	5,450 - 6,570	Hunter No. 1
MWX-1 & Hunter No. 1	4,224	5/18 = 28%	8 - 60, 26	5,450 - 6,570	Hunter No. 1
No. 1 Juhan Federal & Juhan No. 1	4,257	7/20 = 35%	8 - 50, 23	5,400 - 6,375	Juhan Federal
MWX-1 & Federal 3-94	4,554	4/9 = 44%	8 - 50, 20	5,450 - 6,100*	MWX-1
MWX-1 & No. 1 Juhan Federal	5,412	5/21 = 23%	8 - 34, 20	5,450 - 6,560	MWX-1
Federal 30-95 & Federal 28-95	10,400	5/24 = 21%	10 - 66, 22	4,790 - 6,110*	Federal 30-95

* Section not completely penetrated

Figure 9 Degree of Similarity of Fluvial Zone Sandstone Units, MWX-1 and MWX-2

Figure 10 Thorium to Potassium Ratio Crossplot for Correlative Fluvial Sandstone Units, MWX-1 and MWX-2

Figure 11 Degree of Similarity of Paludal Zone Sandstone Units, MWX-1 and MWX-2

Fluvial Zone

The correlation results in each of the subdivided fluvial zones are summarized in Table 1. Overall, the correlation of fluvial sandstone units in these well pairs is summarized as follows:

Well Pair	Correlation Distance, ft	Correlative Sandstone Units, percent
Federal 3-94 and Hunter No. 1	3,498	12/40 = 30
Hunter No. 1 and No. 1 Juhan Federal	4,191	13/46 = 28
MWX-1 and Hunter No. 1	4,224	13/44 = 30
No. 1 Juhan Federal and Juhan No. 1	4,257	18/42 = 43
MWX-1 and Federal 3-94	4,554	11/35 = 31
MWX-1 and No. 1 Juhan Federal	5,412	11/45 = 24

4.1.3 Hayward 25-95 and Hayward 25-95A Analysis

Hayward 25-95 and Hayward 25-95A, located approximately 7 miles southwest of the MWX wells, are spaced 285 ft apart on a northwest-southeast orientation, as was shown in Figure 8. These wells penetrate approximately 2,300 ft of Mesaverde section, which is equivalent approximately to the paralic and fluvial zones.

The quality and quantity of the log data from these wells are not equal to the MWX data; in fact, the only log in common to both wells is the gamma ray log. Still, the data is usable for qualitative correlations. Only significant sand bodies were considered for correlation, or, only sand bodies greater than 8 ft thick and having a shale volume less than 35 percent. Qualitative correlation interpretations, based on gamma ray character and sand body thickness, are illustrated in the cross section located in the pocket following this report.

Paralic Zone

The paralic zone in the interval 6,150 to 6,370 ft of the Hayward 25-95A, contains a sequence of thick, cleaner sandstone bodies similar to those identified in the MWX wells. The blocky character of the gamma ray curve suggests similarity to the MWX paralic zone, although significant shale breaks are evident in this well. Correlations between the Hayward wells is difficult because of log quality problems. However, the usable data in the interval suggest that the paralic sands are correlative.

Fluvial Zone

The fluvial zone in the Hayward wells can also be further divided into the upper, middle and lower zones based on the number of included sand units and average thickness. The characteristics of each zone are summarized in Table 1.

The qualitative correlations from each zone can be summarized as follows:

Upper Fluvial Zone : 8 of 10 (80 percent) sand bodies correlate
Middle Fluvial Zone : 1 of 1 (100 percent) sand bodies correlate
Lower Fluvial Zone : 12 of 16 (75 percent) sand bodies correlate

Overall, 21 of 27 (78 percent) of the significant sand bodies in the fluvial zone are correlative across a distance of 285 feet.

4.1.4 Federal 28-95 and Federal 30-95 Analysis

Federal 28-95 and Federal 30-95 wells are approximately 9 miles southwest of the MWX pair and are spaced approximately 10,400 ft apart on an east-west orientation, as was shown in Figure 8. The wells penetrated approximately 2,300 ft of Mesaverde section equivalent to the paralic and fluvial zones.

Only significant sand bodies, as previously defined, were considered for correlation. Gamma ray and resistivity log character were compared and a qualitative interpretation of sand body continuity was made on this basis.

Paralic Zone

The paralic zone, 3,848 to 4,046 ft in the Federal 30-95, contains thick sequences of cleaner sandstone bodies similar in character to those in the MWX and Hayward wells. The sand percent in this interval is greater than 75 percent in both wells. In this 200-ft interval, one 54-ft section was correlative in both wells with similar gamma ray and resistivity responses. The remainder of the paralic zone, although very sandy, does not have log responses similar enough for correlation.

Fluvial Zone

The fluvial zone in the Federal 29-95 and 30-95 was also divided into upper, middle and lower zones. Characteristics of each of these zones are summarized in Table 1. Overall, 6 of 36 (17 percent) of the sands units were interpreted to be correlative across the 10,400-ft separation.

4.2 RIO BLANCO UNIT CORRELATION ANALYSIS

The Rio Blanco Unit is located 30 miles northwest of the Rulison Field in Rio Blanco County, Colorado. Within the study area, four closely-spaced wells on an approximate north-south orientation were chosen for correlation. They were No. 1 Government Fawn Creek, RB-E-01, RBU No. 4 and RB-MHF-3. As shown in Figure 12, well-to-well spacing ranges from 651 to 3,995 ft. The wells penetrated from 831 to 1,700 ft of Mesaverde section interpreted to be equivalent to the paralic and fluvial zones.

Township 3S, Range 98W, Rio Blanco County, Colorado

Figure 12 Rio Blanco Unit Study Well Location Map

The correlations from all four wells were placed on the composite cross section located in the pocket at the end of this report. As a result, various combinations of well-to-well distances are available to correlate sandstone units along the line of section. Units "bracketed" between the Fawn Creek No. 1 well and the RB-MHF-3 well by correlations can be assigned a maximum correlation distance equal to the distance between the wells. Other sand units which correlate "open-ended" across the section can be assigned a minimum correlation distance equal to the distance between the wells. Sand units which are "open-ended" and are evident in only one well have continuity over an unknown distance.

Correlation of significant sand units between well pairs was qualitatively based on resistivity log character (shape and value), gamma ray character where available, thickness of sand bodies, and spatial relationships between correlated units.

Paralic Zone

The zone interpreted to be paralic ranges in thickness from 50 to 80 ft and the sand percentage ranges from 88 to 100 percent. The sands appear cleaner and thicker, have sharp upper and lower contacts, have uniformly low resistivity, and correlate well across, at least, the 5,865 ft distance between wells Fawn Creek No. 1 and RB-MHF-3.

Fluvial Zone

Correlations in the four-well composite cross section indicate that there are 44 significant sand bodies in the drilled portion of the fluvial zone. Of these 44 units, 16 were continuous across an unknown distance (open-end sand body evident in only one well). The continuity of the remaining 28 units is summarized in Table 2. Overall, these results indicate that 79 percent of the sand bodies are continuous across at least 1,277 ft and that 21 percent of the sand bodies are continuous across a distance less than 4,950 ft.

Table 2 Continuity of Sandstone Units in the Rio Blanco Unit

CORRELATED DISTANCE					
	FC No. 1 to RB-MHF-3	RB-E-01 to RB-MHF-3	RBU No. 4 to RB-MHF-3	FC No. 1 to RBU No. 4	FC No. 1 to RB-E-01
	5,865 ft	4,604 ft	3,995 ft	1,940 ft	1,277 ft
OPEN-ENDED CORRELATIONS (Apparent Minimum Continuity)					
Correlative Sandstone Units	9/28 = 32%	5/28 = 19%	1/28 = 4%	4/28 = 14%	3/28 = 11%
Unit Thickness, min - max, avg.	15 - 40 ft, 24 ft	16 - 35 ft, 23 ft	24 ft	26 - 36 ft, 29 ft	27 - 40 ft, 34 ft
BRACKETED CORRELATIONS (Apparent Maximum Continuity)					
Correlative Sandstone Units	1/28 = 4%* 1/28 = 4%**	3/28 = 11%***	---	1/28 = 4%****	---
Unit Thickness, min - max, avg.	21 - 38 ft, 30 ft	8 - 12 ft, 10 ft	---	---	---
UNKNOWN CONTINUITY:					
16 Sandstone Units					
* Correlation distance may be as much as 5,865 ft and is at least 651 ft					
** Correlation distance unknown but is less than 5,865 ft					
*** Correlation distance unknown but is less than 4,604 ft					
**** Correlation distance unknown but is less than 1,940 ft					

5.0 Conclusions

Close-well correlation of the uppermost Mesaverde Group sands indicates that the section in both the Rulison Field and Rio Blanco Unit has similar log character (thick, clean sandstone), has a characteristically high (greater than 75 percent) sand percentage, and is continuous between wells spaced at 10,400 ft. These observations lead to the conclusion that this section, overall, maintains a blanket-like geometry on a local and regional scale that is characteristic of shoreline sand aprons. This conclusion supports the interpretation made by Lorenz (1982) of outcrop studies at Rifle Gap that the uppermost 300 ft of the Mesaverde Group are paralic (mixed-marine)/shoreline sandstones. Although the section is approximately 200 ft thick in the Rulison Field area and approximately 80 ft thick in the Rio Blanco study area, the difference can possibly be accounted for by an erosional unconformity between the Mesaverde and Wasatch Formations (Johnson and May, 1980).

In the Rulison Field, where the fluvial zone was divided into the upper, middle and lower zones, the following interpretations can be made based on these close-well correlation results.

Upper Fluvial Zone

Relatively higher sand percentages and thicker sand units indicate that this interval may have had longer residence times of meander systems. Therefore, sand units in this interval can be interpreted to be laterally extensive, thicker and possibly interconnected. Based on the extrapolation of the data points in Figure 13, 50 percent of the sand units in this interval with a thickness range of 20 to 30+ ft should be continuous to approximately 3,250 ft.

Middle Fluvial Zone

Relatively thinner and fewer sand units in this interval indicate that although sedimentation patterns are similar to the upper zone, residence times of the meander systems were likely to be much less or there was a decreased sediment supply. Therefore, discontinuity of sand units may dominate and based on extrapolation of data points in Figure 14, 50 percent of the sand units encountered in this interval with a thickness range of 20 to 30+ ft should be continuous to approximately 2,700 ft.

Lower Fluvial Zone

Correlation of sandstone units in this interval appears similar to the upper fluvial zone. Based on the extrapolation of data points in Figure 15, 50 percent of the sandstone units with a thickness range of 20 to 30+ ft, should be continuous to approximately 3,160 ft. Compared to the upper fluvial zone, this decreased correlation distance may reflect lower depositional energy conditions in an environment transitional from paludal to fluvial.

Figure 13 Correlatable Distance of Upper Fluvial Zone Sandstone Units,
 Rulison Field Study Wells

Figure 14 Correlatable Distance of Middle Fluvial Zone, Rulison Field Study Wells

Figure 15 Correlatable Distance of Lower Fluvial Zone, Rulison Field Study Wells

An exceptionally thick sandstone unit in the lower fluvial zone (132 ft net sand in MWX-2) occurs immediately above the paludal zone. In the MWX wells and other wells in their immediate vicinity, the sequence can be characterized by:

- high sandstone percentage;
- correlation between wells spaced at 139 and 5,412 ft; and
- gamma ray log character that is clean and has sharp upper and lower boundaries.

Occuring also in the Rio Blanco Unit, although not seen in the study wells in this report, are thick sand units occuring in the lower fluvial zone near the top of the paludal zone. These sands are regarded as the main Mesaverde pay zone for wells in the Unit (R. Chancellor, Personal Communication, 1982).

The interpretation that the sandy sequences in both areas are time equivalents leads to several possible interpretations of the depositional environment. In one geological scenario, a tectonic and/or climatically induced regional high sand influx created conditions necessary for thick point-bars to develop within meander belts located in the Rulison and Rio Blanco areas. Areas with lower sandstone percentage are those falling outside or near the margin of the meander belt. Another possible interpretation is that this horizon may be analogous to the uppermost Mesaverde delta/shoreline sand apron, but occuring well within the section, as is illustrated in Figure 16. Those areas with a lower sandstone percentage may have been where distributary channels or muddy bays and marshes dominated the local depositional environment.

In any case, further characterization is necessary as this horizon may represent a thick sandy sequence capable of significant gas production.

Close well correlations of the entire fluvial Mesaverde section are summarized in Figure 16. The combined results of the Rulison and Rio Blanco close-well correlation data points indicate that approximately 75 percent of the sand units with average thicknesses from 20 to 30+ ft are correlative across 1,700 ft. Based on a linearly regressive best fit line of the data points, 50 percent of the sand units with thicknesses from 20 to 30+ ft should be correlative across a distance of 3,400 ft and no units should correlate further than 6,800 ft. No obvious correlation of sand body thickness to correlatable distance was apparent in this study as thicker sandstone units did not consistently correlate over longer distances. Therefore, it is not possible to predict which sand units in the 20 to 30 ft thickness range will be more or less continuous than others.

The results of this study compare with those proposed by others. Knutson (1974) proposed a point-bar dimension ratio where a 25-ft thick unit would have a projected length of 4,750 ft and a width of 2,000 ft. Considering these length and width dimensions, the maximum correlatable distance would be 5,150 ft. In another study (Hodges et al, 1981), based on measured outcrops of the fluvial Mesaverde section (Williams Fork Formation) at Rifle Gap, the median apparent length:height ratio was 60, but ranged from less than 20 to greater than 200 [Hodges et al, 1981 (Figure 28)]. Thus, an average 25-ft thick unit is projected to have a median apparent length of 1,500 ft but can range from less than 500 ft to more than 5,000 ft. The correlative distance of 3,400 ft (distance at which 50 percent of the units are correlative) arrived at in this study is within limits of the projected sandstone unit dimensions in both comparison studies.

Figure 16 Correlatable Distance of all Fluvial Sandstone Units, Rulison and Rio Blanco Field Study Wells

With the knowledge that there is a good chance (greater than 50 percent) that a fluvial Mesaverde sandstone unit in the 20 to 30+ ft thickness range will be continuous up to a distance of 3,400 ft, a number of potential applications are possible. These potential uses, valid in other areas if depositional conditions are similar to the Rulison Field and Rio Blanco Unit, are:

- maximization of hydraulic fracturing treatments to extend the fracture to the reservoir limits, and
- calculation of a better gas reserve estimate knowing an approximate reservoir size.

There may be certain limitations to the interpretations of the close-well correlations, however. These limitations are shown by the following examples.

- In one well pair, 17 percent of the sand units were interpreted to be correlative across 10,400 ft. The discrepancy with the predicted maximum correlation distance may illustrate the limitation that as well-to-well distances increase, qualitative correlations made by matching similar log curve shapes may actually be correlations of discontinuous sand bodies coincidentally having similar curve shapes or sand thicknesses at the same horizon. Such a situation, in outcrop, was illustrated in Figure 6.
- Those wells in the study spaced at 139 and 285 ft show that approximately 75 percent of the sand units are correlatable, much less than expected. This may be a result of one wellbore penetration near the edge of a lens and the other outside of the lens. If two wells were spaced inches apart, however, it is likely that 100 percent of the lenses would correlate from well to well. This is the basis for intersecting the y-axis at 100 percent in Figures 12, 13, 14 and 15.
- Depositional trends and the orientation of well placements are not expected to affect the results. As was illustrated in Figure 4, random orientation of the long dimension of point-bars dominate, even though the meander belt has a definite trend. Therefore, placement of wells along the strike or dip of the meander belt should make little difference in close-well correlations.
- A statistically significant number of wells or sandstone units may not have been included in this analysis. Closely-spaced wells drilled in the future should be added to this set of data.
- Interpretations of data from the paludal zone is inconclusive due to a lack of closely-spaced wells penetrating the interval. The best data available in MWX-1 and MWX-2 indicates 63 percent of the sandstone units were correlative across 139 ft. This somewhat poorer correlation percent may indicate the sandstone units are relatively less continuous in comparison to those of the fluvial zone. Dimensions of paludal zone (Iles Formation) sandstone units have been studied by Hodges et al (1981) at the Rifle Gap outcrop. Based on measurements of outcrops, a median apparent length: height ratio of 60 was arrived at; and based on geometric considerations extrapolated from geologically similar areas, a width:height ratio of 38 was calculated. These ratios could be applied as a first approximation of dimensions of channel fill deposits in the lower Mesaverde paludal zone.

6.0 References

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CLOSE-WELL CORRELATIONS IN THE RIO BLANCO UNIT

PICEANCE BASIN, NORTHWESTERN COLORADO

R. E. Peterson

June 1982

Vert. Scale
1 in. = 100 ft.

Horiz. Scale
1/4 in. = 100 ft.

SCALES

WELL LOCATION MAP

SCHLUMBERGER WELL SURVEYING CORPORATION	
Induction-Electrical Log	
COMPANY EQUITY OIL COMPANY	Other Services
WELL FAWN CREEK NO. 1	Location of Well
NO. 1	
FIELD MILDGAT	
LOCATION SEC. 14-35-78N	
SMS OF JMS	
COUNTY RIO BLANCO	Elevation of F. 5,679
STATE COLORADO	W. O. L. 6418
	PLING No. 22

Schlumberger DUAL INDUCTION LATEROLOG	
COMPANY C.R. GEONUCLEAR	
WELL NO. 22-6-01	
FIELD RIO BLANCO UNIT	
COUNTY RIO BLANCO STATE COLORADO	
LOCATION 1089 51 F.W. 5188 49' F.W.	Other Services
SEC. 14-35-78N	CHL-GR-BHC-CH
NO. 14	Top 35
Top 35	89M
Bottom 35	5677
Other 35 5677	
Log Measured From 21	0. R. Adams Park, Denver
Logging Interval From 18	D. 67
	GL 677

Schlumberger DUAL INDUCTION LATEROLOG	
WITH LINEAR CORRELATION LOG	
COMPANY CONTINENTAL OIL COMPANY	
WELL RBW NO. 4	
FIELD RIO BLANCO UNIT	
COUNTY RIO BLANCO STATE COLORADO	
LOCATION 1089 51 F.W. 5188 49' F.W.	Other Services
SEC. 14-35-78N	CHL-GR-BHC-CH
NO. 14	Top 35
Top 35	89M
Bottom 35	5677
Other 35 5677	
Log Measured From 21	0. R. Adams Park, Denver
Logging Interval From 18	D. 67
	GL 677

Schlumberger DUAL INDUCTION LATEROLOG	
WITH LINEAR CORRELATION LOG	
COMPANY MCEC RECO	SWP - 56.19
WELL RB-MHF-3	
FIELD RIO BLANCO UNIT	
COUNTY RIO BLANCO STATE COLORADO	
LOCATION 1089 51 F.W. 5188 49' F.W.	Other Services
SEC. 14-35-78N	CHL-GR-BHC-CH
NO. 14	Top 35
Top 35	89M
Bottom 35	5677
Other 35 5677	
Log Measured From 21	0. R. Adams Park, Denver
Logging Interval From 18	D. 67
	GL 677

Upper Marine Zone

Fluvial Zone

Top of Mesaverde

CLOSE-WELL CORRELATIONS IN THE RULISON FIELD

GARFIELD COUNTY, COLORADO

R. Peterson/J. Kohout

June, 1982

LANE WELLS		Compensated Acoustilog	
FILE NO.	COMPANY	AUSTRAL OIL COMPANY	
	WELL	NO. 25-25 HAYWARD	
	FIELD	RULISON	
	COUNTY	GARFIELD	STATE COLORADO
LOCATION			
694 81' FSL - 235.91' FWL		Other Services	
SEC. 25 TWP. 7S RGE. 35W		VAD. TEMP.	
		CLOG. FT.	
		DIRECTION(S)	

Dresser Atlas		Compensated Densilog	
FILE NO.	COMPANY	AUSTRAL OIL COMPANY	
	WELL	NO. 25-25 HAYWARD	
	FIELD	RULISON	
	COUNTY	GARFIELD	STATE COLORADO
LOCATION			
1813.19' FSL - 1976.31' FWL		Other Services	
SEC. 25 TWP. 7S RGE. 35W		VAD. TEMP.	
		CLOG. FT.	
		DIRECTION(S)	

Schlumberger		Dual Induction	
FILE NO.	COMPANY	CER CORPORATION	
	WELL	NO. 2	
	FIELD	RULISON	
	COUNTY	GARFIELD	STATE COLORADO
LOCATION			
2524' FSL - 201' FWL		Other Services	
SEC. 25 TWP. 7S RGE. 35W		VAD. TEMP.	
		CLOG. FT.	
		DIRECTION(S)	

Schlumberger		Dual Induction-SFL	
WITH LINEAR CORRELATION LOG			
FILE NO.	COMPANY	CER CORPORATION	
	WELL	NO. 1	
	FIELD	RULISON	
	COUNTY	GARFIELD	STATE COLORADO
LOCATION			
2524' FSL - 824' FWL		Other Services	
SEC. 25 TWP. 7S RGE. 35W		VAD. TEMP.	
		CLOG. FT.	
		DIRECTION(S)

Vert. Scale
1 in. = 100 ft

Horiz. Scale
1 in. = 100 ft

SCALES