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# Geologic and Production Characteristics of the Tight Mesaverde Group: Piceance Basin, Colorado

Topical Report

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# DISCLAIMER

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# Executive Summary

## OVERVIEW OF THE STUDY

The Piceance Basin of western Colorado contains a major potential natural gas resource in Mesaverde blanket and lenticular low permeability gas sands. The basin has been a pilot study area for government-sponsored tight gas sand research for over 20 years. This work culminated in the Multiwell Experiment (MWX), a field laboratory consisting of three closely-spaced wells, designed by the Department of Energy to study the reservoir and production characteristics of the low permeability sands of the Mesaverde Group in the Rulison Field near Rifle, Colorado.

The purpose of this study is to compare geologic, production and reservoir characteristics of the existing Mesaverde producing areas in the Piceance Basin with those same characteristics at the Multiwell site near Rifle. The geologic, production and reservoir engineering parameters are developed for the existing Mesaverde gas producing areas through analysis of log suites, well completion information and production histories, and through the identification of natural fracture trends.

A series of Mesaverde gas productivity maps and geologic cross sections were prepared for the basin. These maps include gross interval and sand thickness maps, permeability-thickness (kh) maps, thermal maps (indicating areas of active gas generation), a natural fracture intensity map, and an ultimate recoverable gas production map. The basin is then subdivided into three discrete areas having similar geologic and production characteristics. Stimulation techniques are reviewed to determine the most effective stimulation technique for the Mesaverde in each prospect area.

## SUMMARY OF FINDINGS

The extrapolation of detailed geological and engineering data from MWX into the surrounding Piceance Basin has produced the following conclusions:

- Large areas of marine and paludal source rocks are presently hotter than 190° F, the temperature above which gas is believed to be generated in source rocks. Source rocks at gas generating temperatures are shallower in the southern part of the basin.

- Log data norms determined for MWX can be used to normalize data in the Rulison Field and fields in the central Piceance Basin trough; however, these norms cannot be extrapolated basin wide.

- The TITEGAS log analysis model developed at MWX is able to characterize reservoir parameters basin wide by adjusting some of the constants input to the program.

- Trapped gas is downdip of water in each stratigraphic unit as proposed by Masters (1979). The transition zone between water and gas cuts across stratigraphy near the edges of the basin.

- In the Mesaverde Group in the subsurface, there are two distinct unidirectional, regional fracture systems. These fracture systems occur in different parts of the basin but may overlap in some areas.

- Vast regions of the Piceance Basin have little well control and unproved Mesaverde gas production. In many cases, entire townships are still undrilled. This is particularly true for the northern Piceance Basin where data is too sporadic for adequate mapping control. Topography and pipeline distribution are important factors explaining the lack of drilling in some areas.

- There is considerable gas production potential in each of three partitioned areas in the southern Piceance Basin: the Southeast Uplift area including the Divide Creek Field; the Central Basin area including the Rulison and Grand Valley Fields; and the Southwest Flank including the Plateau Creek Field.

- Log analysis of natural fractures detected the greatest density of natural fractures in the Southeast Uplift partitioned area followed by fewer detected fractures in the Central Basin and Southwest Flank partitioned areas, respectively.

- The higher rates of gas production are in areas of known fractures and are believed to be the result of enhanced permeability along fractures. The highest production rates are probably the result of cross fracturing of multiple sets developed during late Laramide uplift.

- The best wells were completed with minimal or no stimulation.

- More geological and engineering data and study are needed to properly define reservoir and fracture characteristics within each of the three partitioned areas.

## ACKNOWLEDGEMENTS

Several operators from the basin made submittals of logs, maps or sections that were incorporated into the database. Prominent among these operators were Mobil, Exxon, Sun Exploration and Production Company, Coors Energy Company, Occidental Petroleum, Piute Energy Company, Barrett Resources Corporation, David M. Munson and Rio Blanco Natural Gas.

# 1.0 Introduction

The Mesaverde Group of the Piceance Basin in western Colorado has been a pilot study area for government-sponsored tight gas sand research for over 20 years. Early production experiments included both nuclear stimulations and massive hydraulic fracture treatments. These studies left many unanswered questions which were addressed by the Multiwell Experiment (MWX).

The MWX was a field laboratory, consisting of three closely-spaced wells, designed by the Department of Energy (DOE) to study the reservoir and production characteristics of the low permeability sands of the Mesaverde Group. Much knowledge has been gathered through MWX in many disciplines including geology, log analysis, core analysis, stress testing, well testing, reservoir characterization and stimulation technology.

This study provides a critical comparison of the geologic, production and reservoir characteristics of existing Mesaverde gas producing areas within the basin to those same characteristics at the MWX site near Rifle, Colorado. Mesaverde gas fields, which are predominantly in the southern Piceance Basin, are shown in Figure 1. As will be discussed in Section 4.0, the basin has been partitioned into three areas having similar geologic and production characteristics. Stimulation techniques have been reviewed for each partitioned area to determine the most effective stimulation technique currently used in the Mesaverde.

This study emphasizes predominantly the southern Piceance Basin because of the much greater production and geologic data there. There may be Mesaverde gas production potential in northern areas but because of the lack of production and relatively few penetrations, the northern Piceance Basin was not included in the detailed parts of this study.

## 1.1 PURPOSE OF THE STUDY

The purpose of this study is to:

- Compare and contrast the geologic and production characteristics at MWX with the characteristics of other areas in the Piceance Basin to determine the general extrapolation potential of MWX observations and conclusions.
- Partition the Mesaverde Group in the Piceance Basin into areas having similar geologic and production characteristics.
- Compare and contrast the reservoir behavior observed at MWX with the reservoir behavior of other areas in the Piceance Basin to determine optimum stimulation strategies for exploiting the Mesaverde gas resource.

The overriding goal of this investigation is to transfer the technology developed at MWX to the gas producers who can implement it on a scale that will significantly increase economically recoverable gas reserves from tight, naturally fractured reservoirs.

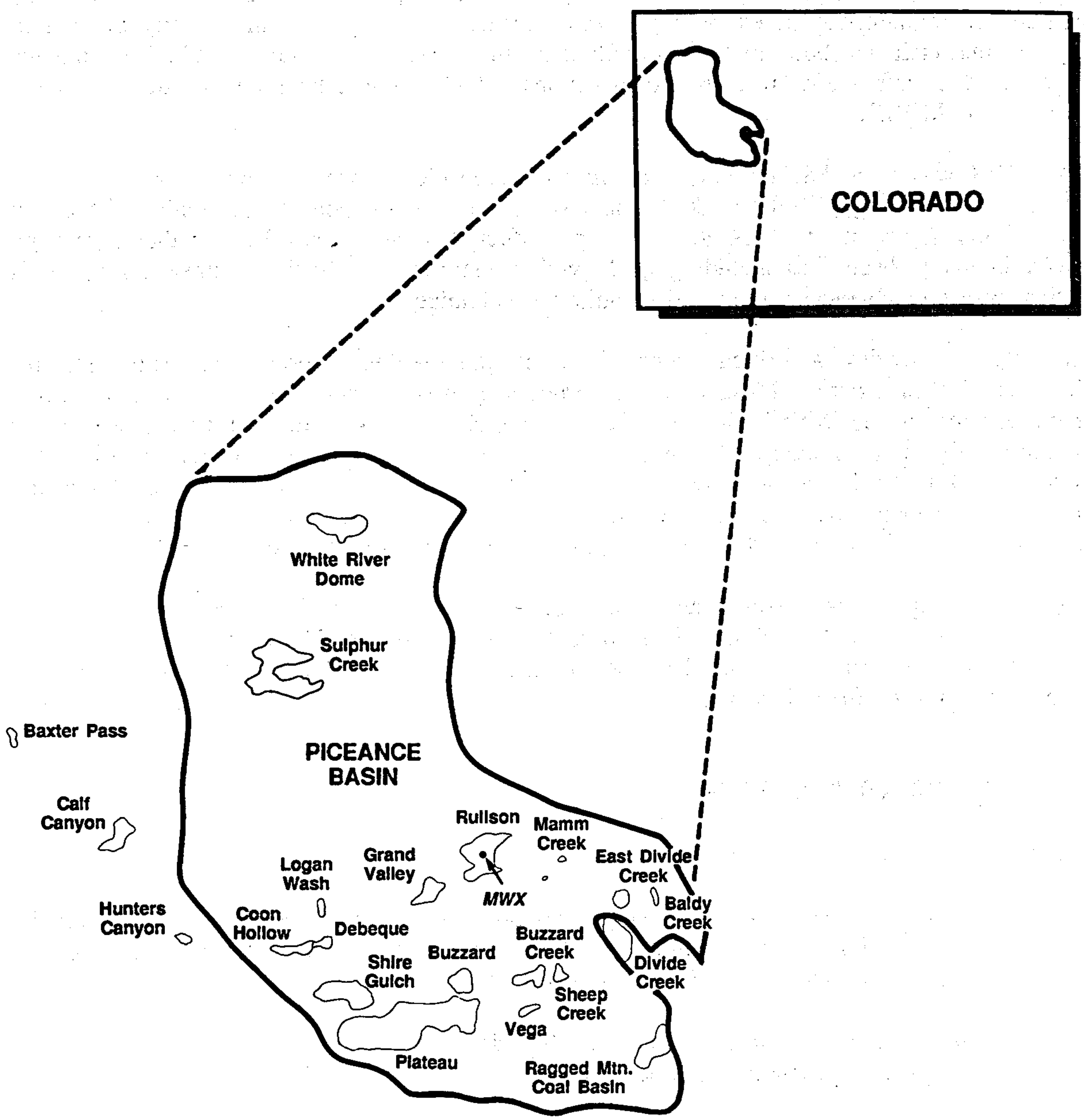



*Figure 1 Piceance Basin of Colorado Showing Mesaverde Gas Fields and MWX Location*

## 1.2 OVERVIEW OF METHODOLOGY

The methodology for this study involved the integration of geological, reservoir and historical production and well stimulation information from existing Mesaverde gas producing areas in the Piceance Basin with the same information from MWX. The six major steps were:

1. **Assemble Mesaverde geological and production data.** The key studies and data sources were:

    - "Geologic History and Hydrocarbon Potential of Late Cretaceous-Age, Low Permeability Reservoirs, Piceance Basin, Western Colorado," by R.C. Johnson (1987).

    - Colorado Oil and Gas Conservation Commission well files and historic production records for Mesaverde gas wells in the Piceance Basin.

    - Dwight's Energydata, Inc. historic production records for Mesaverde gas wells in the Piceance Basin.

    - Well completion records, geophysical well logs, and historic production data from various Piceance Basin gas producers.

    - Multiwell Experiment As-Built Reports and Final Reports (CER Corporation, 1982a, 1982b and 1984; Multiwell Experiment Project Groups at Sandia National Laboratories and CER Corporation, 1987, 1988 and 1989).

2. **Assemble Mesaverde well completion and stimulation database.** The well completion and production histories of 277 Piceance Basin Mesaverde gas wells were assembled. These wells included 243 active gas producers and 34 former gas producers, now plugged and abandoned. After review, the 243 active Mesaverde gas producers were assembled into a database identified by surface location, completion intervals, casing and cementing records, and individual zone stimulation records.

3. **Assemble Mesaverde historical gas production database.** Historical gas production records were obtained from Dwight's Energydata or from the operator for all 243 active Mesaverde gas wells in the basin. Remaining recoverable gas projections to an economic limit of 30 MCFD were undertaken for the 243 active Mesaverde gas wells using decline curve analysis techniques. The first 12 months' gas production, cumulative gas production to March 1988, and projected ultimate gas recovery was developed for each well and entered into the production database.

4. **Assemble detailed log suites on 34 wells distributed across the Piceance Basin.** A detailed log evaluation of the Mesaverde Group was conducted in 34 wells using the TITEGAS log analysis system. Digital log data was obtained from the well operators, digitized in house from paper records or purchased from a log digitizing company. Porosity, gas saturation, net sand thickness and permeability thickness

(kh) were determined for each well analyzed using the TITEGAS log analysis package.

5. **Construct gas productivity maps of the Piceance Basin.** The information derived from log analysis was used to indicate the gas-water transition zone on three Piceance Basin cross sections in addition to delineating the gas package areally in the basin.

   Using a modified version of MWX stratigraphic terminology as defined by Lorenz (1983), more than 150 well-to-well correlations were undertaken and a basin-wide stratigraphic database was compiled. From this database, a structural map on the top of the Rollins Sandstone Member and gross thickness isopach maps were developed for the fluvial, paludal and marine intervals, respectively. Permeability thickness (kh), net sand thickness and a natural fracture distribution map were also developed from the 34 wells analyzed with TITEGAS. The thermal database allowed basin-wide geothermal gradients to be mapped, and the distribution of areas in which the stratigraphic intervals are at temperatures greater than 190°F to be delineated.

   Information developed from the production database was used to analyze the first 12-month cumulative gas production and to construct an ultimate recoverable gas production map.

   A regional synthesis of fracture orientations was compiled from the available field study reports of Mesaverde outcrops around the periphery of the basin.

6. **Partition the Piceance Basin.** The Piceance Basin was partitioned into three areas having similar geologic and production characteristics: the Central Basin area, the Southeast Uplift area and the Southwest Flank area. The stimulation techniques used in each of the three partitioned areas were evaluated and ranked with respect to effectiveness as indicated by ultimate gas recovery. The geologic and production characteristics of each partitioned area were compared to MWX to verify the extrapolation potential of MWX observations and conclusions.

   These three partitioned areas will be the preferred locations for three joint government-industry cooperative wells undertaken to verify the findings of this study.

# 2.0 Basin-Wide Extrapolation of MWX Geologic Characteristics

## 2.1 STRATIGRAPHY

### 2.1.1 MWX Stratigraphic Terminology

Lorenz (1983) was able to study and describe the stratigraphy at the MWX site in great detail because of the abundant, high-quality core and well log data from the experiment and the existence of a relatively complete Mesaverde section exposed at Rifle Gap (12 miles from MWX). These studies have used local stratigraphic nomenclature indicative of paleoenvironments of deposition as shown in Figure 2 (modified by Baumgardner and others, 1988). Lorenz defined four distinct genetic Mesaverde intervals at MWX: shoreline/marine, paludal, coastal and fluvial, overlain by a paralic interval, lowermost to uppermost, respectively. This genetic terminology is germane to the MWX-Rulison Field area and is different from more formal terminology used elsewhere in the basin by the U.S. Geological Survey (Johnson, 1987). Correlations of MWX genetic units with regional nomenclature by Baumgardner and others (1988) are included in Figure 2.

To extrapolate the detailed analysis at the MWX site into the rest of the Piceance Basin the basin-wide terminology of Johnson and that of Lorenz were merged, as shown in Figure 3. Since basin-wide correlations required the use of well logs of various ages and quality, Lorenz's terminology was simplified into three gross genetic units: shoreline/marine, paludal and fluvial intervals. The coastal and paralic intervals were lumped into the fluvial interval for convenience, and the shoreline/marine is referred to as just marine. The paralic sediments are water saturated in the MWX wells and are not considered reservoir in this study. Using the modified MWX terminology in Figure 3, more than 150 well-to-well correlations were made throughout the basin, and a stratigraphic database was compiled. The following stratigraphic interval descriptions in depositional order are derived from the works of Lorenz (1982, 1983 and 1985) performed during the MWX investigations.

#### 2.1.1.1 Marine Interval

Potential reservoirs deposited in the shoreline/marine environment in the southern Piceance Basin consist of the Corcoran, Cozzette and Rollins Sandstone Members. These sandstone bodies can be correlated over great distances (50 to 75 miles) where they occur in the basin. These blanket shaped sand bodies vary in thickness from 30 to 200 ft. They are regressive delta front deposits consisting of shoreline to shallow marine sandstones. Interbedded with the sandstones are offshore marine shales, brackish-water bay mudstones and commonly coaly coastal marsh deposits. The crossbedded, well sorted, blanket sandstone bodies are commonly homogenous on a local scale and form the better reservoirs. Other characteristics of the sandstone bodies included coarsening upwards grain sizes within each body, with interbedded shales near their bases and often overlying coal beds above the sandstones.

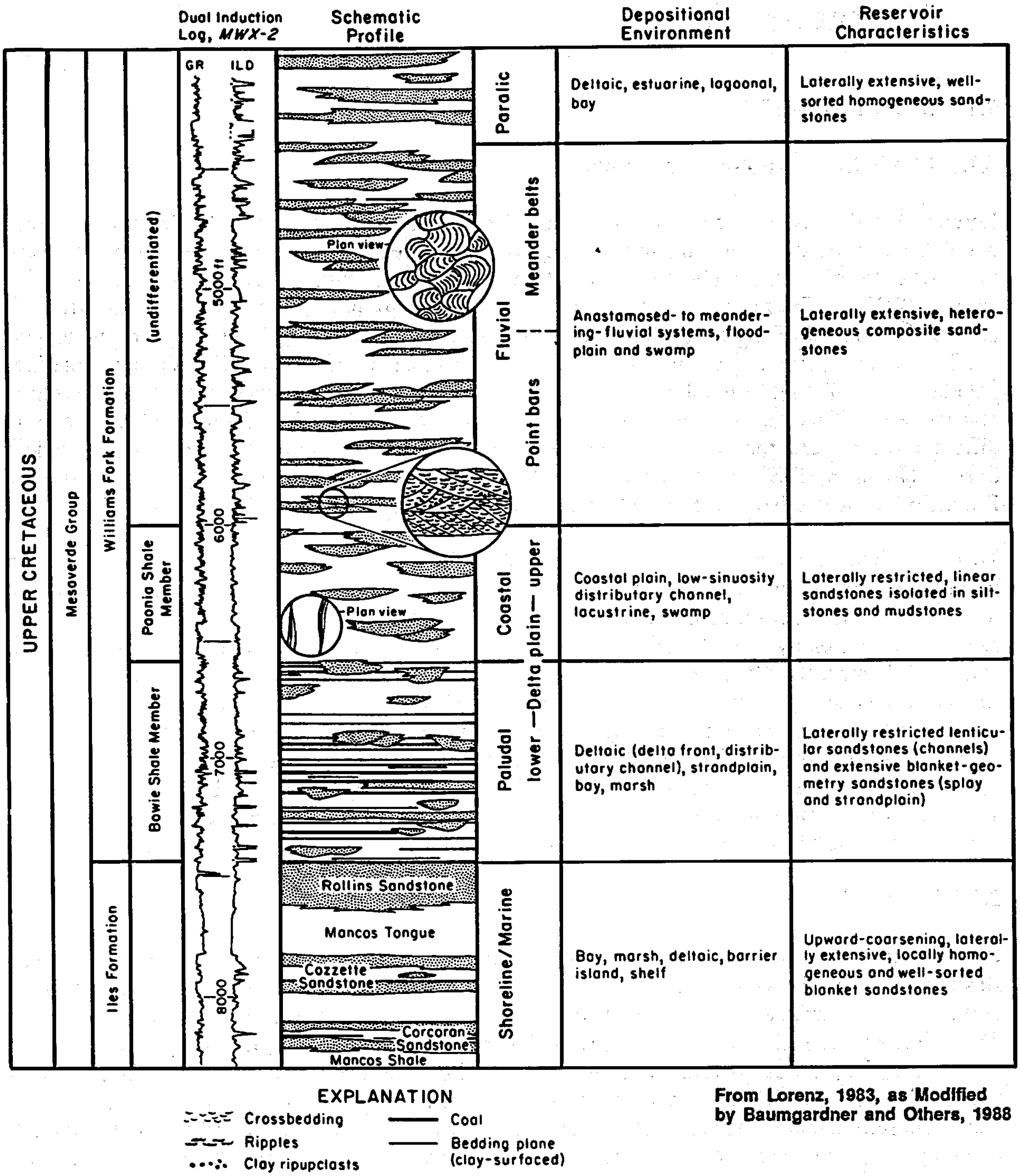



*Figure 2 Correlation of Paleoenvironmental Depositional Units at the MWX Site with Regional Stratigraphic Nomenclature*

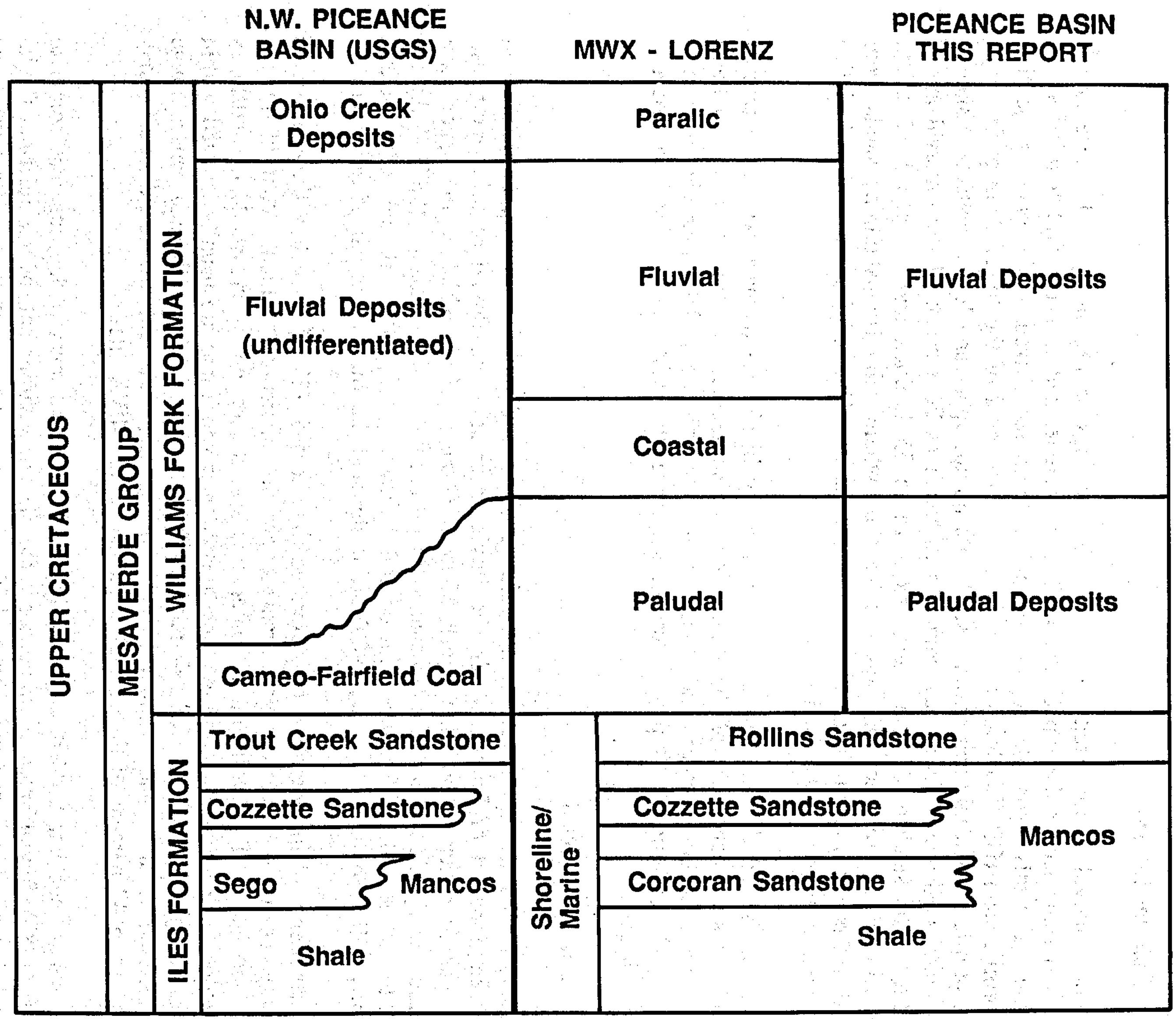



*Figure 3 Stratigraphic Nomenclature Used in This Report Compared With That of Lorenz (1983) and Johnson (1987)*

The depositional environment and especially the coarsening upward grain size and other characteristics (e.g., thickness, interbedding with shale and coals) are readily discernible on gamma ray and SP-resistivity-induction log suites. The base of the Cameo Coal sequence actually defines the top of the Rollins Sandstone Member and is readily identifiable basin wide.

#### 2.1.1.2 Paludal Interval

The paludal interval of this study is recognizable on logs as beginning at the base of the Cameo Coal sequence or the top of the Rollins Sandstone, and is about 860 ft thick at the MWX site. For this study, the top of the paludal was recognized as the base of the first blocky profile sand (GR-ILD logs) above the upper-most coal of the lower delta plain rocks. This log profile is of a uniform channel sand with abrupt upper and lower contacts. Blanket and lenticular sandstone bodies may comprise as much as 26 percent of this interval at the MWX site. The sandstone bodies range from 14 to 35 ft thick and average 17 ft thick. The depositional environment was lower delta plain where delta front/shoreline sands were deposited interspersed with delta distributary channels. This environment also included flanking coal swamps, marshes and bays.

Reservoirs of the paludal interval are characterized by blanket sandstones, which are thinner and less extensive than those of the underlying marine sequences. Interspersed with these relatively homogeneous blanket sandstones are the more numerous lenticular channel sands, extensive coal beds (up to 13 percent of the sequence at MWX), as well as carbonaceous mud and silt beds.

#### 2.1.1.3 Fluvial Interval

This study, as defined by the DOE, necessitates the consideration of the upper delta plain (coastal) environment of Lorenz within the fluvial interval. The fluvial of this report also includes paralic rocks of the Ohio Creek Member (Lorenz, 1982) which is the upper most Mesaverde Group throughout the Piceance Basin according to Johnson (1987). At the MWX site, about 700 ft of upper delta coastal sediments, 1,500 ft of fluvial sediment and 525 ft of paralic sediments (Lorenz, 1983) are designated the fluvial interval of this study.

The upper delta plain environment described by Lorenz (1983) had low-sinuosity river distributary channels traversing low-gradient coastal plains on which occurred muddy swamps and lakes. Reservoirs of this interval are characterized by crossbedded sandstones lenses which have length dimensions much greater than width and are usually isolated within siltstones and mudstones with occasional interbedded coals. The individual lenses range from 12 to 80 ft thick and average 23 ft in thickness. The lenticular sand bodies may comprise up to 42 percent of the coastal sequence at the MWX site.

Channel sandstones interbedded with muddy flood plain and swamp deposits that comprise Lorenz's (1983) fluvial interval were deposited in an environment of meandering fluvial systems. Most of the sandstones were laid down as arcuate point bars. Reservoirs are characterized by extensive, heterogeneous sandstone bodies composed of numerous crossbedded subunits. These bodies often contain silt and clay interbeds. The sand bodies are irregular discs and crescents ranging from 2 to 10 ft thick (averaging 5 ft) in the lower fluvial point bar sequence. The upper fluvial meander belt sequence (Figure 2) is comprised of more irregularly tabular-elongate shaped sand bodies ranging from 10 to 50 ft and averaging 22 ft in thickness.

Rocks of the upper most Mesaverde Group are the laterally extensive, well-sorted homogeneous sandstones of the paralic interval of Lorenz (1983). In a later report by Lorenz and Rutledge (1985), the paralic interval is designated as the Ohio Creek Member of the Mesaverde Group. The Ohio Creek Member is also included in this study as part of the fluvial interval and is about 525 ft thick in the Rulison area. The Ohio Creek Member is considered the uppermost Mesaverde by both Lorenz (1982 and 1985) and Johnson (1987) and was thus used as the upper limit for this extrapolation study. The Ohio Creek Member's top is the surface of an unconformity that is widespread throughout the Piceance Basin. It commonly is a readily identifiable marker basin wide, which also is good reason for adopting it as a limiting boundary for this study. The top of the Ohio Creek Member is manifest on electric logs as an identifiable negative SP response, and a pronounced high resistivity (low conductivity) in sharp contrast with the overlying Paleocene age sediments above the unconformity. The rock of this paralic, Ohio Creek Member are commonly water saturated in the Rulison Field area and do not form gas reservoirs. This interval is gas productive in only a few wells throughout the Piceance Basin (Lorenz and Rutledge, 1985).

### 2.1.2 Basin-Wide Stratigraphic Nomenclature and Correlation

The Mesaverde Group nomenclature is very complex in the Piceance Basin and according to Johnson and others (1987) two or more different systems have been used in many areas. The Mesaverde may be considered a group or a formation depending upon whose terminology is used. A compromise employing the nomenclature of several authors appears in Figure 2.

Nomenclature of units in the marine sequence is overlapping because of depositional complexities (Johnson and others 1987). Transgressive Mancos Shale tongues commonly are considered members, whereas regressive sand units are considered formations in one part of the basin and members elsewhere. In various parts of the basin, these regressive sandstones may be assigned to two different formations. Perhaps the most persistent, widespread and readily identifiable regressive unit is referred to in the southeastern part of the basin as the Rollins Sandstone and in the northwestern Piceance Basin as the Trout Creek Sandstone.

Similarly, the nonmarine rocks of the Mesaverde Group also are the subject of a rather complex terminology employing a number of different formation names.

With numerous maps and cross sections, the detailed stratigraphic nomenclature of the Piceance Basin is presented in Johnson's (1987) study at the field level as well as a basin wide perspective. Limits for the Mesaverde regressive cycles are presented in maps. Sand body age, shape, thickness, depositional environment and reservoir characteristics are given for each stratigraphic unit of the Mesaverde Group. Another paper (Johnson and others, 1987), for simplicity, informally subdivides the Mesaverde Group into two formations: the marine Iles Formation and the overlying coastal plain sequence of the Williams Fork Formation (Figure 3).

Below are the regionally recognized, formal stratigraphic units of Johnson (1987) and correlation with the nomenclature at the MWX. Also included are basin-wide gross interval isopachs for the fluvial and paludal intervals. Because the marine sandstones interfinger with various thicknesses of Mancos Shale and because the number of marine sands in the section varies across the basin, a useful isopach of the marine interval could not be made.

#### 2.1.2.1 Iles Formation

The Iles Formation (Figures 2 and 3) varies in thickness from about 500 to 1,500 ft and include tongues of the Mancos Shale. Individual regressive sandstone units thin and grade into Mancos Shale toward the southeast. Regressive sandstone units recognized within the Iles Formation from the youngest to the oldest are according to Johnson (1987): Rollins Sandstone in the southeast (including Rulison area) and its equivalent Trout Creek Sandstone in the northwest Piceance Basin, Cozzette Sandstone, Corcoran Sandstone, Upper Sego Sandstone, Lower Sego Sandstone, Loyd Sandstone, Castlegate Sandstone and Morapos Sandstone.

The Rollins, Cozzette and Corcoran Sandstones of the Rulison area are probably direct analogues to those of Johnson and are recognized as such within their area of occurrence. The Rollins comprises almost 200 ft of sandstone immediately below the Cameo-Fairfield Coal zone in the Rulison Field. It thins to a number of less pronounced sandstone bodies of the Trout Creek.

Sandstone members not present or not penetrated at the MWX-Rulison site occur stratigraphically below the Corcoran Member elsewhere in the Piceance Basin. Northwest of the Rulison area, the Upper Sego (coeval with the Corcoran and in some places its equivalent) is recognized (Figure 3). Stratigraphically below the Upper Sego occurs the Lower Sego. Farther northwestward and stratigraphically below the Lower Sego occurs the Loyd Sandstone. Farther northwestward near the Colorado-Utah border, stratigraphically below the Loyd Sandstone, the Castlegate regressive sequence is underlain by Morapos Sandstone. The Morapos, the most distant regressive member from the Rulison area, forms the base of the Mesaverde Group in the northwest Piceance Basin (Johnson 1987).

The regressive marine units according to Johnson and others (1987) are lithologically very complex. They are a mixture of persistent marginal marine sandstones, brackish-water lagoonal sequences, lenticular channel sandstones of distributary channel and lower coastal plain origin. Thin, coally intervals, deposited in delta or lower coastal plain environments, are commonly interspersed with the sandstones, siltstones and shale sequences.

The Iles Formation is the lithostratigraphic equivalent of the marine interval of Lorenz (1983) at the MWX site (Figure 3).

#### 2.1.2.2 Williams Fork Formation

The overlying William Fork Formation as recognized by Johnson and others (1987) ranges from 1,500 to 4,500 ft thick throughout the basin. It was deposited in non-marine coastal plain, paludal and fluvial environments which encompass the same intervals described by

Lorenz (1983 and 1985) at the MWX site. Included in the Williams Fork Formation is the parallic Ohio Creek Member (Figure 3).

The basal units of the William Fork Formation are the Cameo and Fairfield Coals which occur basin wide immediately above the Rollins-Trout Creek Sandstones. The Cameo-Fairfield Coals range from about 100 to 1,000 ft thick basin wide and average about 300 ft thick. The total coal in this interval ranges from 20-180 ft and averages 40 to 60 ft throughout much of the basin (Johnson and others, 1987).

Some of the thickest rock sequences deposited in a paludal environment occur in the southeastern Piceance Basin which includes the Rulison Field area. Here, Johnson (1987), Collins (1976) and others recognize another unnamed regressive cycle occurring stratigraphically above the basin wide Rollins-Trout Creek sands. The Middle Sandstone of Collins, along with the overlying coal sequences, are part of this regressive sequence deposited stratigraphically above the Cameo-Fairfield coals. These coal sequences along with the basal Cameo-Fairfield Coals of the Williams Fork Formation form a paludal interval 800 to 1,000 ft thick in the Rulison Field as designated by Johnson (1987). In the nomenclature of Lorenz (1983), these same paludal rock sequences are the lower delta plain-paludal interval rocks that have been extensively researched at the MWX site by a number of organizations. In the Rulison area, the nomenclatures of Lorenz (1983), Johnson (1987) and this report for the paludal interval are essentially coincident and are also coincident with the Bowie Shale Member as recognized by Collins (1976) and others (Figure 2).

Plate 1 is an isopach of the gross paludal interval. The interval is thickest (>1,000 ft) south and west of Rifle. This thick area is a portion of a SE-NW thick trend corresponding with the synclinal trough along portions of the basin axis. The paludal interval thins westward from the basin axis towards the Douglas Creek Arch, which trends almost due south of Rangely. This paludal interval pattern suggests the basin was actively subsiding at the time of its deposition.

This report defines all stratigraphic units of the Mesaverde above the paludal interval in the Rulison area as the fluvial interval. The coastal interval of Lorenz, the Paonia Shale Member of Collins (1976) and the undifferentiated fluvial part of the Williams Fork Formation are all considered here as part of the fluvial interval. Throughout the basin, according to Johnson (1987), "the stratigraphic nomenclature used for the fluvial part of the Mesaverde is almost as ambiguous as our understanding of the unit." This interval consists of several thousands of feet of sandstones, siltstones, mudstones, shale and minor coally intervals deposited on a coastal plain that covered the basin after the earlier Cretaceous seaway retreated. Channel sandstones comprise about a third to half of the rocks of this interval. In some areas, sandstone units several hundred feet thick can be formed by stacking these channel sandstones. The upper parts of the fluvial interval throughout the basin are commonly water saturated and not considered potential reservoir rock and are not the subject of extensive study in this project.

An isopach of the gross fluvial interval is shown in Plate 2. The thickest fluvial section parallels the structural basin axis suggesting that the basin was subsiding during deposition. Local variations in thickness along the southwestern part of the basin are believed to result from both the stratigraphic variations in the depositional environment and erosion of some fluvial section between Cretaceous and Paleocene times. The fluvial interval shows thinning in the Rifle area. This is the result of a locally thicker paludal section as described in the preceding section of this report.

## 2.2 GENERAL STRUCTURAL GEOLOGY

Tectonic features surrounding the Piceance Basin are shown in Figure 4. The basin is flanked on the southwest by the Uncompahgre Uplift, on the west by the Douglas Creek Arch, on the north by the eastern extension of the Uinta Mountains, and on the east by the White River Uplift. Uplift of the White River Plateau has exposed the Mesaverde Group along the Grand Hogback with locally steeply dipping to overturned bedding.

The structure contour map of the Piceance Basin on top of the Rollins Sandstone by Johnson (1983) was used in this study to depict the basic structure of the basin for regional analysis. Johnson's map is the most detailed map of the basin to date. This study did not find any major discrepancies with that map; however, minor changes in the areas surrounding the Rulison and Ragged Mountain Fields are recommended, as shown in Figures 5 and 6. For regional analysis purposes, a computer-drawn structure map on top of the marine interval (Rollins-Trout Creek sandstone) was produced, as shown in Figure 7. The basin is an elongate asymmetric structural basin whose synclinal axis trends northwest-southeast but has at least two axis bifurcations.

The tectonic history of the Piceance Basin and surrounding area has been reviewed by Lorenz (1985) and Johnson (1987). Laramide tectonism was characterized predominately by differential vertical displacements along faults. Numerous thrust faults are present on the northern and eastern sides of the basin. These thrusts have been related to uplift of basement blocks and northeast-southwest directed crustal shortening (Gries, 1983; Perry and Grout, 1988). The structural complexity of the southeastern Piceance Basin has just recently been deciphered. Interpretation of seismic and gravity data by Grout and others (1988) indicate the presence of imbricate stacks of hanging-wall-ramp anticlines involving Pennsylvanian rocks and the Mancos Shale within the Divide Creek structure. The Wolf Creek structure, however, appears to be the result of depositional and tectonic thickening in the Pennsylvanian section only.

Maps of the gross paludal and fluvial intervals thicknesses (Plates 1 and 2, respectively) indicate that the Divide Creek and neighboring anticlines were not active until after deposition of the fluvial interval. In fact, the fluvial interval isopach shows that the depositional basin axis was near the present location of the Wolf Creek structure (unless there was considerable southwestward translation of rock during thrusting). In contrast, Waechter and Johnson (1985) have interpreted from seismic data that the subsidiary folds in the central and western parts of the basin, such as that at Rulison (Figure 5), are bending of the Mesaverde section above older, reactivated, predominately normal faults in the underlying Paleozoic and basement rocks. They have also interpreted that extensive compressive stresses have not folded the Mesaverde except in association with thrusting.

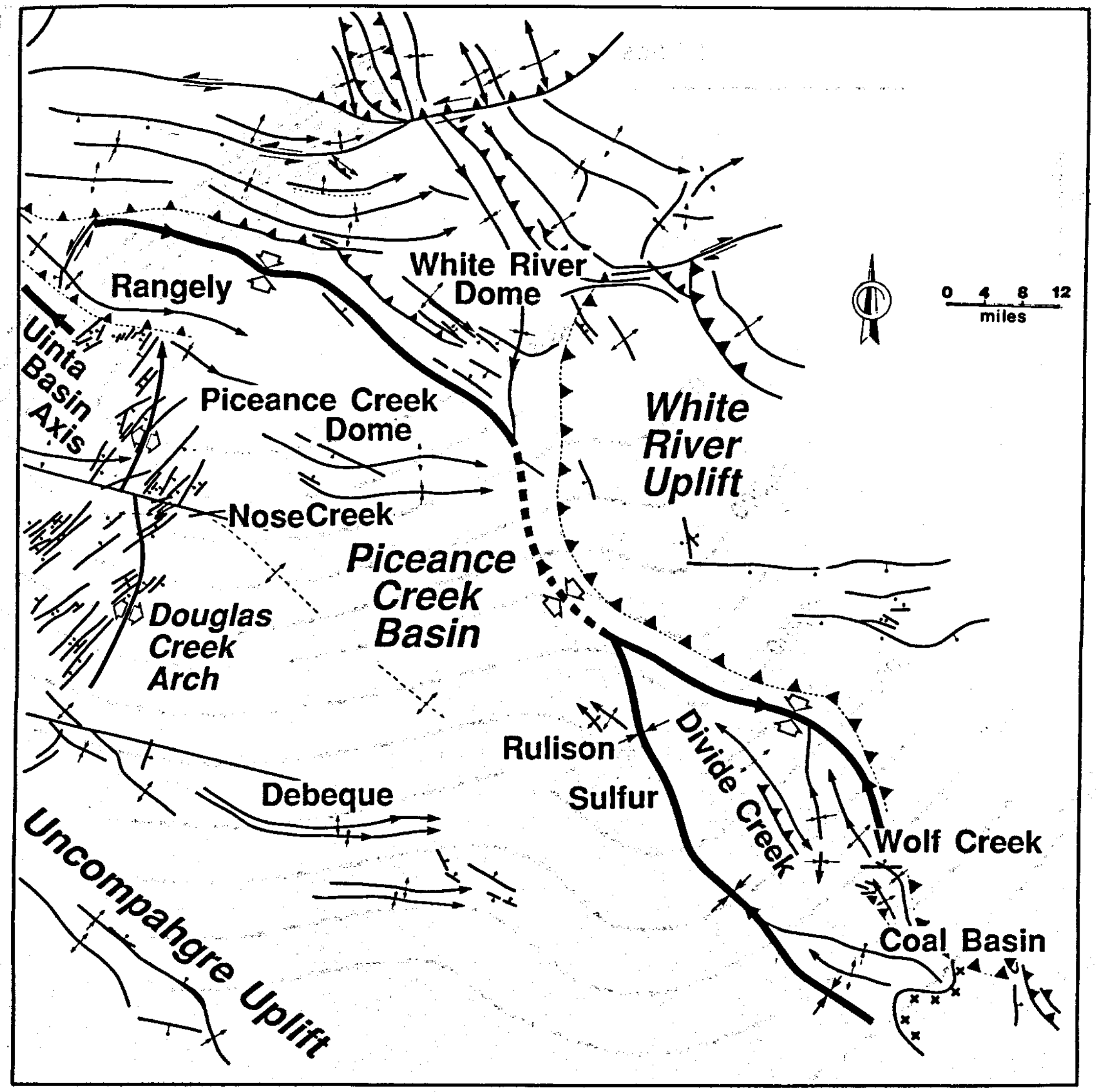



*Figure 4 Tectonic Features of Northwestern Colorado*

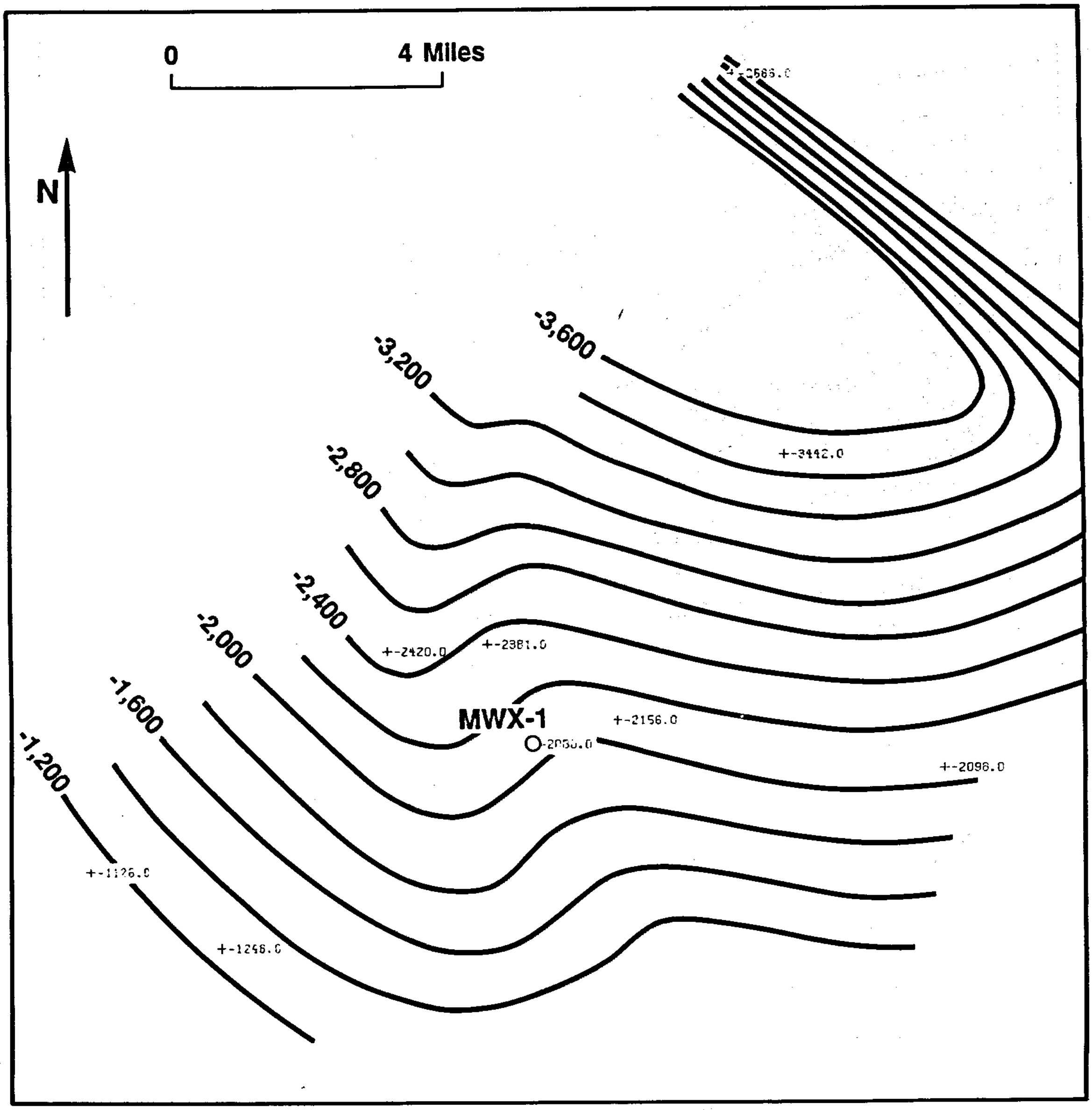



*Figure 5 Structure Contour Map on Top of the Marine Interval (Rollins Sandstone) in the Rulison Area (Contour interval equals 200 ft)*

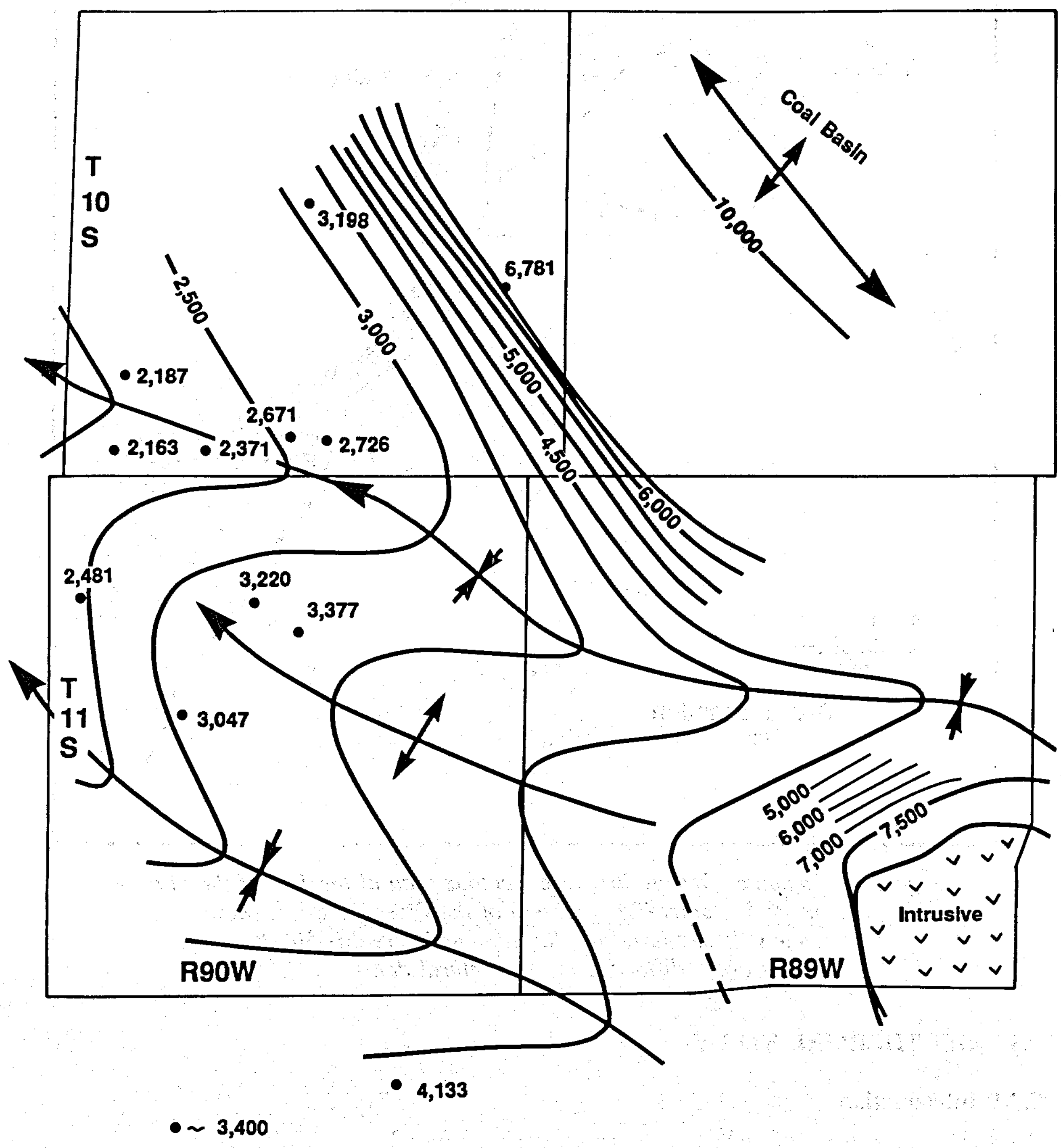



*Figure 6 Structure Contour Map of the Top of the Marine Interval (Rollins Sandstone) in the Ragged Mountain Area (Contour interval equals 500 ft)*

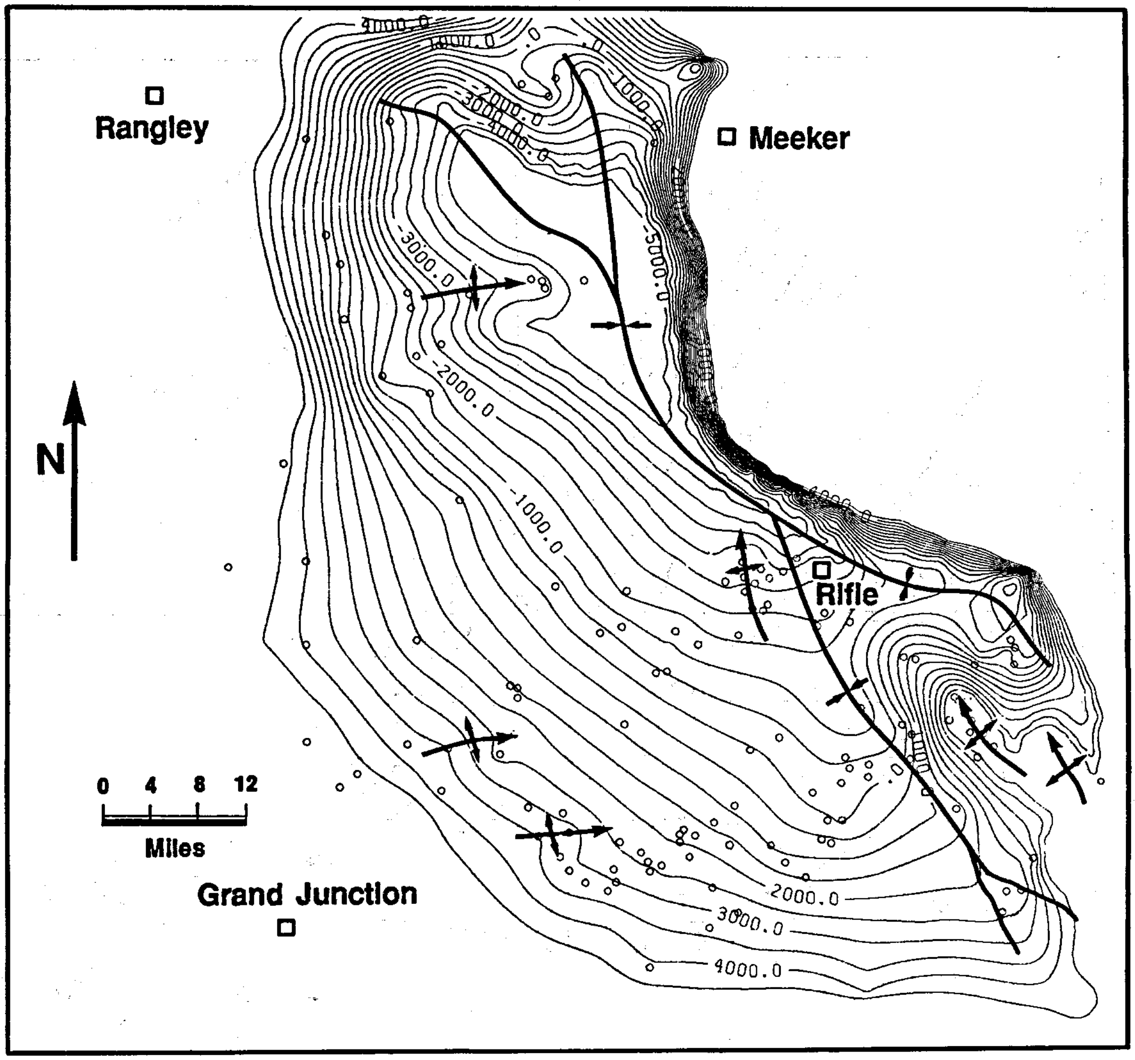



*Figure 7 Computer-Drawn Structure Contour Map of the Top of the Marine Interval (Rollins-Trout Creek) of the Piceance Basin (Zero contour is sea level and the contour interval is 500 ft; circles are well locations of structural data)*

## 2.3 GEOTHERMAL STUDY

### 2.3.1 Introduction

A thermal database for the Piceance Basin was compiled from petrophysical logs of oil and gas wells. This database permits the determination of static bottomhole temperatures (BHT) and geothermal gradients throughout the basin. Calculations of the geothermal gradients ($G^t$) permits the delineation of the 190°F isotherm for the construction of cross sections and maps to show potential gas maturation zones and also is necessary in the TITEGAS log analysis. The 190°F isotherm is the temperature threshold for the generation of significantly large volumes of thermogenic gas in this and surrounding basins (Law, 1980; Law, 1986). Areas of active gas generation so delineated should characterize potential areas for Mesaverde gas development and contribute to optimum procedures for exploiting this Mesaverde gas resource.

### 2.3.2 Data Sources

Various sources of thermal data were investigated, and data from a number of sources were incorporated into the Piceance Basin thermal database. These include CER Corporation's log collection, logs purchased for this project, submittals from oil and gas operators, and the literature. Petrophysical logs from over 1,000 wells in the Piceance Basin were searched for suitable temperature data.

Individual well temperature surveys and the rather extensive literature published on the Piceance Basin were also sources for the thermal database. Temperature surveys on the MWX-1 and MWX-3 were included. Maps, cross sections and reports on the thermal history and current properties of the basin's rocks and heat flow have been published by the U.S. Geological Survey by Johnson (1987), Johnson and Nuccio (1986) and Bostick and Freeman (1984). Brown and others (1986) published a southern Piceance Basin tight gas marine production model incorporating vitrinite reflectance and related thermal properties into their model.

### 2.3.3 Determination of Static BHT From Well Logs

Detailed temperature data were recorded from petrophysical well logs. Several factors, chiefly drilling fluid circulation before logging, affect BHT measurements made during logging runs. In relatively deep wells, drilling fluid characteristically cools the borehole and surrounding rocks at the bottom and elevates the temperature in certain upper portions of the hole. Corrections should be applied to BHT measured on each logging run before using this BHT for thermal analysis. At gas generating depths of the Piceance Basin, a positive correction is applied.

Subsurface temperature data compiled for the Piceance Basin are of three types and are of differing quality or reliability. These data are:

1. BHT from oil and gas wells measured at the time of logging;

2. equilibrium temperatures from wells with long shut in times (Piute: Ragged Mt. Federal 16-4 and 30-4, for example); and

3. temperature surveys which were available on two wells, MWX-1 and MWX-3.

BHT data was the most abundant source of data although its quality is quite variable and generally poor. Also, the literature suggests little uniformity in methods to correct BHT data. Data for determination of bottomhole temperature corrections made in this study are given in Appendix 1.

The highest quality BHT data from logs, and also the most limited, comes from multiple logging runs with individual temperature measurements made at the same depth in a well. This data, with certain assumptions, becomes amenable to Horner type extrapolations of static bottomhole temperature. Only 43 wells in the Piceance Basin were found that met these conditions. After making Horner extrapolations, nine wells were deleted for lack of consistent data.

The Horner method, illustrated in Figure 8, requires the BHT from a maximum recording thermometer on each logging run, circulation time prior to logging, and the time that the logging instrument was last on bottom of the borehole (Fertl and Wichmann, 1977).

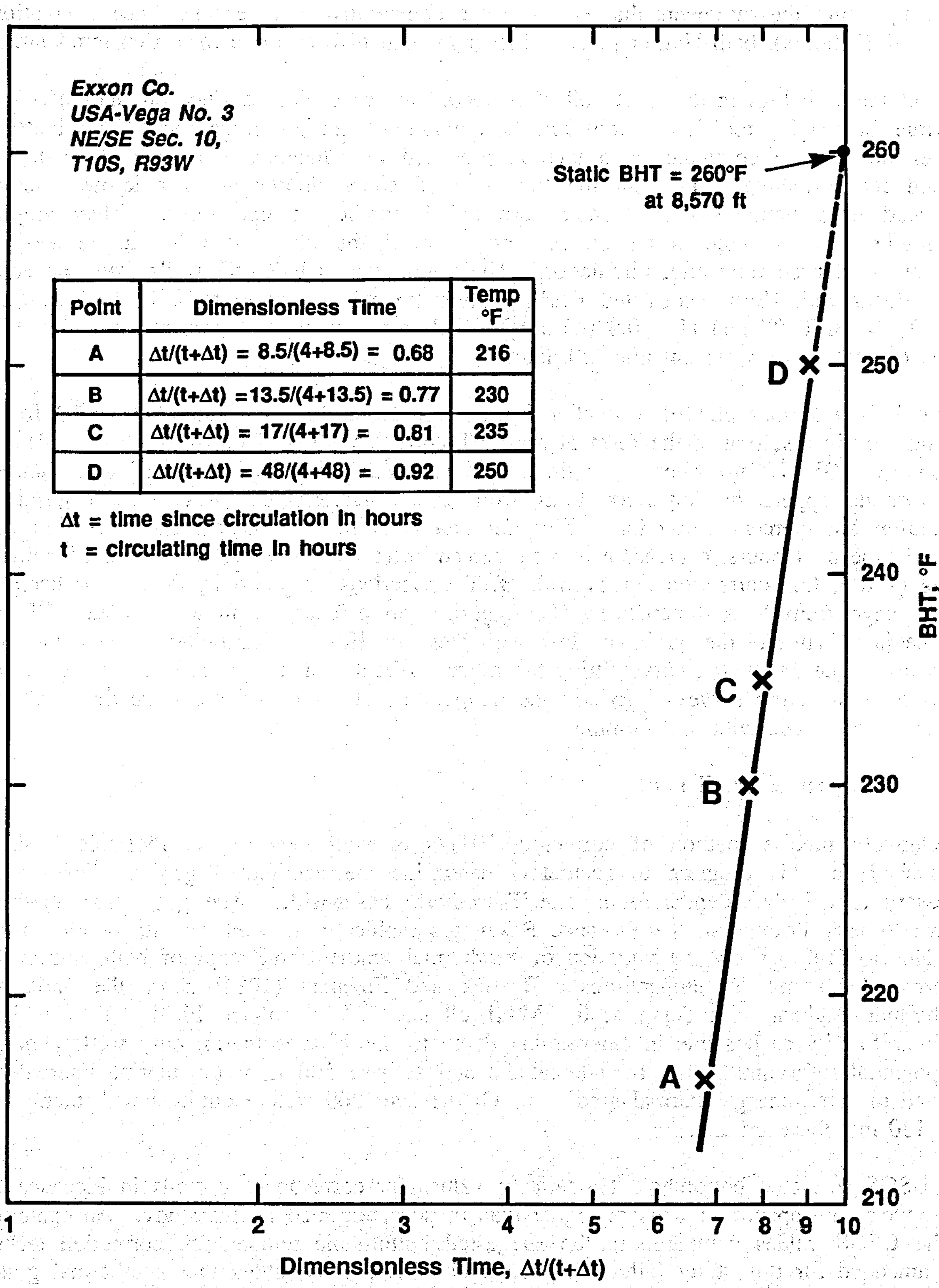
> "The basic criterion for the technique is a straight-line relationship on semilogrithmetic paper of maximum recorded temperature (BHT in °F) versus the dimensionless time ratio of $\Delta t/(t+\Delta t)$... Extrapolation of this straight line to a ratio of $\Delta t/(t+\Delta t) = 1$ will define a static formation temperature," (Fertl and Wichmann, 1977).

Well log headers commonly have the maximum recorded temperature, the time circulation stopped, and the time the logger is on bottom for each logging run. However, circulation time before logging is also a requisite for the Horner method; it is not commonly found on log headers. Based on drilling experience of the MWX wells, the time of circulation before logging was assumed for other wells of the Piceance Basin; these values appear in Appendix 1. These circulation times are the "t" in hours used in calculating dimensionless time (Figure 8). Time elapsed after circulation stopped was determined from the log header for each log run and is the "$\Delta t$" in hours.

An evaluation of the Horner extrapolation technique by Dowdle and Cobb (1975) suggest that these analyses of temperature build up always will yield estimates of static temperatures that are lower than equilibrium temperatures. When other parameters are equal, the longer the circulation time, the greater the error in the estimated static values. Under the assumption of short circulating time and that temperature measurements are not closely spaced in time, the Horner technique may be used for reliable estimates of static temperature. Appendix 1 lists the determinations made for this study.

A model for bottomhole temperature stabilization proposed by Middleton (1979) employs curve fitting techniques and permits BHT corrections without knowledge of circulation time of the drilling fluids. True formation temperature can be found by this simple curve-matching technique if several time-sequential BHT measurements are available in the same well. It is assumed that a thermal diffusivity (K) of 0.01 $cm^2/sec$ is typical for most sediments. Nine wells with BHT corrected by this method appear in Appendix 1.

Formation temperature estimation by inversion of borehole measurements developed by Cao, Lerche, and Hermanrud (1988) require modeling of parameters beyond the scope of this report. They do, however, evaluate five methods for determining static bottomhole temperatures. Middleton's method, they conclude, is known to give estimates of the formation temperature that are too high. They also state prediction of true formation temperature is always uncertain when the temperature measurements have even small errors and are closely spaced in time.




| Point | Dimensionless Time | Temp °F |
|---|---|---|
| A | Δt/(t+Δt) = 8.5/(4+8.5) = 0.68 | 216 |
| B | Δt/(t+Δt) = 13.5/(4+13.5) = 0.77 | 230 |
| C | Δt/(t+Δt) = 17/(4+17) = 0.81 | 235 |
| D | Δt/(t+Δt) = 48/(4+48) = 0.92 | 250 |

*Figure 8 Example of the Horner Method of Bottomhole Temperature Correction*

For temperature measurements that encompass a comparatively large time since circulation (in excess of 12 hours), both Horner plots and their method give accurate formation temperatures.

Most of the well logs in the CER collection record the time elapsed since circulation ceased to the time the logging tool left bottom and the maximum recorded temperature. This bottomhole temperature can be corrected by a method proposed by Chapman and others (1984). Their method for correcting BHT with the time elapsed since circulation as a known factor are calibrated to a population of Horner corrected bottomhole temperatures. They graph the magnitude of bottomhole correction (a percentage of the observed value in degrees) as a function of elapsed time after circulation. The population includes 97 wells from the adjacent Uinta Basin with Horner corrected BHTs. Their typical correction for this data set has the form $T_c$ = BHT (°C) (1.11 - 0.026 Ln $t_e$) which amounts to a 7 percent correction after 4 hours, decreasing to 3 percent after 20 hours.

Figure 9 is a similar plot of a smaller Horner population for this study (43 wells) from the Piceance Basin resulting in the formula for BHT correction ($T_c$) of the form: $T_c$ = BHT (°F) (1.108 - 0.02056 Ln $t_e$) where $t_e$ = time since circulation ceased. Corrected temperatures by this formula appear in Appendix 1 as well as the uncorrected BHT, time elapsed since circulation and percent correction. This formula calls for a 7.89 percent correction for an elapsed time of 4 hours, decreasing to 4.51 percent after 20 hours. According to Chapman and others (1984), this correction agrees with BHT corrections proposed by others for deep wells which range from 5 to 8 percent. The majority (56 percent) of these calculated BHTs are intermediate between the probably low estimates by Horner extrapolations and the higher estimates of the Middleton curve fitting technique. About half are virtually coincident with the precision temperature surveys. Basin-wide temperature corrections for constructing the 190° F isotherm were made with this formula.

### 2.3.4 Geothermal Gradients

A relatively precise method of correcting BHT's of well logs in the Piceance Basin was established for this program to accurately determine the geothermal gradients of the basin necessary to calculate depths to the 190°F isotherm basin-wide. The geothermal gradient is known to vary throughout the Piceance Basin geographically as well as with depth. Johnson and Nuccio (1986) show the variation of geothermal gradients on maps of both corrected and uncorrected bottomhole temperatures. Bostick and Freeman (1984) show the variation of geothermal gradient with depth at the Multiwell site in the Rulison Field. To establish as much uniformity as possible in determining depth to the 190° isotherm, only wells penetrating the potential reservoirs of the fluvial, paludal and at least 500 ft of the marine intervals were selected to determine geothermal gradients. Of the over 200 wells examined with thermal data, only 130 met these criteria.

The USGS corrected bottomhole temperature values for corresponding wells in Piceance Basin also appear in Appendix 1 and are higher than those determined in this study. An examination of the USGS values compared to the suggested bottomhole temperature correction technique recommended for this study (after Chapman and others, 1984) show that geothermal gradients determined for this study will be lower than the corrected values of the USGS. The geothermal gradients of this study will be intermediate to the values appearing on the corrected and uncorrected maps of Johnson and Nuccio (1986).

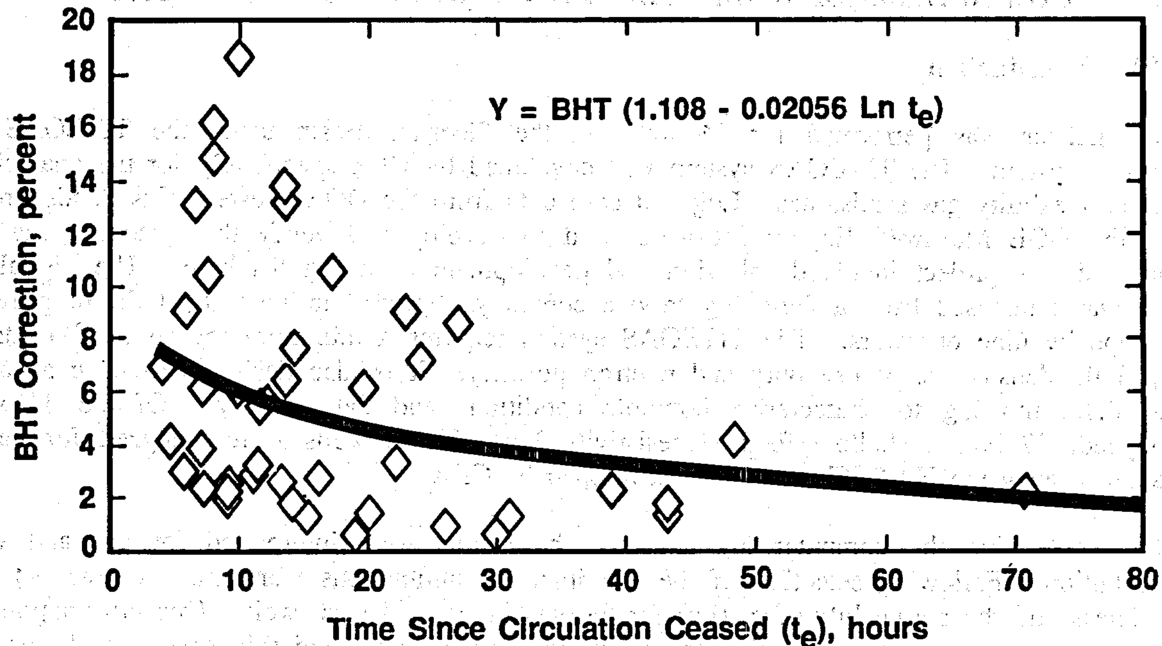



*Figure 9 Magnitude of BHT Correction, as a Percentage of Recorded Value in °F, as a Function of Time Since Circulation Ceased, for 43 Wells with Horner Corrected BHT from Table 1*

A map showing the contact of the calculated 190°F isotherm with the top of the Rollins-Trout Creek sandstone (top of marine interval) structure is shown in Plate 3. Inside this contact (hatchered area), the entire marine interval and the lower portions of the paludal interval are presently hotter than 190°F. Outside the contact, the lower parts of the marine could be above 190°F. Also projected onto the map is the areal extent of the intersection of the 190°F isotherm with the top of the paludal interval (medium shading). This area denotes the region in which the entire paludal and lower parts of the fluvial intervals are buried to sufficient depths such that they are presently hotter than 190°F. This map exhibits essentially the same trends as those of the USGS, i.e., the highest geothermal gradients are in the southern Piceance Basin and the geothermal gradients decrease northward to the limits of the basin.

The southeastern Piceance Basin, locus of Miocene through Recent magmatism, is characterized by higher geothermal gradients. This results in a large area of source rocks of the paludal (coally) interval and underlying marine interval at relatively shallow depths being hotter than 190°F. Northwest of the limit of magmatism, the basin is characterized by lower geothermal gradients. This results in the areas of potentially active gas generation from the paludal interval and the underlying marine source rocks occurring at much greater depths along the basin axis. At the northern end of the basin, source rocks at temperatures of 190°F are 4,000 ft or deeper than corresponding source rocks at the southeast extremity of the basin.

## 2.4 LOG ANALYSIS OF BASIN-WIDE RESERVOIR CHARACTERISTICS

### 2.4.1 Introduction

Log analysis was performed for 34 wells in the Piceance Basin using the TITEGAS log analysis system. The TITEGAS system was developed by CER specifically for the analysis of low permeability gas sandstones. Log and core data from the DOE Western Gas Sands Project and the DOE Multiwell Experiment were used to develop and verify the system. The first phase of this project involved selection and development of a log database. The digital log data was purchased from a digitizing service company, digitized in-house by CER or provided on tape by nine operators. The TITEGAS system requires a minimum log suite of a gamma ray, bulk density, deep resistivity and neutron porosity. It is also desirable to have a caliper and delta rho log to characterize borehole conditions and data quality. Of the 34 wells analyzed, 27 had a shallow focused resistivity log. These wells were analyzed for natural fractures using the NATUFRAC model developed by CER.

After performing the computer log analysis, the results were interpreted for gas and water distribution. Following selection of the gas interval, summations were made of the net sand thickness and the permeability-feet (kh) for the gas interval of each well. This information was then used to prepare maps showing the distribution of net gas sand thickness and kh for each interval, i.e., fluvial, paludal and marine. The NATUFRAC logs were examined, recognizable fractures were counted, and the number of fractures per 1,000 ft of section was determined.

### 2.4.2 Selection of Wells for Analysis

A database with 277 wells was compiled from Dwight's Energydata catalogue of the Piceance Basin. Some additional wells known to penetrate the Mesaverde section were identified from scout cards, FERC Filings, the Colorado Oil & Gas Commission, BLM completion forms as well as numerous other reports and studies.

From this large database, 35 wells were selected for TITEGAS analysis (one well was subsequently deleted because of poor data). Criteria for TITEGAS well selection included the following:

- penetration and logging through the fluvial, paludal and marine intervals;
- requisite suite of logs;
- geographic diversity and areal coverage; and
- availability of production and test data.

Where possible, wells were selected to include the best producing wells in each field, producing wells with less capacity and some dry holes. This provided a wide spectrum of wells for the TITEGAS analytical technique used in this project. Figure 10 and Table 1 show the locations of the wells analyzed in this study.

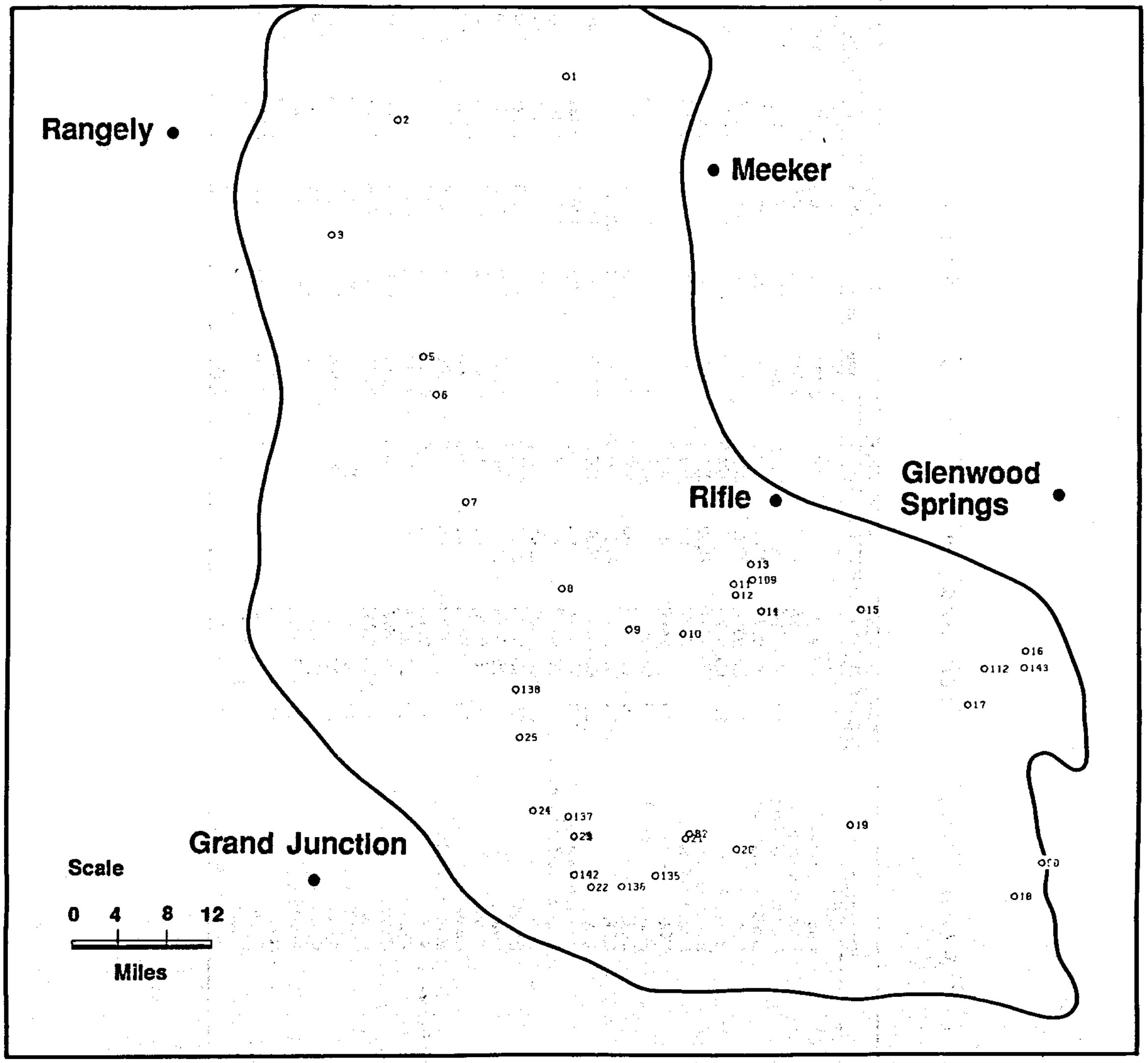



*Figure 10 Location Map of Wells Analyzed in This Study with Numbers Referencing Well Names, Operators and Locations Listed in Table 1*

*Table 1 Reservoir Data for 34 Wells Analyzed by TITEGAS Log Analysis*

| Map No. | Field Name | Well Name | Operator | Well Location | | | Fluvial Interval | | | Paludal Interval | | | Marine Interval | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sec. | TWP | RGE | Gross H | Net H | kh | Gross H | Net H | kh | Gross H | Net H | kh |
| 1 | White River Dome | Federal 6M | Fuelco | 20 | 2N | 96W | 2500 | 56.5 | 1.257 | 566 | 0.0 | 0.000 | np | np | np |
| 2 | Wildcat | Federal 22-12 | Pacific Transmission | 12 | 1N | 99W | 3668 | 36.0 | 0.137 | 370 | 0.0 | 0.000 | 1864 | 180.5 | 0.770 |
| 3 | Sage Brush Hills | Federal 30-1-99 | David M. Munson | 30 | 1S | 99W | 1838 | 0.0 | 0.000 | 589 | 0.0 | 0.000 | 1758 | 70.0 | 1.259 |
| 5 | Sulphur Creek | Federal 398-17-4 | Rio Blanco Nat. Gas | 17 | 3S | 98W | 2907 | 323.0 | 0.944 | 448 | 67.5 | 0.237 | 2050 | 142.0 | 0.423 |
| 6 | Sulphur Creek | Federal 398-33-4 | Rio Blanco Nat. Gas | 33 | 3S | 98W | 3100 | np | np | 473 | 24.5 | 0.255 | 1842 | 228.5 | 0.925 |
| 7 | Grand Valley | Pacific Oil #1 | Chevron | 13 | 5S | 98W | 2335 | 291.0 | 2.734 | 430 | 156.5 | 1.228 | 1260 | 313.5 | 3.043 |
| 8 | Grand Valley | Crystal Creek 1-23, No. 2A | Barrett Energy | 23 | 6S | 97W | 2433 | 424.5 | 1.472 | 450 | 112.0 | 0.536 | 682 | 131.5 | 0.952 |
| 9 | Grand Valley | Federal1 | Barrett Energy | 3 | 7S | 96W | 2290 | 395.5 | 2.913 | 695 | 131.0 | 0.931 | 770 | 146.0 | 0.605 |
| 10 | Rulison | Battlement 1 | Fina Oil & Chemical | 9 | 7S | 95W | np | 287.5 | 1.030 | np | 131.5 | 0.450 | np | 98.0 | 0.139 |
| 11 | Rulison | DOEXM19 | DOE | 19 | 6S | 94W | np | 308.0 | 1.398 | np | np | np | np | np | np |
| 12 | Rulison | Clough 21 | Fina Oil & Chemical | 20 | 6S | 94W | np | 406.0 | 3.412 | np | 129.5 | 0.669 | np | 127.0 | 0.189 |
| 13 | Rulison | DOEXM9 | DOE | 9 | 6S | 94W | np | 388.0 | 4.732 | np | np | np | np | np | np |
| 14 | Rulison | MWX - 1 | CER | 34 | 6S | 94W | 2732 | 408.5 | 2.597 | 860 | 295.5 | 2.695 | 778 | 178.0 | 0.975 |
| 15 | Mamm Creek | Federal 1-36 | Arco | 36 | 6S | 93W | 3007 | 170.5 | 0.243 | 768 | 112.5 | 0.475 | 1102 | 141.0 | 0.152 |
| 16 | Baldy Creek | Federal 2-20 | American Matrix | 20 | 7S | 90W | np | np | np | np | 126.0 | 0.462 | np | 77.5 | 0.217 |
| 17 | Divide Creek | Unit 21 | Sun Expl. and Production | 9 | 8S | 91W | np | 0.0 | 0.000 | np | 107.5 | 1.293 | np | np | np |
| 18 | Ragged Mountain | Federal 30-4 | Piute | 30 | 10S | 90W | 2388 | 136.5 | 1.215 | 860 | 242.5 | 1.091 | np | 93.5 | 0.210 |
| 19 | Vega | Vega Unit 4 | Exxon | 35 | 9S | 93W | 2492 | 342.0 | 2.472 | 543 | 87.0 | 0.826 | np | 66.5 | 0.193 |
| 20 | Plateau | Colorado Land 3 | Fuelco | 7 | 10S | 94W | 2417 | 98.5 | 1.263 | 359 | 12.5 | 0.060 | np | 82.0 | 1.104 |
| 21 | Plateau | Webb 11-4 | Coors | 4 | 10S | 95W | np | 65.0 | 0.580 | 598 | 47.0 | 0.365 | np | 68.0 | 0.105 |
| 22 | Plateau | Bevan 1-30 | Coors | 30 | 10S | 96W | np | 0.0 | 0.000 | 373 | 0.0 | 0.000 | 540 | 131.5 | 1.983 |
| 23 | Shire Gulch | Federal 1-3 | Martin Expl. Mgt. | 1 | 10S | 97W | np | 0.0 | 0.000 | 303 | 42.5 | 0.351 | 565 | 135.5 | 1.974 |
| 24 | Shire Gulch | Horseshoe Canyon Federal 2 | Koch | 29 | 9S | 97W | np | 0.0 | 0.000 | 310 | 0.0 | 0.000 | 700 | 114.0 | 1.720 |
| 25 | Debeque | Federal 30-3 | Piute | 30 | 8S | 97W | np | 151.0 | 2.535 | 448 | 50.5 | 0.371 | 591 | 88.5 | 0.663 |
| 82 | Plateau | Webb 3-4 | Coors | 4 | 10S | 95W | 1998 | 48.0 | 0.551 | 548 | 51.5 | 0.165 | np | 77.0 | 0.374 |
| 90 | Ragged Mountain | Federal 16-4 | Piute | 16 | 10S | 90W | 2702 | 73.5 | 0.970 | 862 | 272.5 | 1.381 | 982 | 77.0 | 0.096 |
| 109 | Rulison | Langstaff No. 1 | Fina Oil & Chemical | 16 | 6S | 94W | np | 259.5 | 0.779 | np | np | np | np | np | np |
| 112 | Divide Creek | Federal 26-3 | Piute | 26 | 7S | 91W | np | 74.5 | 0.106 | 727 | np | np | 1031 | 67.0 | 0.180 |
| 135 | Plateau | Milholland 24-1 | Bow Valley | 24 | 10S | 96W | np | np | np | 300 | np | np | 573 | 50.0 | 0.350 |
| 136 | Plateau | Moran 27-2 | Bow Valley | 27 | 10S | 96W | np | np | np | 285 | np | np | 583 | 85.5 | 0.525 |
| 137 | Shire Gulch | Federal 26-1 | Norris | 26 | 9S | 97W | np | 0.0 | 0.000 | 448 | 34.0 | 0.473 | 500 | 152.5 | 1.958 |
| 138 | Logan Wash | Cowperthwaite 2-6LW | Coors | 6 | 8S | 97W | 2156 | 221.0 | 7.349 | 430 | 37.0 | 0.276 | np | 64.0 | 0.762 |
| 142 | Plateau | Davis 1-24 | Coors | 24 | 10S | 97W | 1934 | 0.0 | 0.000 | 355 | 0.0 | 0.000 | 611 | 98.0 | 0.682 |
| 143 | Baldy Creek | Federal 3-28 | American Matrix | 28 | 7S | 90W | 3355 | 103.0 | 0.228 | 760 | 98.0 | 0.177 | 1185 | 189.5 | 0.553 |

### 2.4.3 Methodology

The log analysis began with wells in the Rulison Field where MWX data were used to normalize erroneous log data. As the analysis proceeded to other areas, it soon became apparent that natural geologic variations between areas were significant, and the MWX norms could not be extrapolated outside of the Rulison and Grand Valley Fields. A study of density histograms from various wells showed that the maximum Mesaverde density in the Plateau Field is significantly less than in the Rulison Field. It seemed reasonable that this variation is due to diagenetic factors associated with differences in the paleo maximum depth of burial. A study was therefore conducted to ascertain the effect of depth of burial on maximum lithologic density. Density histograms were prepared for the fluvial interval in each well, and a characteristic line of maximum density was selected for each plot. Johnson and Nuccio (1986) have determined that during Oligocene and Miocene, a time of deep burial of the Mesaverde Group, the surface of the Piceance Basin was an erosional plateau at about 10,000 ft in elevation near the center of the basin. Using an assumption of a constant paleo land surface elevation of 10,000 ft, the maximum depth of burial for the bottom of the fluvial interval of each well was calculated (+10,000 ft minus present elevation).

Figure 11 shows a plot of this data. The plotted points are broadly keyed according to area. Points keyed as Rulison include MWX-1, Rulison, Mamm Creek and Grand Valley Fields. Points keyed as Plateau include Shire Gulch, Debeque, Logan Wash and Vega Fields as well as the Plateau Field. Divide Creek points include East Divide Creek, Baldy Creek and Ragged Mountain Fields as well as the Divide Creek Field. Rio Blanco is the key used for the Northern Piceance Basin in general.

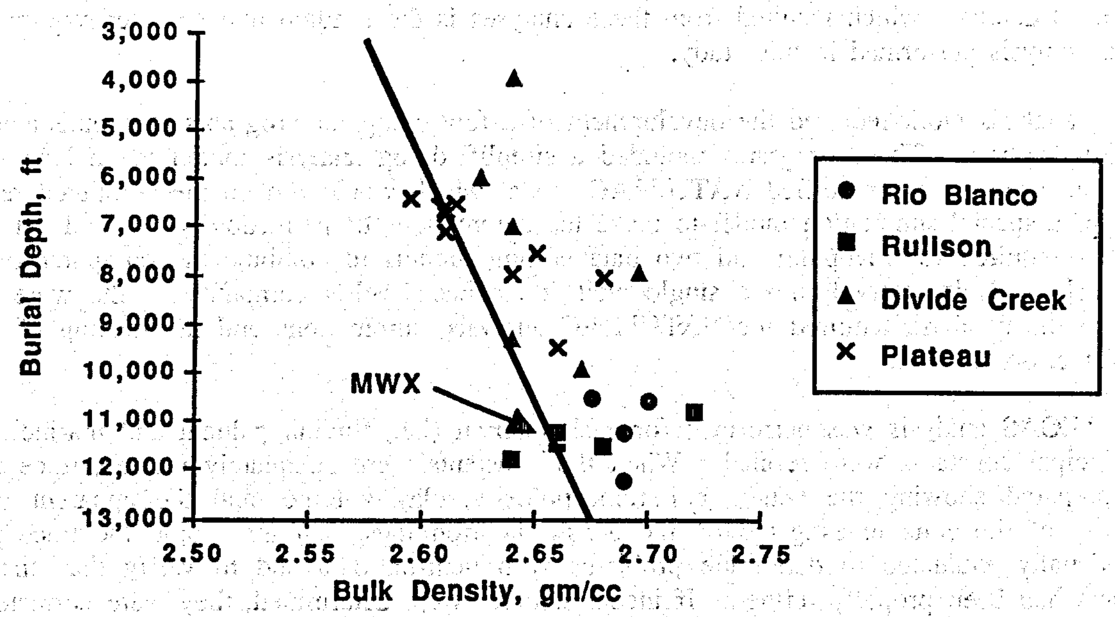



*Figure 11 Variation of Maximum Bulk Density with Interpreted Paleo Depth of Burial, by Area*

The line shown on Figure 11 is not a statistical best fit line. Rather it is a line drawn through a grouping of Plateau data and MWX data. This data shows an overall trend for increasing density with increasing burial depth. The line was used as a reference to recognize and normalize erroneous data as well as to interpret geologic variations between areas.

Several conclusions are made from this plot. The Plateau area appears to have had a relatively shallow maximum depth of burial as evidenced by the low values of maximum density. The Divide Creek wells show a broad range in maximum depth of burial. The data indicates that the Divide Creek area may very well have had a surface elevation that was greater than 10,000 ft at the time of maximum burial. This is evidenced by local outcrops of volcanic rock presently found at elevations greater than 10,000 ft. Another explanation for the higher trend of density at Divide Creek is the higher temperature gradients in the southeastern Piceance Basin and the effect that this may have had on diagenesis. The higher than expected densities observed in the northern Piceance Basin can be accounted for by lithologic variation, specifically, dolomite cement. Dolomite cement is common in core taken from the Pacific Transmission Supply Federal 22-12 well (Well No. 2 in Figure 10) which was one of the wells studied during the Western Gas Sands Project.

Neutron normalizations were also performed. The study showed that it was not possible to use the neutron data norms developed at MWX to normalize data in other areas. The neutron log could not be normalized until TITEGAS analysis was performed. The neutron log is sensitive to both the fluid saturation and the clay volume of the rock, thus field wide norms could not be determined. Neutron norms were determined by examining the calculated water resistivity ($R_W$) using the density-neutron saturation. If the calculated $R_W$ was unusually high or low in a gas interval where the $R_W$ could be approximated by nearby well control, then clearly the neutron response was not compatible with the porosity and clay volume of the rock. The neutron data was then normalized, and the well was re-analyzed with the new data. The normalized database which resulted from these analyses is the fundamental data set required for the log analysis performed in this study.

The log analysis work required the development of a few computer programs to supplement the TITEGAS system. These programs included a simplified log analysis model to analyze wells without neutron data; a modified NATUFRAC model which would run on the computed results database; a special summation model to make the summations of permeability-feet and net sand thickness required for mapping; and two data editing models to combine the computer results from each analysis interval into a single well file. Each well's computed results were then added to the database required for NATUFRAC analysis, summations and the making of trace plots for cross sections.

The TITEGAS analysis was performed for each interval (i.e., fluvial, paludal and marine), and the principal constants were refined. When the constants were adequately refined, trace plots were prepared showing the water saturation, porosity, clay volume, and the apparent water resistivity of the zone investigated by the density-neutron logs. At this point, the trace plots were visually evaluated to determine problems with neutron data and to verify that analysis constants had been properly refined. If inconsistencies were determined, they were corrected at this time, and the well was re-analyzed.

In general, changes in water resistivity occur between the geologic intervals and may divide some geologic intervals into subintervals. After refining the water resistivity, the TITEGAS model was executed and the computed results were saved. This file was then edited to compile the computed results for the entire well into one well file which was then added to the computed results database.

For each well, depths were selected for the gas bearing interval. These depths were then used as input into the summation model used to calculate net gas sand thickness and permeability-feet for the marine, paludal and fluvial intervals. The results of this analysis are shown in Table 1.

Some wells in the table may have a net thickness but do not have a gross thickness. This is possible in wells where the fluvial interval may not have been logged to the top, but the interval becomes 100 percent water saturated within the logged interval.

### 2.4.4 Interpretation of Reservoir Maps

The log analysis results summarized in Table 1 were used to prepare contour maps showing the distribution of reservoir quality throughout the Piceance Basin. The net gas sand thickness (net h) and permeability-feet (kh) maps are presented in Plates 4 through 9. All of these maps have some degree of uncertainty associated with their contours. This uncertainty is indicated by the dashed contours and the question marks. The northern part of the basin has insufficient data to accurately map. In general, the maps are adequate in showing regional trends of net gas sand thickness and permeability-feet; however, their utility is limited by the sparse data control.

The Piceance Basin gas and water distribution exerts a major influence on the net h and kh maps. This is particularly true for the fluvial maps (Plates 4 and 5). There are both regional and local influences. The regional influences correlate closely with basin structure. Along the updip basin margins, water saturation goes to 100 percent, and the net h goes to zero. Since the thickness of the kh calculation is based on net h, kh also goes to zero.

Going downdip from the basin margins, the gas saturated interval increases in thickness as the water saturated interval decreases; this exerts a major control on the appearance of the fluvial net h and kh maps. This trend is partially offset by regional diagenetic reductions in porosity where the porosity of downdip sands is generally less than the equivalent updip sand porosity.

The local water saturation influences on these maps occur on the updip basin margins where gas occasionally accumulates in combination structural-stratigraphic traps. For example the Cowperthwaite 2-6LW well (Well No. 138 in Figure 10) has an unusually high kh value which is the consequence of the well having one unusually good reservoir sand. A well located just 2,000 ft away is a dry hole. Because of this variability associated with lenticular, fluvial sand bodies, it is not possible to accurately map reservoir properties throughout the Piceance Basin using just 34 wells. Therefore, caution should be used when interpreting these maps.

There are also some depositional influences on the maps, particularly for the paludal and marine intervals. The paludal interval is noticeably thicker in the southern Piceance Basin, from the Rulison area southward. This thickening is probably associated with a transgressive-regressive cycle above the Rollins Sandstone Member in this portion of the basin. This increase in thickness can be seen on the gross thickness map (Plate 1), and this pattern carries over to these reservoir properties maps (Plates 6 and 7). The paludal thickening also affects the fluvial interval maps to some extent because the additional thickness of paludal section results in a partial thinning of the fluvial interval.

The marine interval maps (Plates 8 and 9) exhibit a pattern which is related to regional variations in the number of marine transgressive-regressive cycles. The blanket geometry of the marine sands makes areal correlations more reliable than for the paludal and fluvial interval; however, these correlations are meaningful only over portions of the Piceance Basin. For example, in the Rulison area southwest to Ragged Mountain, only the Cozzette and Corcoran Sandstones are present. However, these sands do not extend into the northern Piceance Basin. In the northern area, the marine interval includes several regressive sands such as the Morapos Sandstone, Castlegate Sandstone, Loyd Sandstone and the Sego Sandstone. Johnson (1987) discusses the stratigraphy of the Piceance Basin in detail. Because of these differences in deposition, it is not possible to make valid comparisons of marine reservoir quality between the northern and southern portions of the basin or the eastern and western portions of the basin. This study has determined that it is more meaningful to map each marine regressive sand individually.

The kh maps depend upon a calculated matrix permeability that relates permeability to other reservoir parameters. The equations used were developed by Kukal and Simons (1986) using MWX data. The calculated permeabilities are net stress corrected. The kh map assumes that the MWX permeability equation extrapolates to other areas of the Piceance Basin. In reality, it is unlikely that the equation gives accurate estimates of matrix permeability throughout the basin. This is particularly true for updip sands of higher porosity where pore geometry is not similar to sands of the Rulison Field. A consequence of these differences would be a more pessimistic view of the updip areas where permeability would be underestimated.

### 2.4.5 Log Interpretation of Gas and Water Distribution

The gas and water distribution in the Mesaverde section was studied in detail for 34 wells in the Piceance Basin. The log interpretation of gas and water were correlated between wells. These correlations and associated cross sections serve as the basis for defining regional basin trends in gas and water distribution.

Figure 12 shows the locations of three Piceance Basin schematic cross sections, X-X', Y-Y' and Z-Z'. These cross sections are presented in Figures 13, 14 and 15, respectively.

Figure 13 is a structural schematic along X-X' that crosses the central Piceance Basin generally from west to east. This section is centered on the Rulison Field and shows the position of the MWX-1 well (No. 14). To the west, the section goes updip through the Grand Valley Field, Logan Wash Field, Debeque Field and Shire Gulch Field. To the east, the section goes updip through the Mamm Creek Field and East Divide Creek Field. The section does not show true relative horizontal distances between wells. Vertical depths are presented as elevations relative to sea level. The schematic shows the tops of the marine, paludal and fluvial Mesaverde intervals. Ground level is shown, as well as the total penetration of each well.

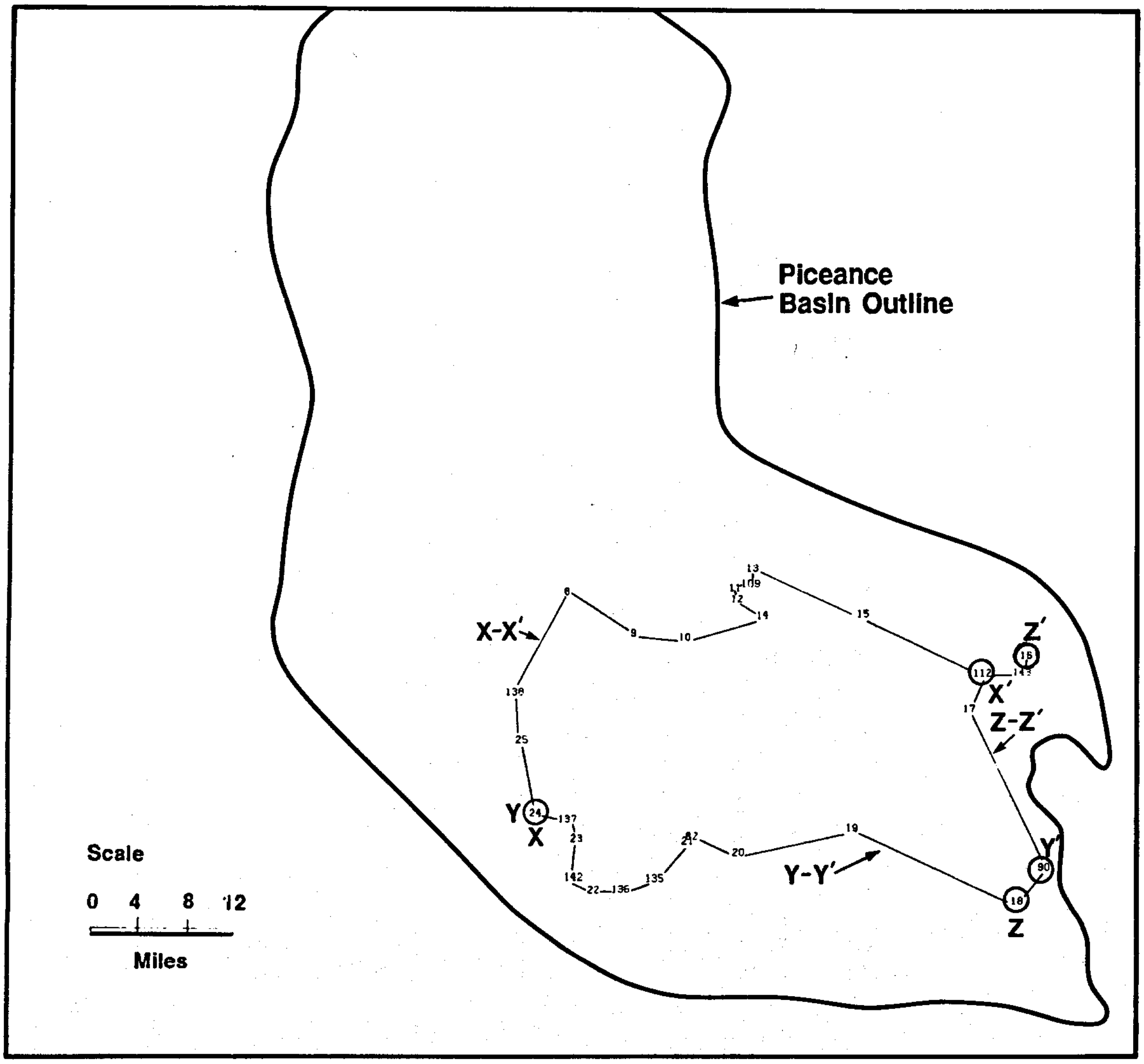



*Figure 12 Locations of Schematic Basin-Wide Cross Sections Shown in Figures 13, 14 and 15 (Circled wells denote cross section end points)*

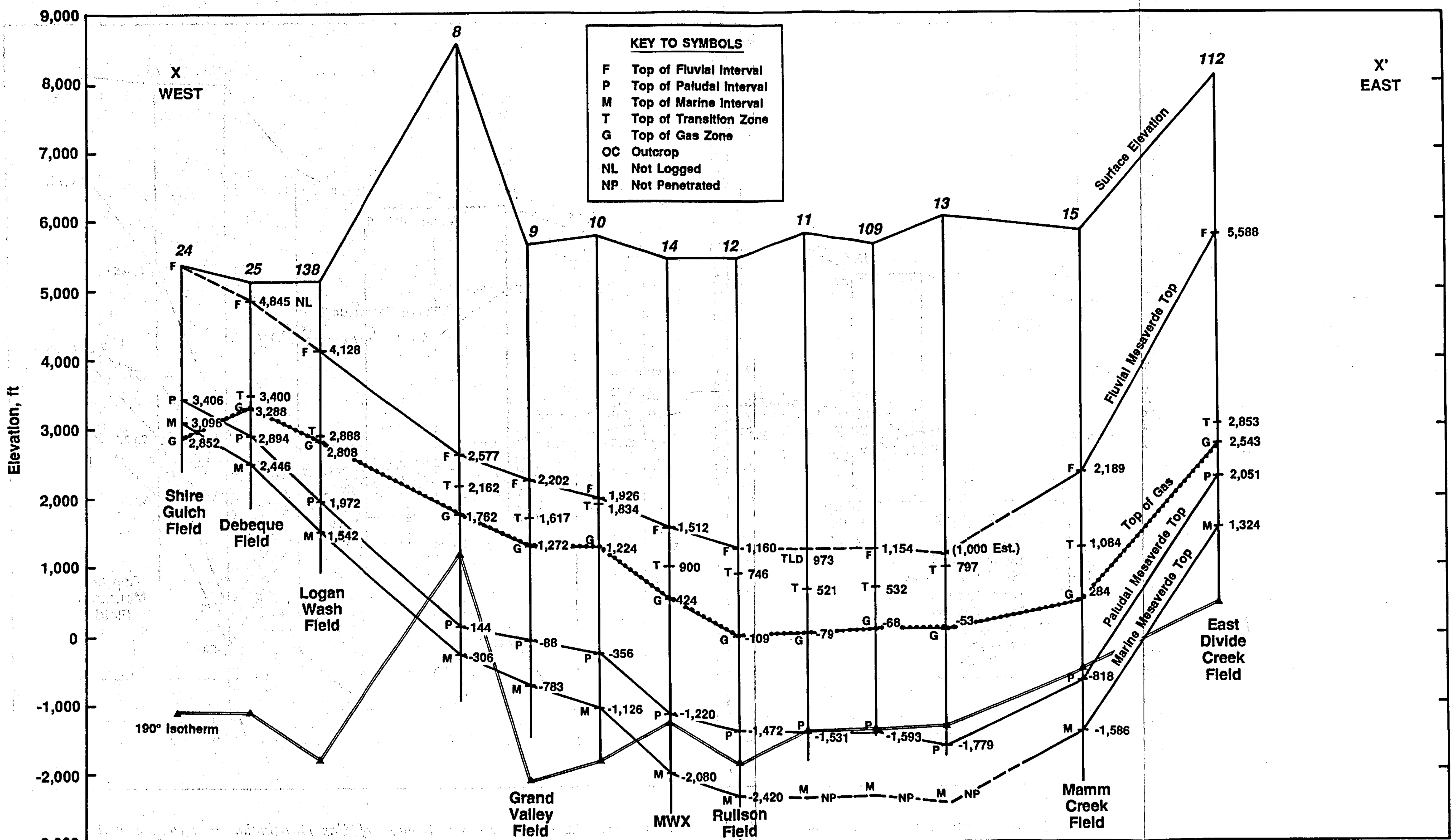



*Figure 13 Schematic Cross Section of the Central Piceance Basin Showing the Relation of Gas Distribution to Structure and Stratigraphy (Location of section shown in Figure 12 and well names given in Table 1)*

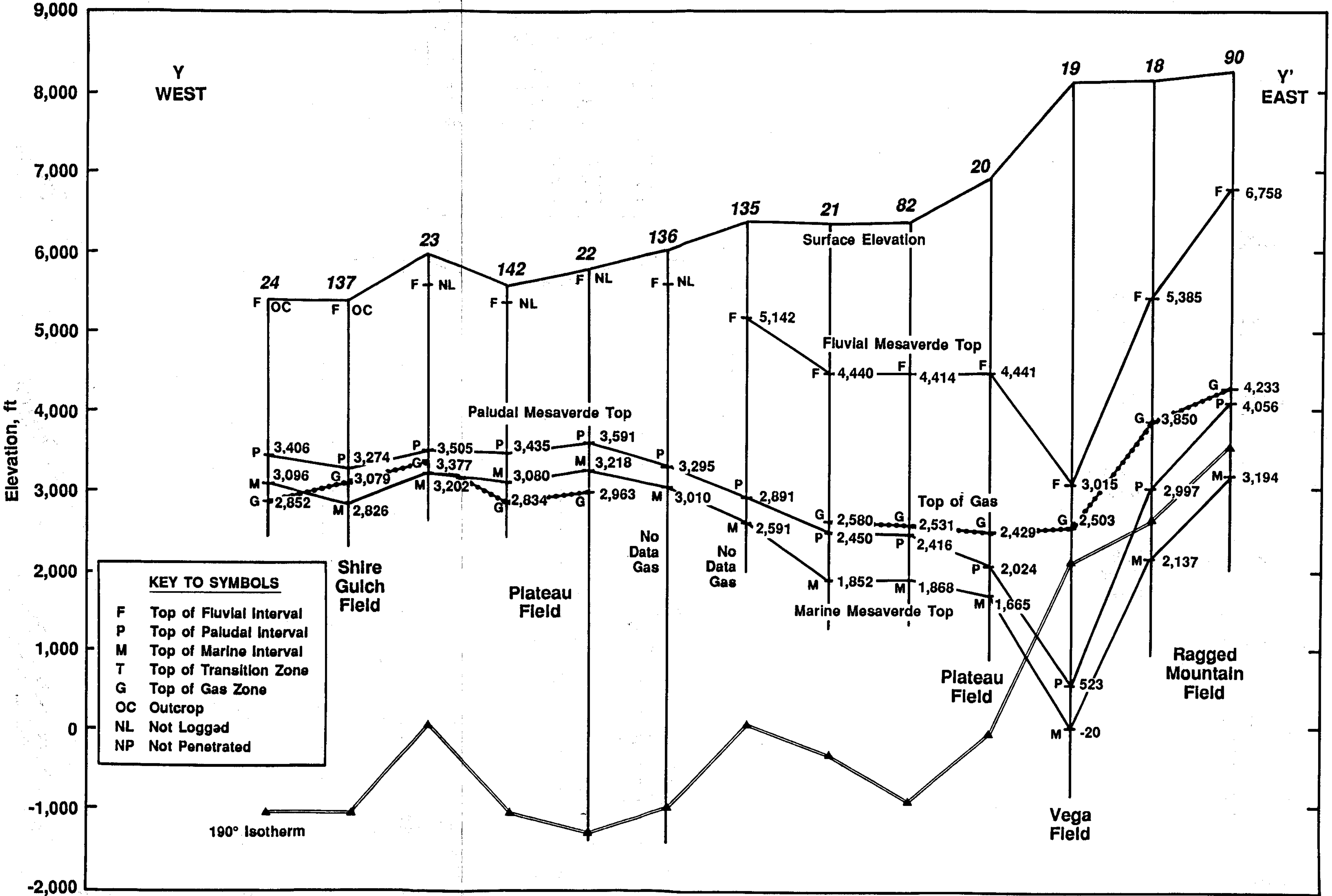



*Figure 14 Schematic Cross Section of the Southern Piceance Basin Showing the Relation of Gas Distribution to Structure and Stratigraphy (Location of section shown in Figure 12 and well names given in Table 1)*

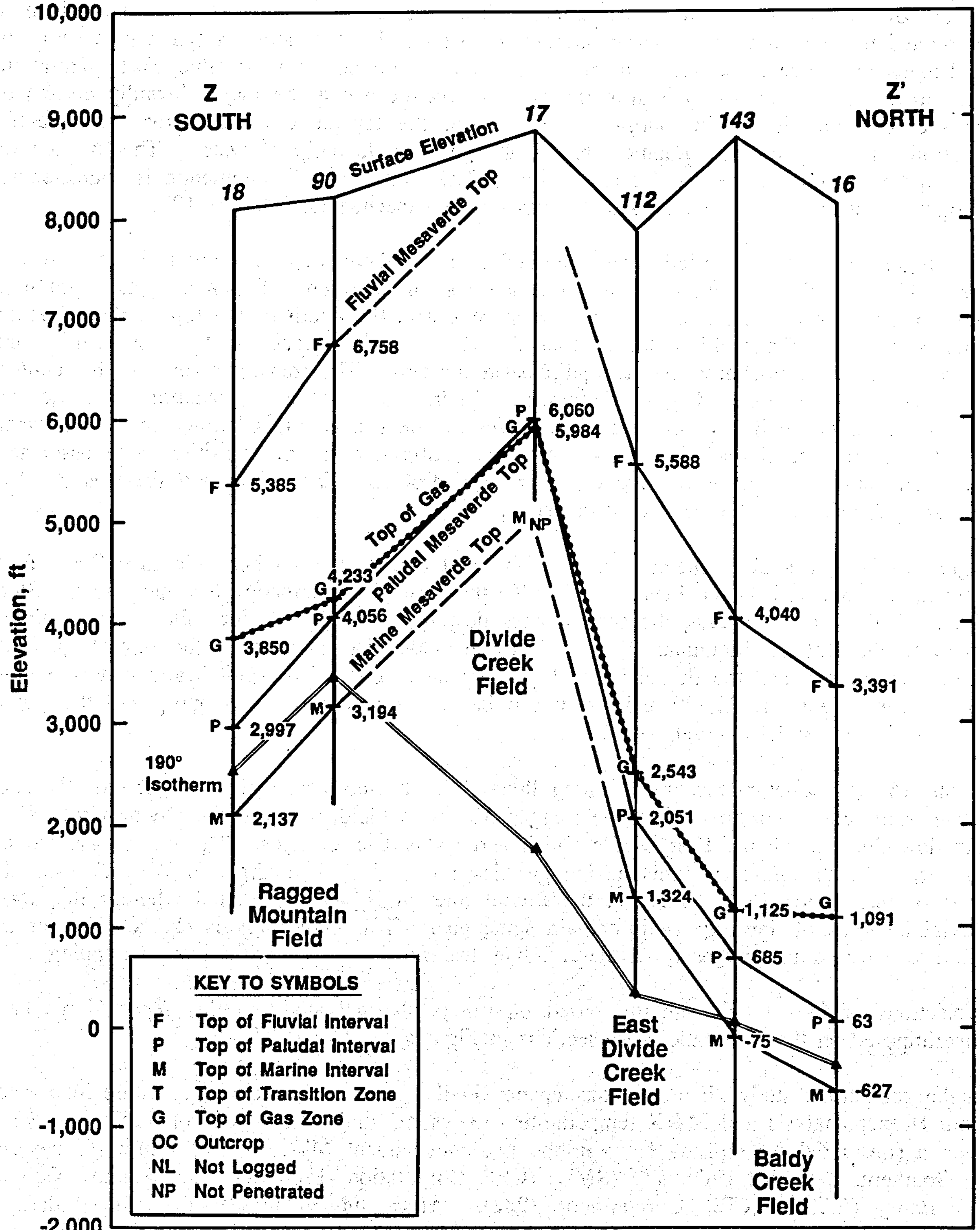



*Figure 15 Schematic Cross Section of the Eastern Piceance Basin Showing the Relation of Gas Distribution to Structure and Stratigraphy (Location of section shown in Figure 12 and well names given in Table 1)*

A "top of gas" is shown on the schematic. This top is the uppermost sandstone which is interpreted to be at irreducible water saturation. Above this top, there is typically a series of sandstones that have some gas content; however, they are not at irreducible water saturation. The top of gas roughly parallels stratigraphy and structure across the major downdip portion of the section. On the updip margins of the basin, the top of gas cuts across stratigraphy. Generally, for a given stratigraphic interval, the gas lies downdip of water. This is seen on both updip margins of the X-X' cross section. The water updip phenomenon is characteristic of tight gas sand basins and relates to the gas trapping mechanism (Masters 1979).

This report refers to a partially gas saturated section where water saturation is greater than irreducible. Called a "transition zone," it is a transition between 100 percent water saturation and irreducible water saturation. In the Piceance Basin, the depth to the top of the transition zone is shown in Figure 13 as the symbol T. This zone is typically 400 to 500 ft thick and tends to reduce in thickness on the updip basin margins. The transition zone in this context could be called a zone of gas entrapment. There is a complete gradation from no gas entrapment to irreducible water saturation; therefore, the gas is trapped downdip of the water. The transition zone described here is not to be confused with the transition zone associated with conventional hydrocarbon reservoirs where hydrocarbon is on top and there is a water saturation transition to the water contact below.

Figure 14 is a structural schematic along Y-Y' that crosses the southern Piceance Basin from west to east centered on the Plateau Field. To the west, the schematic goes updip to the Shire Gulch Field, and to the east, the section goes downdip through the Vega Field and continues updip to the Ragged Mountain Field. This schematic also shows that the top of gas cuts across stratigraphy and the fluvial interval is water saturated at Shire Gulch and Plateau Fields. Going from Wells 21, 82, 20 and 19, it can be seen that the water is updip and the gas is downdip in the fluvial interval.

Figure 15 is a structural schematic along line Z-Z'. It runs across the southeastern Piceance Basin from south to north through the Ragged Mountain Field, updip to the Divide Creek Field and downdip through the East Divide Creek and Baldy Creek Fields. The top of gas crosses stratigraphy with equivalent units having gas downdip and water updip. In Well 17, near the crest of the Divide Creek anticline, the fluvial interval is water saturated whereas the lower fluvial intervals of downdip wells contain some gas. This relationship is characteristic of the basin as a whole and suggests that the anticline does not have effective structural trapping.

Projections of the 190°F isotherm, based on the geothermal study in this report, have been superimposed on the schematic cross sections in Figures 13, 14 and 15.

In the geothermal study, there is a discrepancy in the static bottomhole temperature interpreted from Horner analysis and MWX temperature surveys run under stabilized conditions. There is even a substantial discrepancy between the two independent MWX-1 temperature surveys run by Southern Methodist University (SMU) (CER Corporation, 1984) and Los Alamos National Laboratory (LANL) (CER Corporation, 1982). Since limited temperature survey data is available for Piceance Basin wells and since there are inconsistencies in that data, this study relied upon bottomhole temperatures extrapolated to static conditions.

The 190° isotherms plotted in Figures 13, 14 and 15 are based chiefly on Horner extrapolated temperatures or the equation derived from Piceance Basin Horner data. As already pointed out, Horner temperatures are probably somewhat lower than static temperatures. The 190°F isotherm could therefore actually plot several hundred feet shallower than shown in the figures. Not withstanding this discrepancy, there are several observations that can be made from the cross sections:

- Generally, the isotherm mimics topography and cuts across stratigraphy.
- Cross section X-X' (Figure 13) shows that in the vicinity of the Rulison Field, the marine interval and part of the paludal interval are hotter than 190°F, the threshold temperature for active dry gas generation.
- In the Plateau Field, cross section Y-Y' in Figure 14, the isotherm is as much as 4,000 ft below gas producing sands in the marine interval. This is evidence for considerable vertical or lateral updip gas migration.
- Cross section Z-Z' in Figure 15 shows that in the Ragged Mountain-Divide Creek area, the southern end of the section is hotter than the northern end, in that the 190°F isotherm occurs at shallower depths to the south.
- At MWX, the 190° isotherm is about 700 ft below the overpressured Mesaverde section. This indicates that cooling has taken place (possibly associated with the downcutting of the Colorado River), that there has been an updip migration of gas from deeper in the basin, or that the isotherm is actually shallower than shown in Figure 13.

The interpretation of water saturation for the Piceance Basin Mesaverde reservoirs is difficult. Formation water resistivity ($R_W$) varies over two orders of magnitude between 0.10 ohm-meters to about 10 ohm-meters. The interpretation of $R_W$ in low permeability gas sandstones is not straightforward. These problems were discussed by Kukal and others (1983). In this study, $R_W$ interpretations were made for each well analyzed by TITEGAS. The $R_W$ interpretation technique used by TITEGAS was explained previously by Kukal (1983).

Figure 16 is an example of the $R_W$ interpretations performed for each well. The figure shows $R_W$ interpreted for the Colorado Land No. 3 well. $R_W$ varies from 0.12 ohm-meters in the Cozzette Sand at 5,600 ft to 3.7 ohm-meters at 3,800 ft and 3,200 ft. Formation water has a fairly constant salinity between 4,400 and 6,000 ft. Over this interval, $R_W$ change is predictable and varies with formation temperature. This interval is marked by water saturated intervals in the Rollins Sandstone at about 5,200 to 5,300 ft and an unnamed sand in the fluvial interval at about 4,400 to 4,500 ft. These water saturated intervals have an $R_W$ which is similar to the $R_W$ interpreted for the gas sandstones. Above 4,400 ft, $R_W$ is highly variable. The section is marked by three tongues of fresh water. The fresh water is interpreted to be of meteoric origin where incursion is from Mesaverde outcrops to the west or south of this well. Distances for subsurface movement of meteoric waters in this area are probably about 10 to 18 miles if they are stratigraphically confined. Between tongues of fresh water, there is some entrapment of gas; however, water saturations are high. The interval 3,800 to 4,400 ft probably represents an interval of mixing of connate and meteoric water.

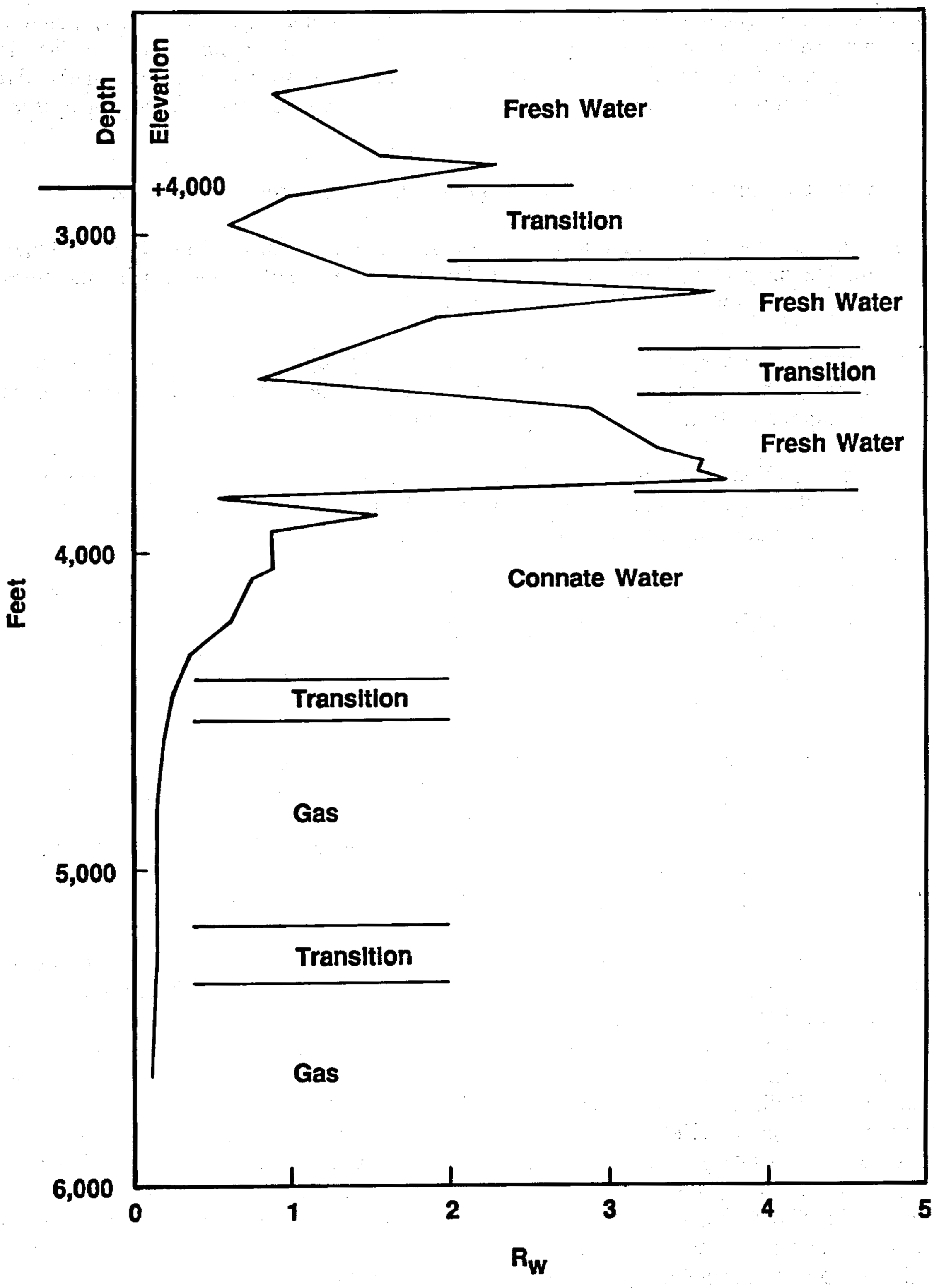



*Figure 16 $R_w$ Interpretation for the FUELCO Colorado Land No. 3 Well, Sec. 7, T10S, R94W*

$R_W$ profiles, such as Figure 16, are combined into two structural cross sections presented in Plate 10. The upper cross section, D-D', traverses from the western margin of the Plateau Field from south to north through the Shire Gulch, Debeque and Logan Wash Fields. The lower cross section, E-E', traverses from west to east across Plateau Field. Although the Plateau Field produces from the Cozzette and Corcoran Sands, the sections are illustrative of the gas and water distribution in the Mesaverde interval, including fluvial sands. They also provide some data for the interpretation of the mechanisms for gas entrapment.

At Well No. 142 (Davis 1-24) in the Plateau Field, the entire fluvial and paludal intervals, as well as the Rollins Sandstone, are water saturated. There is a distinct water resistivity break at about 1,900 ft which is indicative of water having two different origins. The water of the lower interval is interpreted to be of connate origin whereas the upper interval is interpreted to be of meteoric origin, i.e., surface water that has moved downdip from outcrop. Referring to section D-D', Well Nos. 142 and 24 (Horseshoe Canyon No. 2) are on strike and show the same general water pattern. The movement of meteoric water is interpreted to be from the southwest to northeast. Looking at Well No. 25 (Federal 30-3) and No. 138 (Cowperthwaite 2-6), the meteoric water is seen to continue downdip, again moving from the southwest. Going downdip to the north and east, the meteoric water begins to interfinger with connate water, and the meteoric water is confined to progressively higher stratigraphic intervals. Also going downdip to the north and east, gas is trapped in progressively higher stratigraphic intervals. This progression continues downdip eastward from Well No. 138 to the Grand Valley and Rulison Fields.

Cross section E-E' also shows that the meteoric water incursion begins to finger out going downdip to the east across the Plateau Field. This section also shows that going downdip, the meteoric water is confined to and gas is trapped in progressively higher stratigraphic intervals.

An understanding of the physical mechanism for gas entrapment has not been a major objective of this study. The $R_W$ profiles presented in Plate 10 are of a regional scale for wells many miles apart. Their primary purpose was to define the gas interval. Nevertheless, several observations have been made from this study:

- Intervals that have meteoric water incursion do not trap gas. As the meteoric water zone begins to finger out downdip, gas may be trapped between the fingers.

- Intervals of meteoric water incursion generally have higher porosity (typically greater than 15 percent) and are presumably more permeable than stratigraphically equivalent downdip gas reservoirs.

- Along the updip margins of the basin, there is good potential for stratigraphically trapping gas in reservoirs immediately below the meteoric water zone. These reservoirs tend to have well defined gas/water contacts. The more normal case in downdip portions of the basin, such as in the Rulison Field, is that the top of the gas (irreducible water saturation) is generally about 500 ft below the meteoric water zone. The intervening interval is generally a transition between 100 percent water saturation and irreducible water saturation.

## 2.5 NATURAL FRACTURE CHARACTERISTICS

### 2.5.1 Introduction

The MWX studies have shown that the orientation of Mesaverde sandstone fractures with respect to the present stress field is a significant factor controlling production (Lorenz and others, 1986; Lorenz and Finley, 1989). Fracturing is probably more important to production than total sand thickness (Peterson, 1984).

This study of fracture orientations in the Piceance Basin Mesaverde Group is a regional synthesis from other studies. The approach was to combine what was learned in MWX fracture studies of well data and nearby outcrops, with regional data from other outcrop studies. Also included is a study of the distribution of larger, fluid conductive fractures as determined from log analysis of the 34 wells basin wide.

### 2.5.2 General Characteristics of Mesaverde Fractures

An understanding of the significance of fracture orientations throughout the Piceance Basin is difficult without understanding the three-dimensional geometry and interrelationships of different fracture sets. Characteristics of fractures in the Mesaverde Group at and near the MWX site have been studied in greatest detail by Clark (1983), Lorenz and others (1986), Verbeek and Grout (1984c), and Finley and Lorenz (1988). These studies have identified the following characteristics:

- Fractures are numerous and occur throughout the Mesaverde section.
- Both shear fractures (small faults) and extensional fractures (joints) are present. Most shear fractures are interpreted to be syndepositional and not important in reservoir production. Extension fractures and other shear fractures, all of which are mineralized, are believed to be open at depth.
- Fractures in sandstones are most common in the lower part of the fluvial interval and upper part of the coastal interval.
- Fractures in sandstones tend to terminate against lithologic discontinuities such as mudstone layers or against other fractures.
- A single, older extension fracture set (related fractures of similar orientation) is usually dominant, particularly at depth.
- The dominant set consists of sub-parallel, non-planar, fractures that have infrequent, low-angle intersections.
- In the subsurface at MWX, orthogonal connecting fractures to the dominant set are rare in fluvial and coastal lenticular sandstones; however, they may be more common but subordinate in marine sandstones. Orthogonal fracture sets in outcrop are well developed because they are produced by differential topographic stress relief and may be enhanced by weathering.

- Extension fractures at MWX strike predominately west-northwest.

- Fracture mineralization is variable and has been used to determine relative ages of fracture sets.

The USGS has carried out an extensive fracture analysis in outcrops of the central and northern parts of the Piceance Basin (Verbeek and Grout, 1983; Grout and Verbeek, 1983; Verbeek and Grout, 1984a, b). Their work demonstrated the presence of two distinct fracture systems related to depth of burial. The older and deeper Hogback system generally is present only in Mesaverde Group rocks and consists of two episodes of fracturing. The younger Piceance system, consisting of as many as five fracturing episodes, is generally present in the Wasatch Formation and not the Mesaverde Group. However, because the development of the different fracture systems was related to depth of burial, the narrow transition zone between the two systems cuts across formational boundaries. This means that fractures in Mesaverde Group rocks in an area that has been buried less deeply, such as those exposed in Debeque Canyon, are interpreted to be of the shallower Piceance system and not necessarily related to Hogback system fracturing at MWX and the Grand Hogback area.

### 2.5.3 Orientations of Fractures in the Mesaverde Group

Orientations of fractures within the Mesaverde Group have been measured at outcrops (primarily in sandstones and associated coals) on the peripheries of the Piceance Basin. These studies have been done by Murray (1967) along the Grand Hogback from Glenwood Springs north to Meeker, by Clark (1983) along the Grand Hogback at Rifle Gap near the MWX site, by Verbeek and Grout (1984c) along the Grand Hogback from Rifle Gap to Meeker, and by Lorenz and Smock (1985) along the Grand Hogback at Rifle Gap. In the southern part of the basin orientation information was compiled by Verbeek and Grout (1984c) and Grout and Verbeek (1985) in the DeBeque Canyon and Plateau Creek areas, and by Decker and Seccombe (1986) in coal outcrops along the southern margins of the basin. A fracture orientation study in the Mesaverde Group in the Uinta Basin by Knutson (1977) carries over into the western Piceance Basin both northwest of Grand Junction and northwest of Rangely. Plate 11 is a compilation of Mesaverde outcrop fracture orientations from these studies.

#### 2.5.3.1 Grand Hogback

Murray (1967) did an extensive analysis of fracture orientations along the Grand Hogback. He concluded that there are two approximately perpendicular fracture sets that predate the Grand Hogback tilting. By rotating the stratigraphic layering dip back to horizontal, Murray found that fracture orientations were consistent even in sections of the hogback with differing trends. The more strongly developed fractures (dominant) trend generally west-northwest, and the more weakly developed fracture set (subordinate) trends north-northwest. Murray did not observe any conclusive evidence to indicate which joint direction developed first.

Fractures along the Grand Hogback have also been examined by Verbeek and Grout (1984a) who agreed that there are two pre-tilting fracture sets belonging to the older Hogback system of fractures. From observations of cross-cutting relationships and the nature of mineral fillings, they determined that the west-northwest striking set is the older. It also contains the most abundant fractures. Fractures of the north-northeast-striking set are subordinate in number and degree of development. Pre-tilting strike orientations of both sets of the Hogback system along the Grand Hogback from Verbeek and Grout (1984c) are shown in Plate 11. The plate demonstrates that at any particular location the two sets are approximately perpendicular. Significant variations in the strike of both sets along the Grand Hogback could be the result of rotations in strike of sedimentary layering during uplift (which were not corrected as were the rotations for correction of dip to horizontal). At Rifle Gap, a 15° clockwise rotation of both sets with depth in stratigraphic section (more than 6,000 ft of section) was also noted.

Fracturing in outcrop at Rifle Gap in the Grand Hogback has also been examined by Clark (1983) and by Lorenz and Smock (1985), both of which report the dominant fracture set trends west-northwest but also indicate the presence of two other fracture sets not perpendicular to the dominant set. Lorenz and Smock reasoned that all but the dominant set were produced during monoclinal uplift and enhanced by erosion and weathering. They concluded that only the dominant set should be present in deeper, unexposed Mesaverde Group in the basin.

#### 2.5.3.2 Debeque Canyon - Plateau Creek Area

Fracture orientations within the gently dipping Mesaverde Group sandstones at Debeque Canyon and Plateau Creek were measured by Verbeek and Grout (1984a) and Grout and Verbeek (1985). They found similarities with the fracturing in the Grand Hogback:

- Both areas are dominated by a relatively simple fracture pattern comprising two sets nearly at right angle to each other and to bedding.

- Joints of the older set generally are long, nearly planar, and calcite-filled.

- Joints of the younger set are more irregular, shorter and less commonly mineralized.

However, a major difference with the Grand Hogback is that the more pronounced and older fracture set trends northeast instead of west-northwest with the lesser set nearly orthogonal and trending northwest. Verbeek and Grout suggested that the Debeque Canyon-Plateau Creek area fracture sets may not be correlative with the Hogback system but may be similarly oriented sets of the Piceance system imposed on the older rocks because of their shallow depth of burial.

Lorenz and Smock (1985) also examined the nature of fractures in a Mesaverde Group sandstone in Coal Canyon of the Cameo area. They agreed with Verbeek and Grout that the primary fracture set trends northeast (N60°E to N70°E). The outcrop examined by Lorenz and Smock was selected in a stream bed where the local effect of topographic slope weathering might be minimal. A very important observation is that secondary cross fractures were not orthogonal to the primary set but oblique and were interpreted to be parallel to the axis of a local anticline.

Coal face cleat orientations were determined down hole in the Deep Coal Seam Project at the Red Mountain Site, sponsored by the Gas Research Institute (Decker and Seccombe, 1986). Face cleat strikes range from N69°E to N87°E and are near vertical.

### 2.5.3.3 Southeastern Piceance Basin

The southeastern Piceance Basin has little published fracture information. It contains areas of high flexure, such as the northwest-trending Divide Creek anticline, as well as bifurcations of the present basin synclinal axis. In coal outcrops, east-northeast-trending face cleats and nearly orthogonal butt cleats have been mapped along the eastern margin of the basin (Decker and Seccombe, 1986). This suggests that the Piceance system is also present in the southeastern margin of the basin on trend with those of the Debeque area.

### 2.5.3.4 Southern Douglas Creek Arch

Fracture orientations were examined in the Mesaverde Group sandstones by Knutson (1977) in the Salt Creek and East Salt Creek area of the Grand Valley along the Douglas Creek Arch (generally on strike with the Debeque area). He interpreted systematic fracturing in these moderately inclined layers to be more complex than those described in the Grand Hogback. Fractures are interpreted to occur in multiple conjugate sets consisting of the major and less prominent members of the major set and principal and less prominent members of the secondary conjugate set.

Relative ages of the various fracture orientations were not determined so correlation of fractures from Knutson's study with either the Hogback or Piceance systems of Verbeek and Grout is not apparent. At each location, however, a "master joint set" is most prominent and consistently oriented toward north-west to north-northwest (Plate 11). Less prominent fractures of the major set trend generally east-northeast at an oblique angle to the most prominent fractures. The northwest trend of the dominant fractures is suggestive of the Hogback system but that could not be ascertained in this compilation.

### 2.5.3.5 Rangely Anticline

Knutson (1977) also measured fracture orientations in Mesaverde Group sandstones along the southwestern limb of the Rangely anticline. Fracture patterns similar to those of the southern Douglas Creek Arch area were found. The most prominent systematic fracture set, "master joint set," trends northwest parallel to the layering strike. The less prominent major fracture set is generally orthogonal, trending northeast. This configuration is similar to that described above at Rifle Gap in the Grand Hogback.

## 2.5.4 Discussion of Fracture Orientation

The above compilation has shown that rocks which have had similar history of deeper burial near the synclinal basin axis (at MWX and the Grand Hogback) have similar fracture history and trends. The Hogback system fractures (Plate 11) more closely parallel the Piceance Basin synclinal axis than the trend of local tectonic uplifts such as the White River Uplift. Clark (1983), Verbeek and Grout (1984b) and Lorenz and others (1986) have suggested that they are related to uplift of more deeply buried rocks along the basin synclinal axis.

Fractures in the Rangely anticline area closely parallel the dominant northwest trend with approximately orthogonal subordinate fractures. The relative age of these fractures compared with those of the Grand Hogback has not been determined. The parallel trends and their structural position on the flanks of the Rangely anticline look remarkably similar to the fracture pattern at Rifle Gap. However, a major difference is that the Rangely area on the Douglas Creek Arch has never been deeply buried (Johnson, 1987).

Knutson's work carried the same fracture trends at Rangely farther west into the northern flanks of the Uinta Basin where the most prominent fractures parallel the Uinta Basin axis. The Rangely fractures may be a separate Uinta system that is not necessarily the same relative age as the Hogback system. Another possibility is that the Rangely fractures are part of the Hogback system and that proximity to the basin axis was a controlling factor for Hogback system more than the depth of burial. A third possibility is that the dominant northwest trending fractures at Rangely belong to younger fracture sets of the Piceance system (the $F_{2c}$ and orthogonal $F_4$ fractures of Verbeek and Grout (1984c) which would be similarly oriented at that location).

Verbeek and Grout (1984a, b) and Grout and Verbeek (1985) have interpreted the fracture system at Debeque Canyon and in the Plateau Creek area to be correlative with the Piceance system because of their relative depth of burial and because their orientations are dissimilar to those along the Grand Hogback. Fractures in the southern Douglas Creek Arch area should be younger fractures, after the reasoning presented by Verbeek and Grout (1984b) for the Debeque area. It has a similar shallow burial history. Correlation with other fracture trends remains enigmatic because relative ages of fracture sets has not been determined. The presence of several fracture sets might be representative of overlap between the Piceance and Hogback systems. These fractures trend into the southeastern Uinta Basin with similar orientations of the dominant fractures trending northwest. More work needs to be done to correlate the Douglas Creek Arch area fractures with either the Piceance system, the Hogback system or a distinct Uinta system.

It has been postulated that in areas of the Piceance Basin that have not experienced tectonic deformation, subsurface fractures should be predominantly short, poorly interconnected, and unidirectional with very little cross fracturing or "orthogonal" fractures (Lorenz and Smock, 1985; Lorenz and others, 1986). This idea has been supported with the findings in the MWX wells where the dominant extension fractures were unidirectional and very few high angle orthogonal cross fractures were found. Lorenz and Smock argue that the numerous orthogonal fractures in outcrops may be the product of very small and subordinate fractures being enhanced or reactivated by topographic stresses during surface erosion. This would indicate that fractures of the Hogback system would be unidirectional at depth and trend west-northwest to northwest. Lorenz and Smock also found similar characteristics in the younger fractures at Coal Canyon near Cameo (Plate 11) which suggest that even younger fracturing is also essentially unidirectional in the subsurface.

### 2.5.5 Mesaverde Fracture Orientation Domains

The above discussions have demonstrated that sandstones of the Mesaverde Group at any particular location may have been fractured by either the Piceance system or the Hogback system depending on the depth of burial. Areal domains of interpreted dominant, unidirectional fracture orientations have been delineated and are shown in Figure 17.

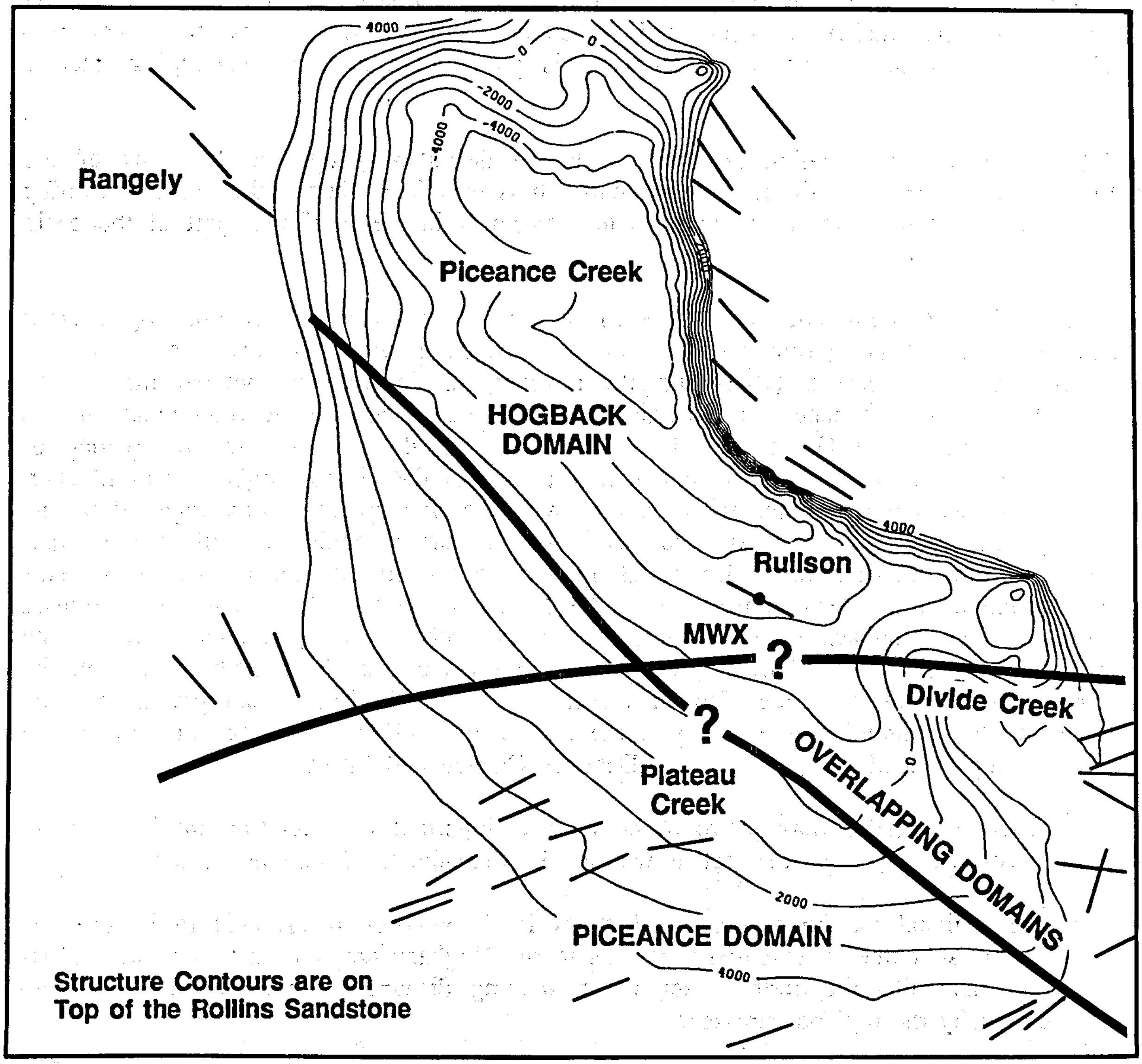



*Figure 17 Summary of Mesaverde Regional Fracture Orientations and Domains*

The area containing the northwest-southeast trending fractures of the Hogback system contains those parts of the basin that were the most deeply buried near and parallel to the basin axis. This includes the Rulison area, the White River Uplift and the Piceance Creek area. In the southwestern part of the basin, the Mesaverde contains predominantly the east-northeast trending Piceance system fractures in shallower-buried rocks. In this fracture orientation domain, coal face cleats also trend east-northeast parallel to the regional fractures. The Plateau Field lies within the Piceance fracture domain.

Fracture information in the southeastern Piceance Basin remains enigmatic. Fracture orientations parallel to those of the Piceance system are present in part of the area. However, the gross fluvial interval isopach in Plate 2 shows that the Divide Creek anticline area actually contains one of the thicker (deeper) fluvial sections. The Divide Creek area, therefore, probably contains Hogback system fractures and is possibly an area of overlapping fracture domains.

Too little subsurface information is available to be definitive about the locations of the transition or overlap between the fracture systems. It is not clear whether the domains overlap in area or vertical extent, nor is it clear whether fractures in the northwest part of the basin belong to either domain.

From the work of Lorenz and others (1986), it can be deduced that natural, open cross fractures to the dominant unidirectional set in the subsurface would be advantageous to gas production. Lorenz and Smock (1985) suggest, however, that in areas without tectonic flexure, fractures of both the Piceance and Hogback systems are probably unidirectional in the subsurface. Verbeek and Grout (1984a) have shown that there is an area of overlap or transition between the two systems documented just west of the Grand Hogback near Meeker. There, both systems are interpreted to be present with Piceance fractures superimposed on the Hogback system. Gas flow between fractures in the subsurface could be facilitated in areas where both systems are superimposed, particularly if the dominant direction on the two systems intersect at high angles. Because fractures in the Mesaverde at the MWX site are interpreted to be of the older Hogback system, and those in the Debeque Canyon area to be of the Piceance system, Verbeek and Grout (1984b) have postulated that the transition between the two would underlie the Debeque Canyon outcrops. It could also be interpreted that the transition, possibly containing intersecting dominant fractures of both systems, lies within the Mesaverde Group at depth laterally between Debeque Canyon and MWX.

The local fracture domains may prove to be a very important consideration in development planning but considerably more research is warranted. Consider the following questions:

- The regional maximum horizontal stress field has been determined to be oriented northwest-southeast, essentially parallel to the Hogback domain fracture trends. Does this mean that the northeast-southwest trending Piceance domain fractures are held closed by the regional stresses?

- Should a horizontal well drilled in the Piceance domain be oriented toward the north-northwest?

- What is the orientation of Mesaverde fractures at depth in the Grand Valley area? Douglas Creek Arch? Ragged Mountain area?

### 2.5.6 Fracture Distributions from Log Analysis

NATUFRAC is a computed log which is designed to detect major open natural fractures through recognition of log data anomalies. Since the log anomalies are sometimes subtle, as in the case of small aperture fractures, the confidence level for these interpretations is not always high.

NATUFRAC log analysis was performed on 27 wells. Each of the computed NATUFRAC logs was studied over the gas interval to identify the natural fractures. To reduce the uncertainty, only the more positive indications were counted as natural fractures. The total number of fractures per 1,000 ft of interval were calculated for each well. The results of this interpretation are shown on the structure base map in Figure 18.

The map shows the highest frequency of natural fractures occurred in the Divide Creek area. The Rulison Field has a moderate fracture frequency, and the updip basin margins to the west and southwest, including the Plateau Field, have a low fracture frequency. The map for the northern part of the basin has a lower confidence level owing to poorer well control.

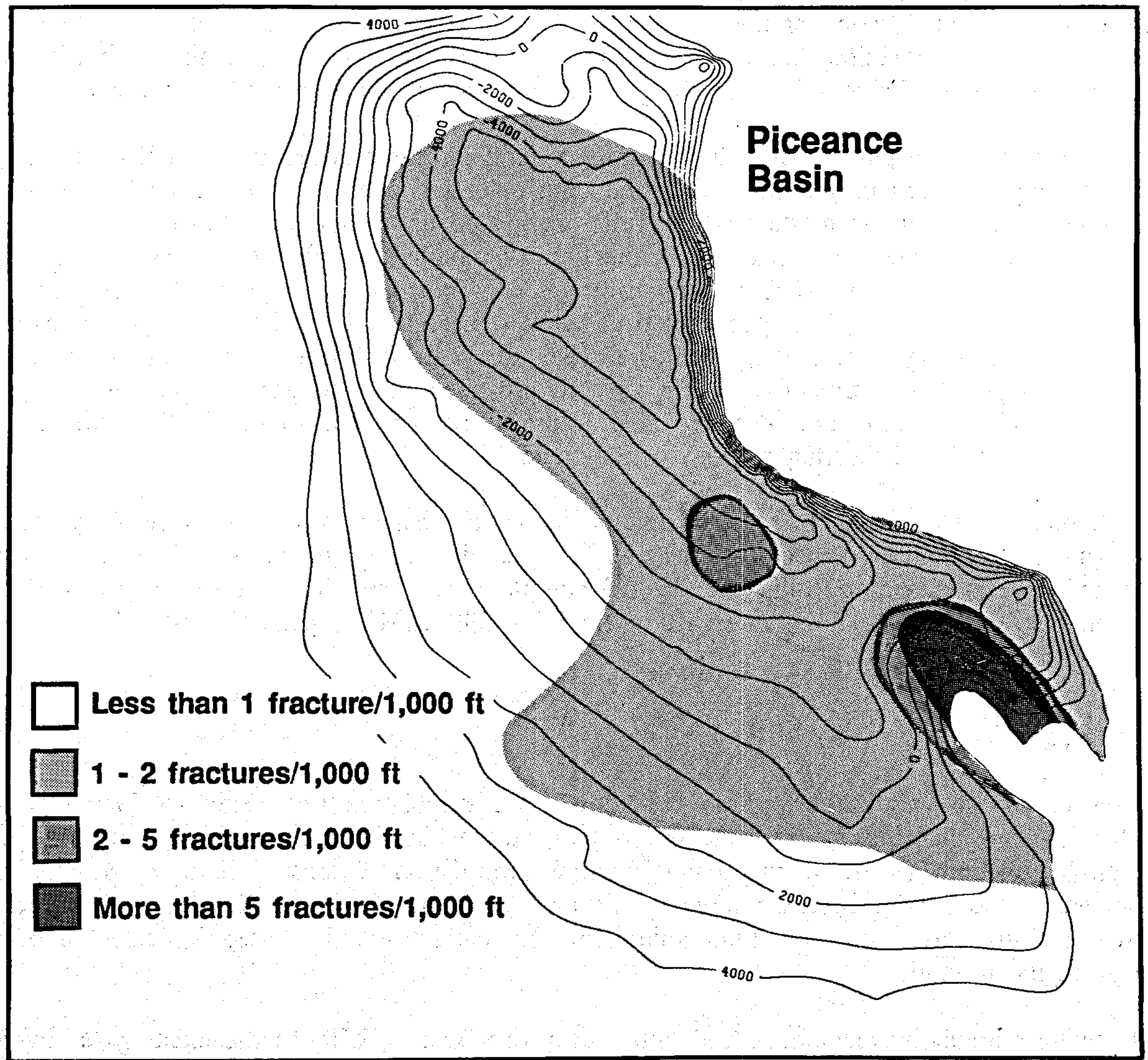



*Figure 18 Structure Base Map (Top of Rollins) Showing the Distribution of Fracture Density Interpreted from NATUFRAC Log Analysis*

# 3.0 Basin-Wide Production Characteristics

## 3.1 ULTIMATE GAS RECOVERY PROJECTIONS

Well completion reports and production information were examined for 243 active Mesaverde gas wells in the Piceance Basin to determine the Mesaverde producing interval, well completion intervals, stimulation type, stimulation size, first 12 months' cumulative gas production and the individual well production history. The individual well production histories were used to project ultimate gas recovery, using decline curve analysis techniques, to an abandonment rate of 30 MCFD per well for each active Mesaverde gas well.

Appendix 2 contains several tables depicting Mesaverde gas activity in the Piceance Basin. Table A2-1 presents a listing of the 243 active Mesaverde gas producing wells in the Piceance Basin, along with production data and the projected ultimate gas recovery to the 30 MCFD per well economic limit. Table A2-2 lists the permanently abandoned Mesaverde gas wells.

The projected ultimate gas recovery is generally a good indicator of reservoir quality. However, poor operating practices may prohibit the producing potential to be fully realized. For instance, gas producing capability is masked when wells are loaded up with liquids causing the wells to produce gas at low rates. For this reason, the first 12 months' cumulative gas recovery is used as a supplemental indicator of reservoir performance. This data tends to be less sensitive to poor production practices. The poor practices tend to be masked by the flush gas production immediately following stimulation, when gas velocities are sufficient to lift liquids from the wellbore. Mapping and critically comparing both projected ultimate gas recovery and first 12 months' cumulative production has provided a useful set of data for evaluating stimulation effectiveness and for delineating gas production trends.

Table 2 presents a summary of this information indicating that of the 243 Mesaverde gas wells investigated, 34 are fluvial completions, 40 are paludal completions, and 169 are marine (Corcoran, Cozzette, and/or Rollins Sandstone) completions. The average ultimate gas recovery per well for each of the three intervals is fluvial - 399 MMCF, paludal - 496 MMCF and marine - 454 MMCF.

## 3.2 STIMULATIONS EVALUATION

The results of the various perforation breakdown and stimulation treatments conducted at the MWX indicated that the natural fracture system present in the Mesaverde Group was very susceptible to damage by conventional fracture stimulation liquids. Further, stimulations conducted in the fluvial Mesaverde using nitrogen to break down perforations and nitrogen-based foam to carry proppant (and minimize stimulation liquid phase) indicated minimal damage to the formation.

To compare stimulation techniques with ultimate gas recovery (UGR) in the existing Mesaverde gas producing areas and to determine the effect of stimulation fluid liquid phase on ultimate gas recovery, all well completions were grouped into one of the following five stimulation fluid categories: (1) AGW, carbon dioxide or nitrogen-assisted gelled or crosslinked gelled water

*Table 2 Piceance Basin Mesaverde Group Completion Statistics*

| Formation | No. of Wells | Average UGR, MMCF |
|---|---|---|
| Fluvial | 34 | 399 |
| Paludal | 40 | 496 |
| Marine | 169 | 454 |
| **TOTAL** | **243** | **453** |

carrying proppant; (2) N2F, nitrogen-based foams carrying proppant; (3) NON, no stimulation; (4) OTHER, small sand-oil, sand-gelled condensate or sand-gelled weak acid stimulations; and (5) UGW, unassisted gelled or crosslinked gelled water carrying proppant.

Table 3 presents the stimulation statistics for the 243 Mesaverde gas wells located in 22 separate fields in the basin. Figure 1 showed the location of these fields areally in the basin in reference to the MWX site.

The highest average ultimate gas recovery of 1,662 MMCF per well was from 29 unstimulated wells. This high average ultimate gas recovery reflects encountering open natural fractures during drilling, primarily at the Divide Creek Field but also to a lesser extent in the Rulison and Plateau Fields.

The second highest ultimate gas recovery of 574 MMCF per well was from 16 wells having small perforation breakdown acid stimulations or small sand-oil hydraulic fracture treatments. These wells are located primarily in the Divide Creek and Rulison Fields in areas known to have open natural fractures.

The third highest average ultimate gas recovery of 326 MMCF per well was from 77 wells having major assisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments.

The fourth highest average ultimate gas recovery of 276 MMCF per well was from 83 wells having major gelled water or crosslinked gelled water hydraulic fracture treatments with no entrained or dissolved gas phase in the treatment fluid. The 50 MMCF per well of incremental gas production for wells utilizing nitrogen or carbon dioxide in the stimulation fluid reflects the assistance given to treating liquids recovery, following hydraulic fracture stimulation, by the entrained or dissolved gas phase in the stimulation fluid. It should further be realized that the

*Table 3 Piceance Basin Mesaverde Group Stimulation Statistics (243 Wells)*

| Stimulation Type | No. of Wells | Average UGR, MMCF | % Wells to Achieve UGR |
|---|---|---|---|
| AGW | 77 | 326 | 27 |
| N2F | 38 | 158 | 29 |
| NON | 29 | 1,622 | 17 |
| Other | 16 | 574 | 25 |
| UGW | 83 | 276 | 37 |

vast majority of these wells, whether or not they used a gas phase to assist with fracture treatment liquids recovery, would not have produced gas in sufficient quantities to warrant pipeline connection without fracture stimulation treatment.

The nitrogen-based foam stimulations averaged 158 MMCF per well from 38 wells. This is the lowest per well recovery for any of the stimulation techniques evaluated in the active Piceance Basin Mesaverde gas wells. However, 27 of the 38 wells stimulated with nitrogen-based foam are concentrated in the marine interval in areas of Plateau, Shire Gulch and Buzzard Fields that showed similar response to assisted gelled water stimulations. Two wells located in Brush Creek Field and 6 wells located in Shire Gulch and Plateau Fields have shown excellent response to relatively small nitrogen-based foam hydraulic fracture treatments. Consequently, the poor response to nitrogen-based foam hydraulic fracture treatments in some areas may reflect a poorly developed natural fracture system.

## 3.3 GAS WELL DEWATERING

Results from MWX indicated gas production from naturally fractured reservoirs is restricted by liquids remaining in both the fracture system and the wellbore. These liquids can be the result of well stimulation operations or indigenous liquids produced in conjunction with gas production operations. Sweeping produced liquids from the wellbore in tight gas sand wells minimizes bottomhole pressure, allows the natural fracture system to be produced with maximum differential pressure toward the wellbore and the well to produce at maximum capacity into the gas gathering system.

Evidence of liquid loading in a gas well is indicated by erratic and intermittent gas flow rates. This "paint brushing" by the differential pen on the orifice meter flow chart is caused by gas rates insufficient to move slugs of liquid up the tubing and out of the well. Plunger lift equipment has proved successful in minimizing liquid buildup and maximizing gas production from low rate Mesaverde gas wells in the Piceance Basin.

One area having successful applications of plunger lift is the East Divide Creek area in the Cozzette and Rollins sandstones of the marine interval. The Rifle Boulton 1 and Federal 26-3 indicated difficulty staying on production due to liquid loading. Decline curves of these wells are shown in Figures 19 and 20, respectively. Plunger lift equipment was installed to continuously remove wellbore liquids in December 1981 and May 1983, respectively. Gas rates were brought back up to the previously established decline rates, and commercial gas producing rates were maintained. During 1982, following plunger lift installation, the Rifle Boulton 1 averaged 59 MCFD and 9 BWPD. During 1983, following plunger lift installation, the Federal 26-3 well averaged 115 MCFD and 3.9 BWPD. A third well in the immediate area was put on plunger lift with similar results. It is CER's interpretation that lifting the liquids allowed the natural fracture system to cleanup.

A second area having outstanding success with plunger lift is in the Plateau Field in the Corcoran, Cozzette and Rollins Sandstones in the marine interval. The Kathlyn Young 4-15, Figure 21, and the Walck 23-2, Figure 22, had reached uneconomic gas rates of approximately 23 MCFD and 29 MCFD, respectively, prior to installation of plunger lift equipment. Following installation of plunger lift in July 1984, the Kathlyn Young 4-15 steadily cleaned up with continuous liquid removal from the wellbore and peaked in July 1985 at approximately 95 MCFD and 7.4 BWPD. Following installation of plunger lift in the Walck 23-2 during November 1984, the formation steadily cleaned up with continuous liquids removal from the wellbore; gas production peaked during October 1985 at approximately 140 MCFD and 3 BWPD. Both wells subsequently went on a shallow decline and are maintaining commercial gas producing rates. Plunger lifts were installed on seven additional wells in the area by the operator with long term stabilization or improvement in production rate observed in all seven wells.

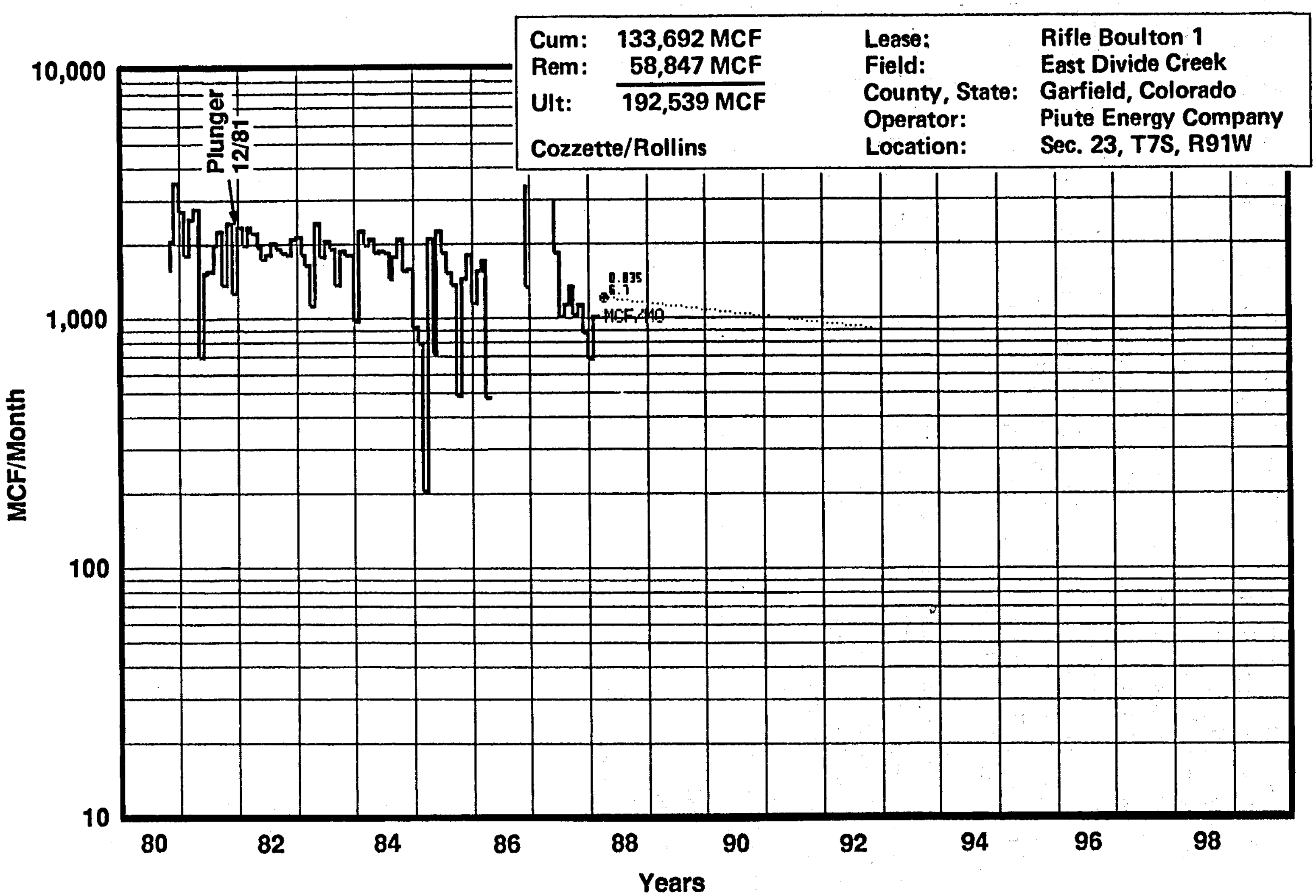



*Figure 19 Production Decline Curve Demonstrating a Plunger Lift Application in the East Divide Creek Field (Dotted line is projected decline)*

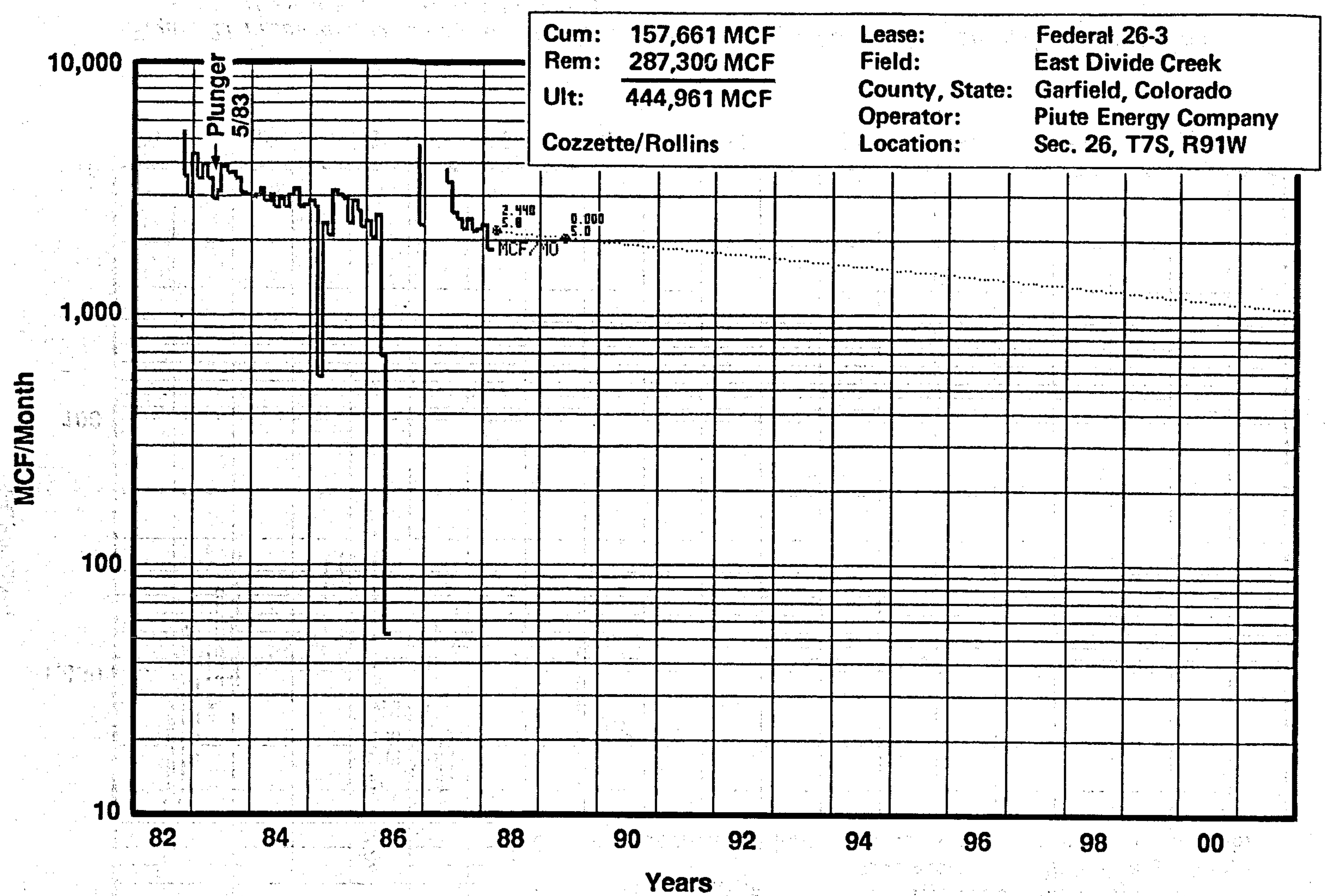



*Figure 20 Production Decline Curve Demonstrating a Plunger Lift Application in the East Divide Creek Field (Dotted line is projected decline)*

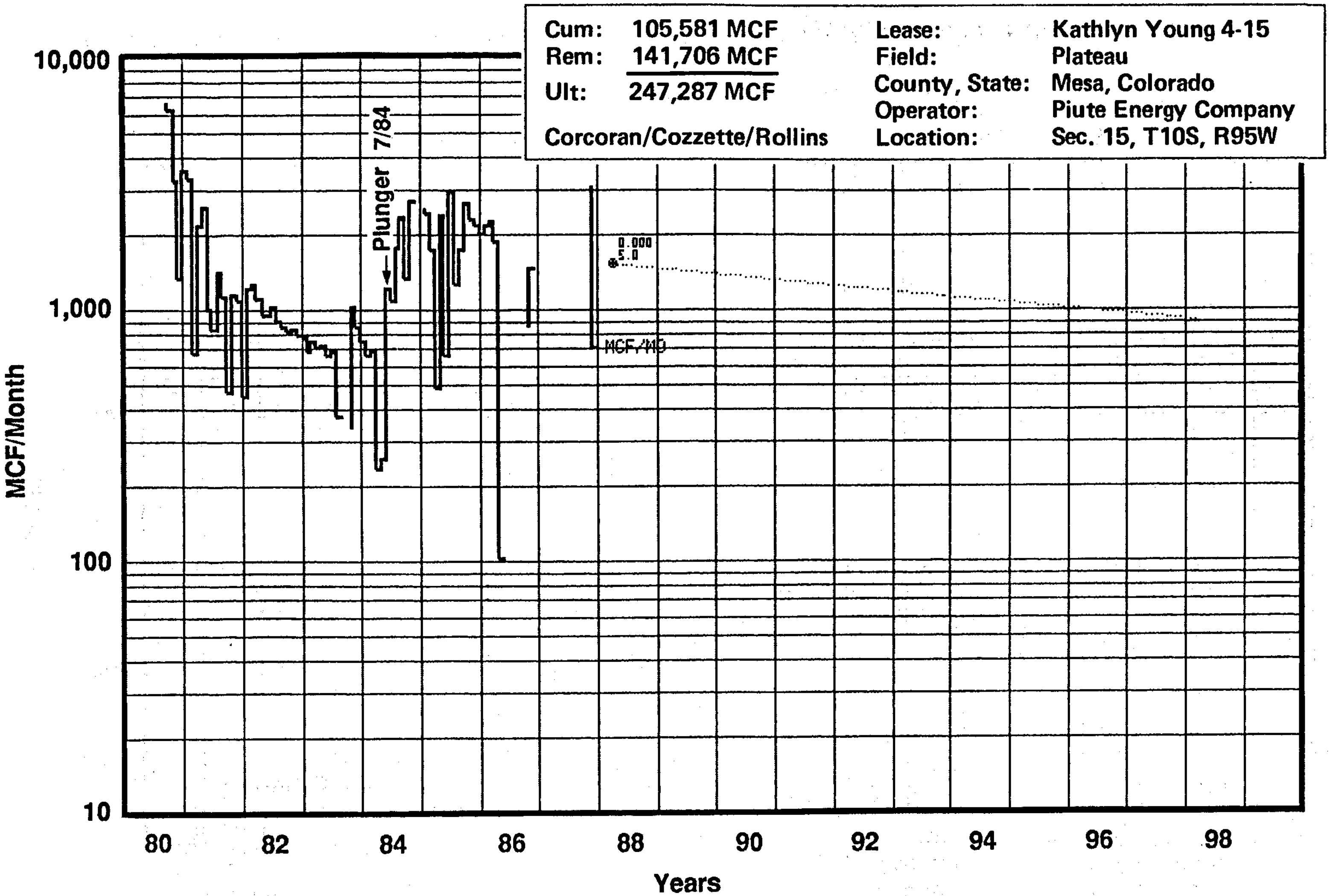



*Figure 21 Production Decline Curve Demonstrating a Plunger Lift Application in the Plateau Field (Dotted line is projected decline)*

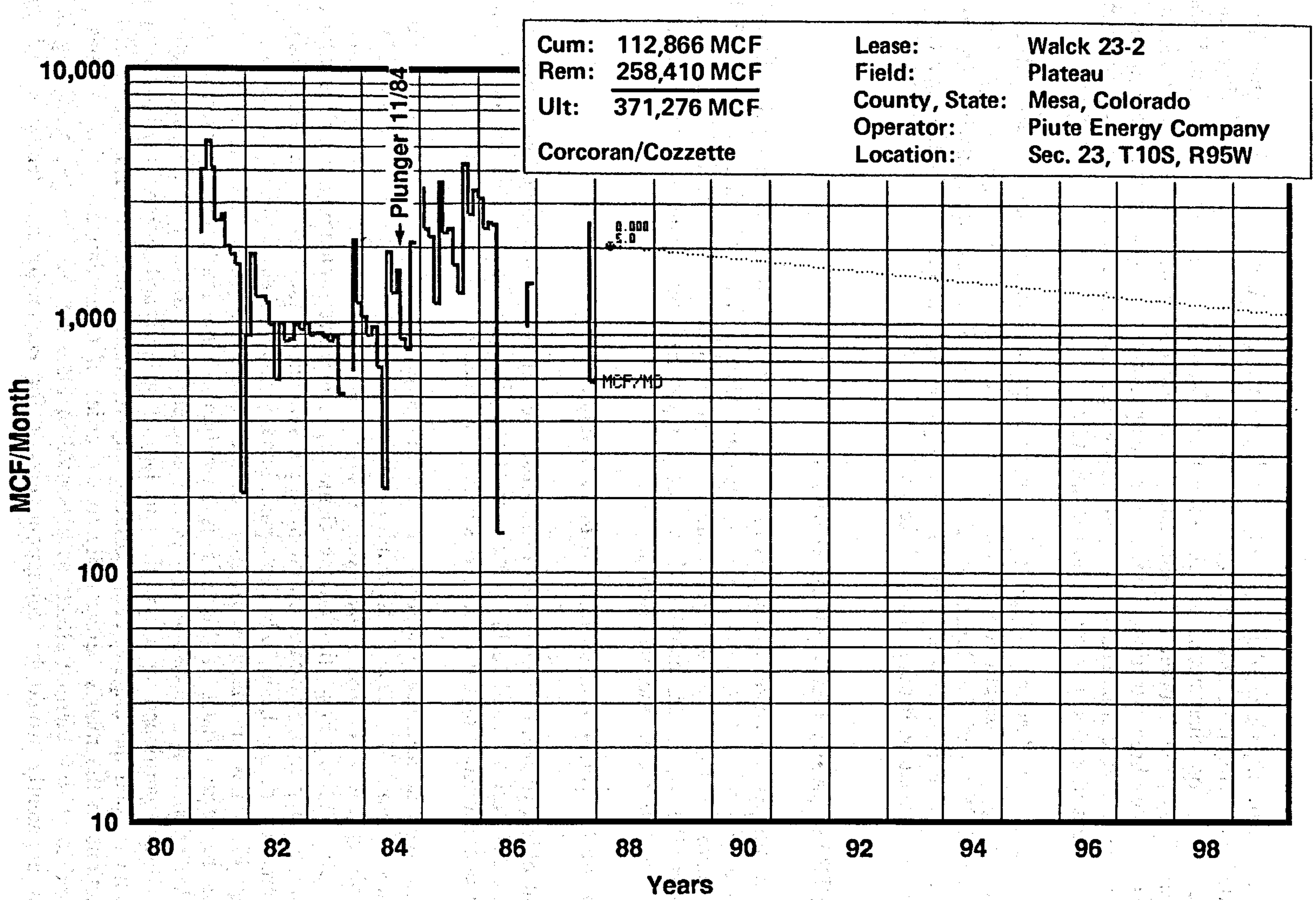



*Figure 22 Production Decline Curve Demonstrating a Plunger Lift Application in the Plateau Field (Dotted line is projected decline)*

# 4.0 Partitioned Areas

As a result of evaluating all available geologic and production information, the Piceance Basin was subdivided, or partitioned, into three discrete Mesaverde gas producing areas having similar geologic and production characteristics. As shown in Figure 23, these three partitioned areas are (1) Central Basin, (2) Southeast Uplift, and (3) Southwest Flank. Areas in the Piceance Basin outside of the three partitioned areas were judged to have insufficient data to define geologic and production characteristics. Entire townships are left undrilled in this undefined area and where control exists, gas production is sporadic.

The sections that follow describe the geologic and production characteristics of each partitioned area and give a general description of the undefined area. The geologic and production characteristics at MWX and the Rulison Field in the Central Basin are extrapolated outward to the Southeast Uplift and Southwest Flank so the significance of the MWX findings can be better defined in context with other parts of the basin.

## 4.1 CENTRAL BASIN PARTITIONED AREA

The Central Basin partitioned area occupies the central basin trough and includes the following fields: Rulison, Grand Valley, Mamm Creek, Buzzard Creek, Sheep Creek and Vega. Table A2-3 in Appendix 2 lists the 49 wells within this partitioned area of which 17 are fluvial Mesaverde completions, 22 are paludal Mesaverde completions and 10 are marine completions in the Corcoran and/or Cozzette Sandstones.

### 4.1.1 Geologic Characteristics as Related to Production

The principal objective of this study is to extrapolate the geologic and production characteristics at MWX and the Rulison Field to the remainder of the Piceance Basin. This section discusses the geologic characteristics of the Central Basin as they relate to gas production.

The dominant regional structural feature of the Central Basin area is the southern bifurcation of the basin axis (Figure 4). The axial trend is well defined to the southeast in the Buzzard Creek and Sheep Creek Fields. The axial trend is less well defined in the Rulison Field (Figure 5). The Rulison Field lies on the flanks of a northwest plunging anticline which is flanked by an accompanying northwestward plunging syncline in the west (Peterson, 1984). The northern bifurcation of the basin axis lies approximately eight miles northeast of MWX. The Grand Valley Field lies on the western flank of the southern basin axis. The Mamm Creek Field lies on the eastern flank of this axis, is on a flank of the northwestern extension of the Divide Creek Anticline, and lies southwest of the northern basin axis. The unifying features of the Central Basin partitioned area are the similarities in gas and water distribution in the Mesaverde interval and the original deep burial of the Mesaverde interval. The deep burial has caused reductions in the matrix permeability to the order of micro-darcies. The area has also been subjected to similar thermal effects as presented in Plate No. 3. The gas producing fields in this area apparently would be contiguous except for economic considerations. Rugged

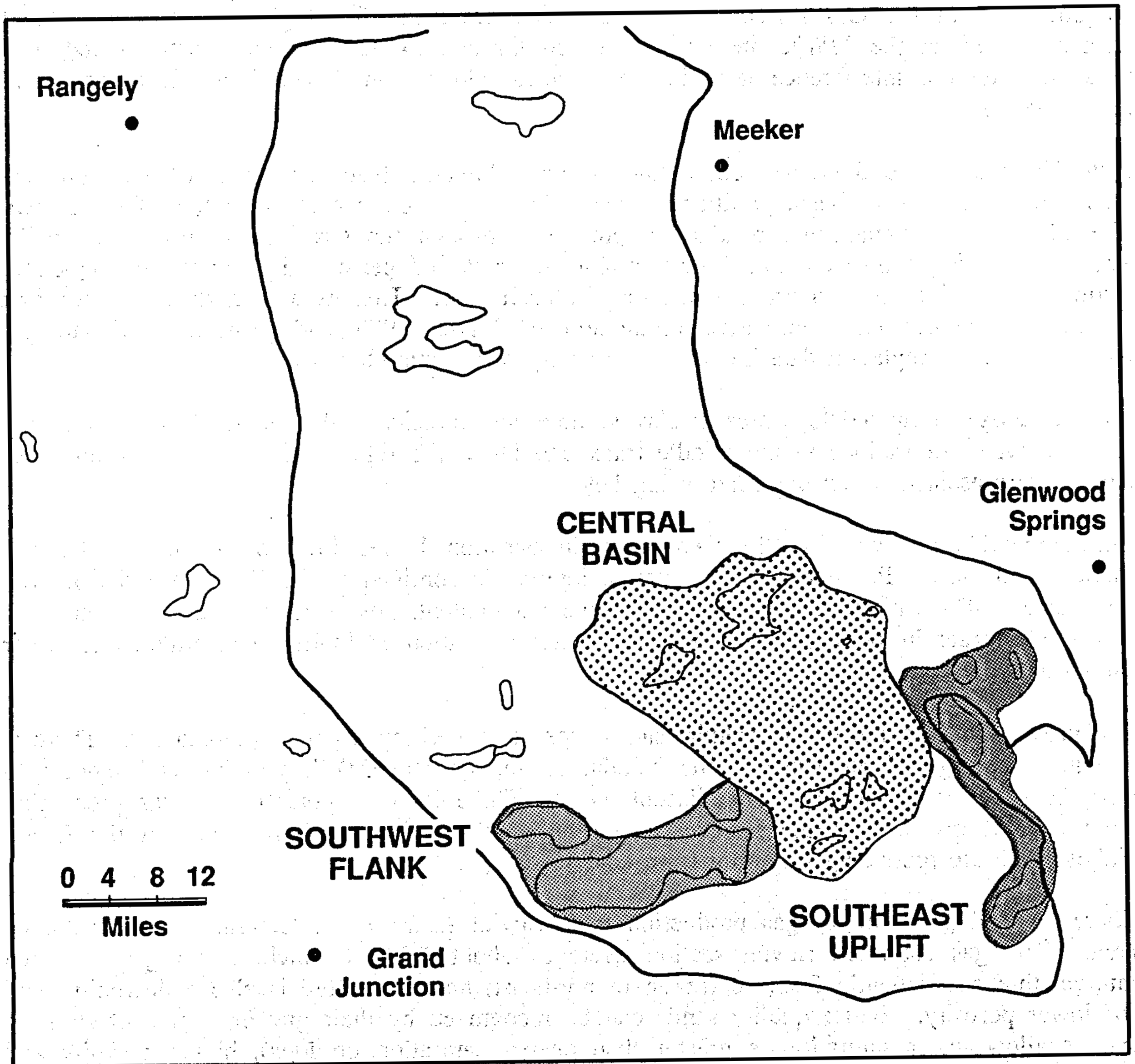



*Figure 23 Map Showing the Three Selected Partitioned Areas: Central Basin, Southeast Uplift and Southwest Flank*

topography with associated increased drilling depth appears to be the most important economic consideration which separates the fields.

Natural fractures are an important gas production mechanism in the Central Basin. Natural fractures have been observed in core taken at MWX in all Mesaverde intervals and were also described in core from the Barrett Energy Grand Valley No. 2. This core was taken in conjunction with the Gas Research Institute. The presence of a highly anisotropic, natural fracture system at the MWX site was confirmed through extensive, highly instrumented well tests and pressure interference tests in the marine, paludal and fluvial intervals (Lorenz and others, 1986).

Plate 12 is a structural cross section that traverses downdip from southwest (A) to northeast (A') across the Central Basin partitioned area. The cross section centers on the MWX-1 well. The TITEGAS computed log results are presented through the gas interval for seven wells. The cross section shows correlated stratigraphic intervals and perforated intervals. Completion, testing and production data are summarized for each well. The production data includes first 12 months' production, cumulative production to March 1988 and projected ultimate gas recovery. The completion data includes a summary of the stimulation data.

The TITEGAS computed logs present clay volume and porosity in the left track, near zone and far zone water saturations in the middle track and kh in the right track. The scales for these curves are presented on an explanatory log key.

The producible reservoirs in the Central Basin partitioned area include fluvial, paludal and marine sandstones. Production in the marine interval is confined to the Cozzette and Corcoran Sandstones. The Rollins Sandstone shows some gas content; however, the blanket character of this sand results in poor trapping, and the water saturation is higher than irreducible water saturation.

The production potential of the paludal sandstones at MWX appears to be anomalous. There is a high percentage of sandstone in the paludal section and the MWX paludal sands appear to have better reservoir quality than adjacent wells. There is some potential for gas production from coal seams in both the Rulison and Grand Valley Fields. Some wells in the Grand Valley Field are producing primarily from coal seams.

There is good potential for gas production from fluvial sands in the Central Basin partitioned area. The gas saturated fluvial section averages about 1,500 ft thick. The gas saturated interval thickens downdip from southwest to northeast; however, there is also a downdip trend for lower porosity. Better quality sands can be recognized by their greater degree of flushing (i.e., shallow water saturation is greater than deeper saturation on logs), higher porosity and lower overall water saturation. Better quality sands appear to occur randomly both vertically in the section and laterally in the area. The percentage of sand in the interval decreases east of the Rulison Field toward Mamm Creek. The fluvial production potential is best demonstrated by the Langstaff No. 1 well which is completed totally in this interval and has a projected ultimate gas recovery of 1,742 MMCF.

### 4.1.2 Ultimate Gas Recovery

Table A2-3 in Appendix 2 presents a summary of the 49 active Mesaverde gas wells in the Central Basin partitioned area including the first 12 months' cumulative gas production, projected ultimate gas recovery to an economic limit of 30 MCFD, completion interval and type of stimulation treatment.

This area has the second highest average projected gas recovery per well, 650 MMCF/well from 49 wells. The average projected gas recovery for the 17 fluvial completions is 562 MMCF/well while the projected average gas recovery for the 22 paludal completions is 672 MMCF/well. The 10 marine completions in the Corcoran and Cozzette Sandstones have an average projected ultimate gas recovery of 755 MMCF/well. However, the Central Basin marine gas production is dominated by one well, the T.C. Currier No. 1, which has a projected ultimate gas recovery of 6,404 MMCF. If this well is excluded, the statistics change to an average projected ultimate gas recovery of 128 MMCF/well for 9 wells.

The distribution of projected ultimate gas recovery in the northern portion of the Central Basin partitioned area is shown in Figure 24. At Rulison, production is generally associated with the Rulison anticline but production trends are not well established. Peterson (1984) noted that production at Rulison is more correlative to proximity of the Rulison anticline than to the amount of sand present. Too little production data is available from the other fields in the Central Basin to be definitive about mapping production trends.

### 4.1.3 Production Type Curve

Figure 25 is a composite production type curve based on 20 years of production history from 14 fluvial Mesaverde completions in the Rulison field. As can be observed from the type curve, the gas production decline rate stabilizes at a 3 percent per year constant percentage decline at the end of the sixth year.

Figure 26 is a composite production type curve developed from eight years of paludal sands gas production history from six wells in the Rulison Field and three years of paludal sand and coal (Cameo) gas production history from eight wells in the Grand Valley Field. The gas production decline rate stabilizes for the paludal sands at 4.8 percent per year constant percentage decline at the end of the fifth year. The Cameo gas production decline rate stabilizes at 4.3 percent per year constant percentage decline rate at the end of the first year. These two paludal composite production type curves indicate that stimulation of the coals (with probable fracture growth into adjacent paludal sands) results in similar initial production rates as achieved in the paludal sands. However, similar stabilized gas production decline rates are achieved much earlier in wells stimulated in the paludal coals as compared with the paludal sand completions. The stabilized gas production rates are 4 times higher in the paludal coal completions when compared with the paludal sand completions.

### 4.1.4 Fluvial Stimulation Evaluation

Stimulation data from 17 fluvial Mesaverde gas wells representative of the Central Basin partitioned area are presented in Table 4. These completions are located in the Mamm Creek Field in T6S and T7S, R93W and in the Rulison Field in T6S and T7S, R94W and R95W.

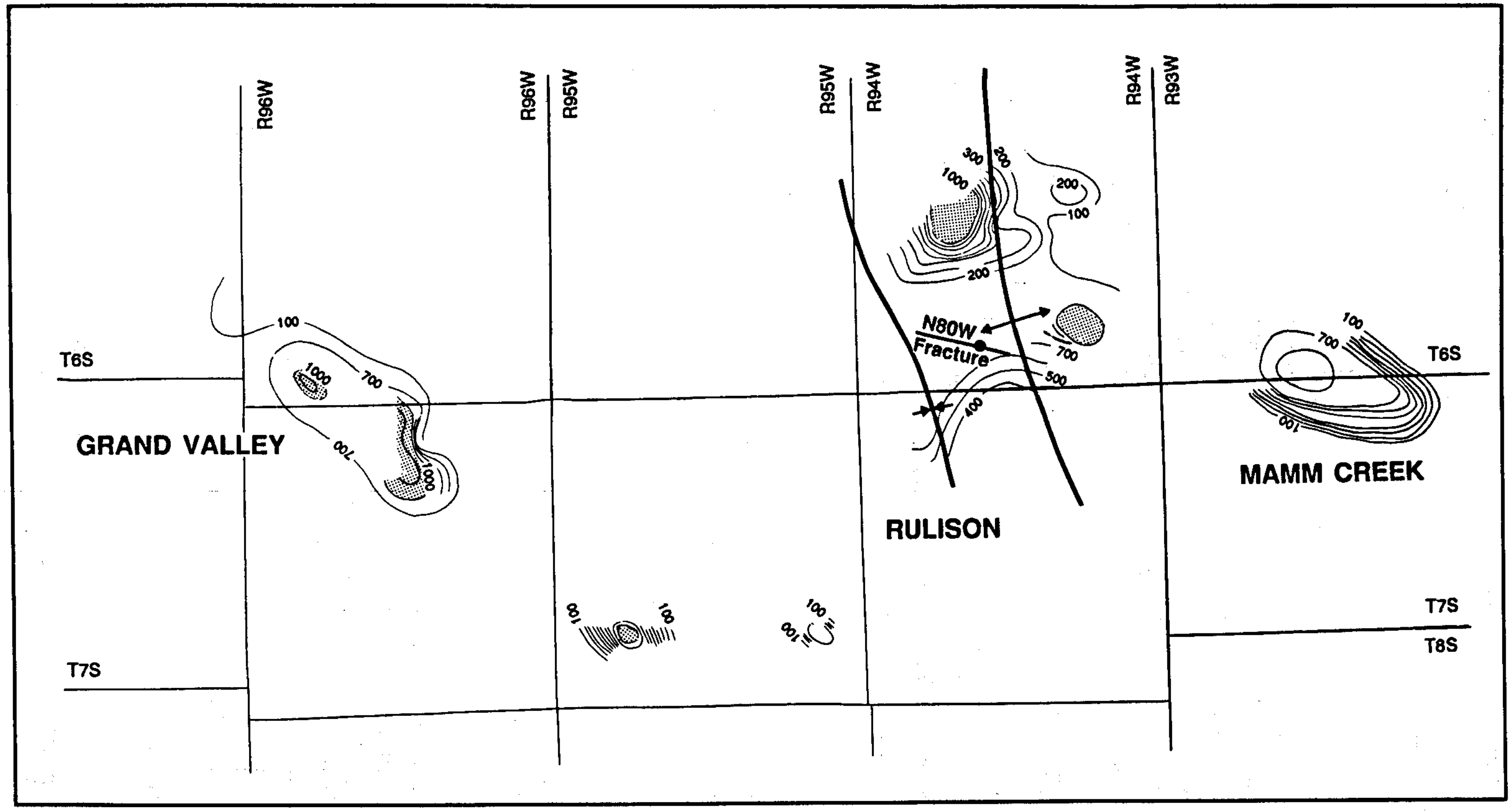



*Figure 24 Projected Ultimate Gas Production in the Northern Central Basin Partitioned Area with Ultimate Production Greater Than 1 BCF Shaded (Fracture orientation at the MWX site is from Lorenz and others, 1986)*

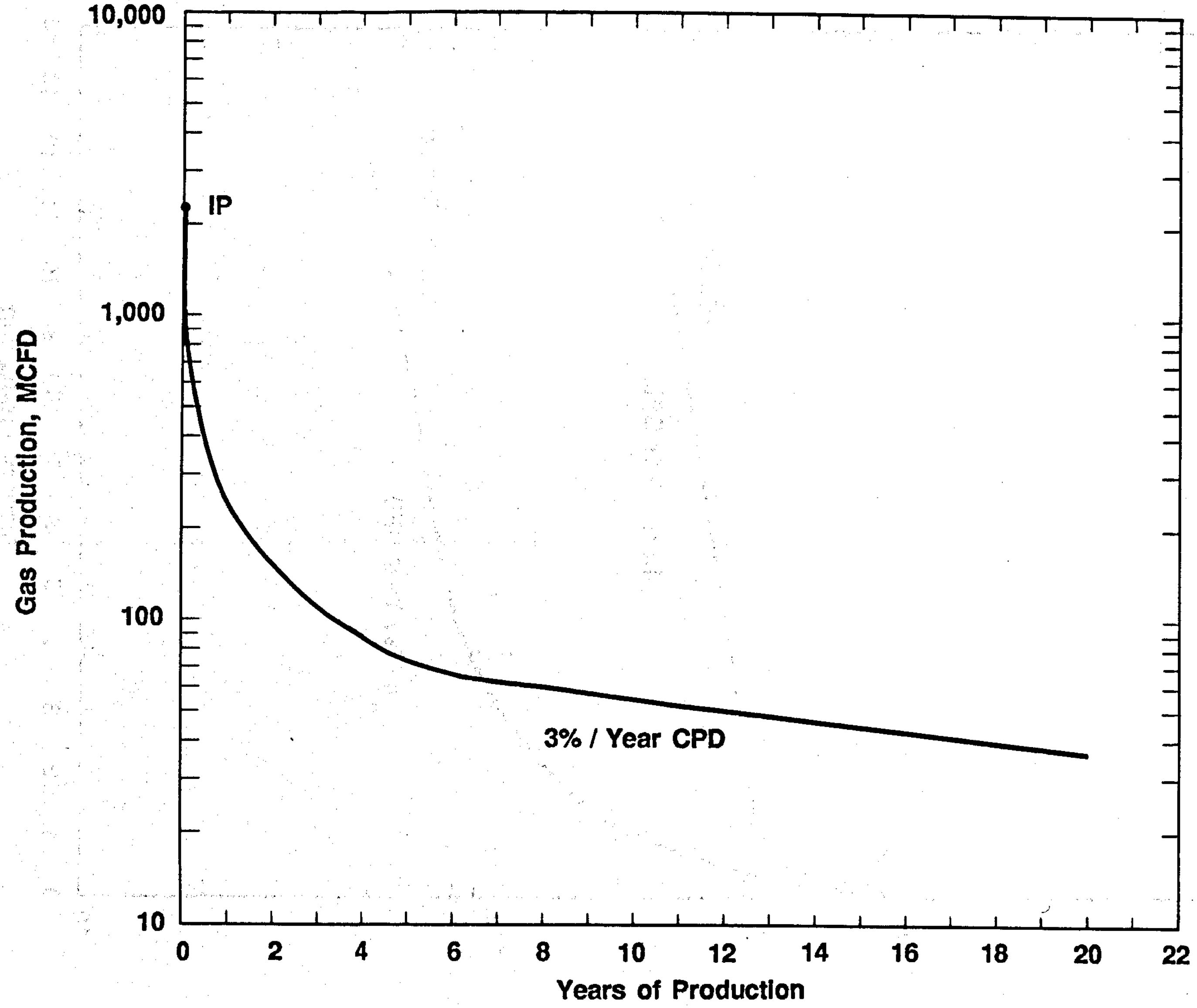



*Figure 25 Fluvial Interval Type Curve, Central Basin Partitioned Area*

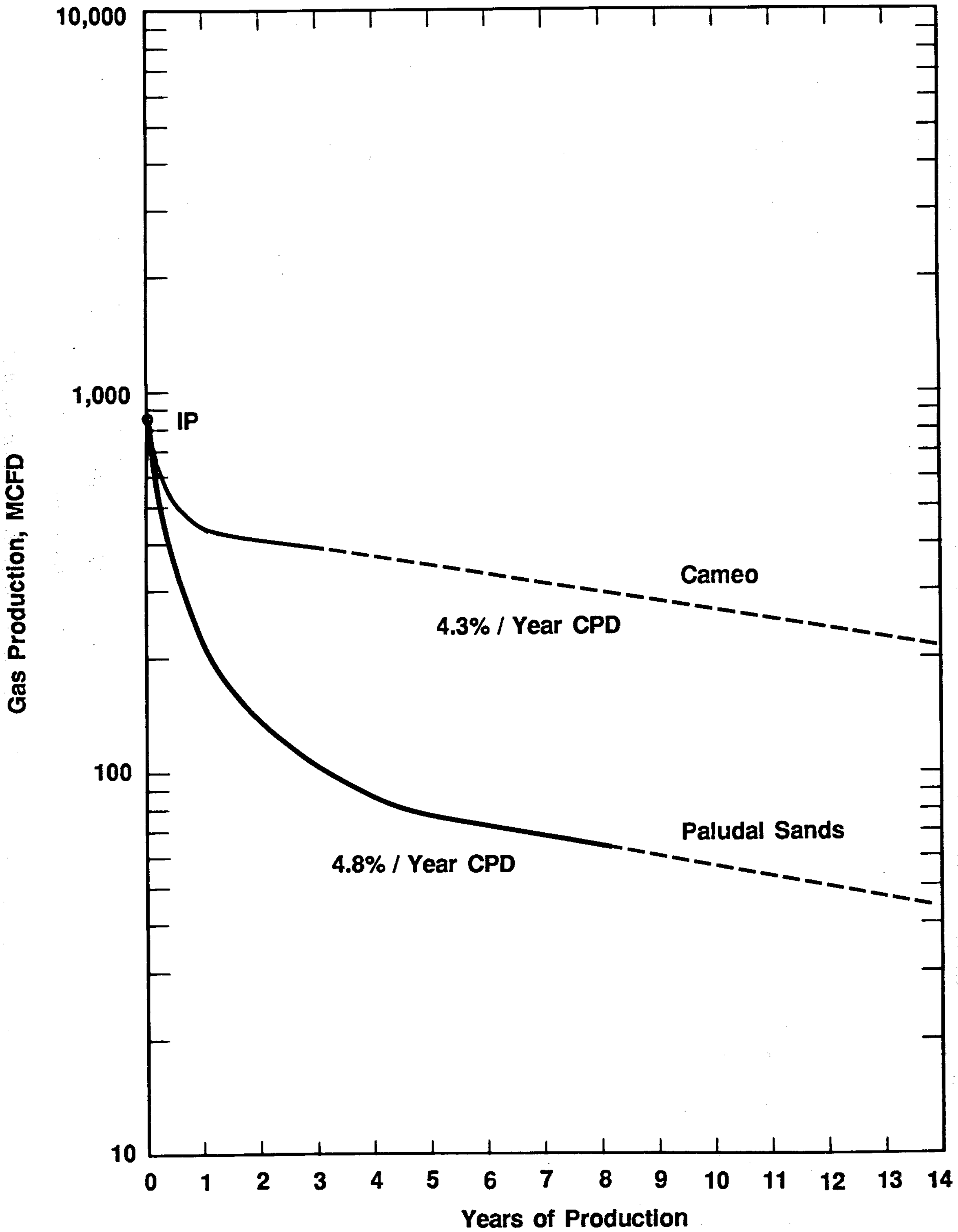



*Figure 26 Paludal Interval Type Curve, Central Basin Partitioned Area*

The stimulations were classified into five types to evaluate the effectiveness of various types of treatment. In some cases, a type of treatment is represented by one well while in other cases, the type is represented by an average of many wells.

*Table 4 Central Basin Area*
*Fluvial Stimulation Statistics*

| Stimulation Type | No. of Wells | Average UGR, MMCF |
|---|---|---|
| AGW | 3 | 78 |
| N2F | 1 | 1,413 |
| NON | 1 | 1,070 |
| Other | 3 | 553 |
| UGW | 9 | 575 |

The highest ultimate gas recovery of 1,413 MMCF per well was from R.H. Ranch 1 in the Mamm Creek Field. This well was stimulated through 34 perforations between 6,856 and 7,491 ft with 3,572 BBL of nitrogen-based foam containing 280,000 lb 20/40 sand.

The second highest ultimate gas recovery of 1,070 MMCF per well was from one nonstimulated well, the Federal 29-95 in the Rulison Field. This well was completed unstimulated, open-hole, from 4,880 to 6,509 ft in the fluvial Mesaverde. Because of the high production rate without stimulation, this well is interpreted to have natural fracture enhanced production.

The third highest ultimate gas recovery of 575 MMCF per well was from 9 wells having major unassisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments. One well was located in the Mamm Creek Field and the other eight were located in the Rulison Field.

The fourth highest ultimate gas recovery of 553 MMCF per well was from three wells, each utilizing a different stimulation fluid. The Federal 1-36 was hydraulic fracture treated through 114 perforations between 5,406 and 6,680 ft with 5,798 BBL of polyemulsion fluid containing 480,000 lb 40/60 sand. The Federal 28-95 was hydraulic fracture treated through 48 perforations between 5,084 and 7,204 ft with 4,286 BBL of 1 percent HCl containing 192,000 lb 20/40 sand. The Juhan 1 was hydraulic fracture treated through 96 perforations between 5,600 and 5,624 ft with 810 BBL lease crude containing 30,000 lb 20/40 sand.

The lowest ultimate gas recovery of 78 MMCF per well was from 3 wells receiving small assisted gelled water or crosslinked gelled water hydraulic fracture treatments. The Clough 13 was treated between 6,438 and 7,360 ft through 25 perforations with 1,344 BBL gelled water containing 55 tons $CO_2$ and 88,240 lb 20/40 sand. The Federal 8 was treated between 5,121 and 6,280 ft through 22 perforations with 1,402 BBL gelled water containing 65 tons $CO_2$ and 100,000 lb 20/40 sand. The McNary 6 was treated between 6,789 and 7,456 ft through 14 perforations with 1,077 BBL gelled water containing 44 tons $CO_2$ and 41,000 lb 20/40 sand. The small sand and fluid volumes used in these stimulations along with the large gross interval being treated resulted in poor response to the stimulation treatment and low ultimate gas recovery.

### 4.1.5 Paludal Stimulation Evaluation

Stimulation data from 22 paludal Mesaverde gas wells, representative of the Central Basin, are presented in Table 5. Six of these wells are paludal sand completions located in the Rulison Field in T6S, R94W, 14 are Cameo (paludal sands and coals) in the Grand Valley Field in T6S and T7S, R96W and R97W, and 2 are Cameo completions in the Vega Field in T9S, R93W. The same classification is used for the paludal stimulations as was used in Section 4.1.4.

*Table 5 Central Basin Area Paludal Stimulation Statistics*

| Stimulation Type | No. of Wells | Average UGR, MMCF |
|---|---|---|
| AGW | 10 | 886 |
| N2F | 1 | 396 |
| NON | 0 | 0 |
| Other | 0 | 0 |
| UGW | 11 | 502 |

The highest average projected ultimate gas recovery of 886 MMCF per well in Table 5 was from 10 wells having major assisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments. Eight of these wells were Cameo completions in the Grand Valley area, and two of these wells were paludal sand completions in the Rulison area.

The second highest projected ultimate gas recovery of 502 MMCF per well was from 11 wells having major unassisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments. Six of these wells were Cameo completions in the Grand Valley area, three were paludal sand completions in the Rulison area, and two were Cameo completions in the Vega area. The 384 MMCF per well of incremental gas production for the 10 wells using nitrogen or carbon dioxide in the stimulation fluid versus the 11 wells that did not, reflects the assistance given to the treating liquids recovery by an entrained or dissolved gas phase in the stimulation fluid.

The lowest projected ultimate gas recovery of 396 MMCF per well was from one well given a major nitrogen-based foam hydraulic fracture stimulation. The Clough 14-24A, located in Sec 14, T6S, R94W, Rulison Field, was perforated only in the paludal sands between 6,898 and 7,388 ft with 24 perforations and broken down with 3,500 gal of 7.5 percent HCl. This interval was then stimulated with 1,160 BBL of nitrogen-based foam containing 800,000 SCF $N_2$ and 120,000 lb 20/40 sand. This is the only paludal sand completion in the Central Basin area given a nitrogen-based foam fracture treatment.

## 4.2 SOUTHEAST UPLIFT PARTITIONED AREA

The Southeast Uplift partitioned area is located in T7S and T8S, R90W and R91W and in T10S and T11S, R90W and includes the following fields: Divide Creek, East Divide Creek, Baldy Creek, Ragged Mountain and Coal Basin. The 20 producing wells in this area are shown in Table A2-4 in Appendix 2. Eighteen of these wells produce from the Corcoran, Cozzette or Rollins Sandstones of the marine interval of the Mesaverde. Two wells, the Divide Creek Unit 15A and Unit 21, are completed in the paludal Mesaverde.

### 4.2.1 Geologic Characteristics as Related to Production

The Southeast Uplift partitioned area is one of the more structurally complex parts of the Piceance Basin. The area includes high structural relief anticlines such as the Divide Creek, Wolf Creek and Coal Basin anticlines having structural relief of over 6,000 ft. Only the Divide Creek anticline is a prolific gas producer.

The relationship of structure to production in the Southeast Uplift partitioned area is predominately that of an inferred higher degree of fracturing associated with anticlinal flexure. Analysis of cores taken in two Divide Creek development wells indicated open natural fractures in both the Cozzette and Corcoran Sandstones (Colorado Oil and Gas Conservation Commission records). Core taken from Divide Creek Unit No. 3 between 4,998 and 5,049 ft in the Cozzette Sandstone indicated numerous vertical fractures. The well was completed through perforations from 4,977 to 5,012 ft, naturally, for 3,700 MCFD at 150 psi FTP. Core from Divide Creek Unit No. 4 indicated numerous vertical natural fractures in both the Cozzette and Corcoran Sandstones. The well was completed in the Cozzette through perforations from 4,522 to 4,600 ft, naturally, for an open flow potential of 15,900 MCFD. The Corcoran was hydraulically fractured through perforations from 4,734 to 4,776 ft with 857 BBL gelled water containing 25,000 lb sand. Following cleanup, the Corcoran had an open flow potential of 7,600 MCFD.

The structural configurations of the Ragged Mountain area wells were shown in Figure 6. The wells lie on the southwestern flank of the Coal Basin anticline, the accompanying syncline and an adjoining northwestward trending anticlinal nose.

Core taken in the Ragged Mountain Federal 10-90-31SE (Synder Oil Co., 1981) indicated the presence of natural fractures in the Corcoran Formation. Following separate hydraulic fracture treatments in the Cozzette and Corcoran, the well tested 550 MCFD and 2 BCPD at 1,100 psi FTP.

Cross section B-B' in Plate 13 traverses from south to north across the Southeast Uplift partitioned area. The cross section centers on a well near the crest of the Divide Creek anticline. Downdip wells to the south are in the Ragged Mountain Field, and downdip wells to the north are in the East Divide Creek and Baldy Creek Fields.

A total of six computed logs are represented in the cross section. The cross section includes geologic correlations, completion, well test and production data as described in the previous section for cross-section A-A' of the Central Basin partitioned area.

The major potential for gas production in the Southeast Uplift partitioned area is from the regressive marine sands. The productive units include the Corcoran and Cozzette sands. In some cases, good production is achieved even though the particular sand does not appear to be well developed. An example of this is the Federal 30-4 well where the projected ultimate gas recovery from the Corcoran is 734 MMCF even though the reservoir appears to be too shaly to produce. The Rollins Sandstone is water saturated in the Southeast Uplift partitioned area.

Paludal sands are poorly developed in the Southeast Uplift partitioned area; however, there appears to be some potential for paludal gas production in the Ragged Mountain Field. In general, updip fluvial wells are water saturated, thus indicating a lack of structural closure on the Divide Creek anticline. There appears to be some potential for fluvial production downdip at the Ragged Mountain and Baldy Creek Fields.

### 4.2.2 Ultimate Gas Recovery

Table A2-4 in Appendix 2 presents a summary of the 20 active Mesaverde gas wells in the Southeast Uplift partitioned area including first 12 months' cumulative gas production, projected ultimate gas recovery to an economic limit of 30 MCFD, completion interval and type of stimulation treatment.

The Southeast Uplift area has the highest average projected gas recovery per well, 1,658 MMCF/well from 20 wells. The 18 marine completions in this area average 1,796 MMCF/well while the two paludal Mesaverde completions average approximately 417 MMCF/well.

Figure 27 is a map showing the distribution of projected ultimate production within the Southeast Uplift partitioned area. Production on the Divide Creek anticline shows a direct relationship to the anticline crest; however, specific structural geometry and fracture orientation and distribution about the anticline are not available. It is presumed that a higher degree of fracturing is present in the anticline hinge, but, at present, it is not known if the fractures are:

- part of a regional set (Hogback or Piceance) which have been modified by anticlinal folding,
- part of folding strain along the anticlinal hinge zone, or
- a result of the two above diachronous processes.

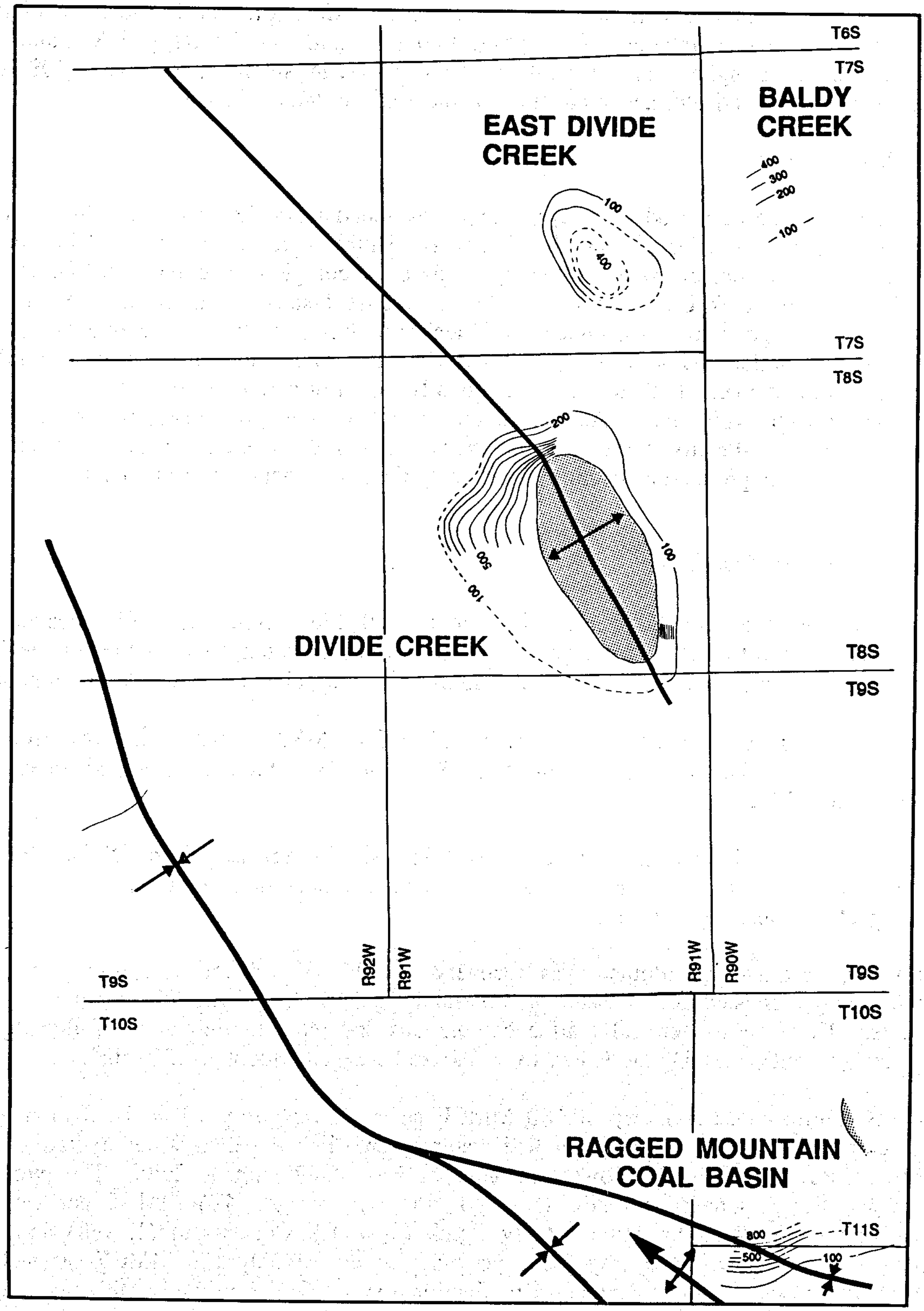



*Figure 27 Projected Ultimate Gas Production in the Southeast Uplift Partitioned Area with Ultimate Production Greater Than 1 BCF Shaded*

The relationship of production to structure in the Ragged Mountain area is shown in Figure 27. There is not an obvious relationship of production to folding in the Ragged Mountain Field, except that the well highest on the flank of the Coal Basin anticline, Sec. 16, T10S, R90W, has the highest projected ultimate production in the Ragged Mountain area.

### 4.2.3 Production Type Curve

Figure 28 is a composite production type curve developed from the production histories of 14 of the 18 marine completions in the Southeast Uplift partitioned area. This curve is representative of the decline rate for the tight gas sand completions outside the Divide Creek Unit. The Divide Creek Unit data was excluded because historical gas production information was not available, prior to 1970, on an individual well basis for the four active Divide Creek Unit marine completions, Unit wells 1, 2, 9 and 10. Furthermore, the information available after 1970 was market demand limited, and consequently no information from these four wells was used to develop the type curve. As can be observed from the type curve, gas production rate decline is severe for the first three years but stabilizes at six percent per year at the end of the sixth year. Such a production decline curve is typical of production from naturally fractured reservoirs.

### 4.2.4 Stimulation Evaluation

Table 6 presents the stimulation statistics for the 20 Mesaverde gas wells located in the Southeast Uplift partitioned area. Eighteen of these wells are completed in the marine interval and two wells, Divide Creek Unit No. 15A and No. 21, are paludal Mesaverde completions.

The highest average ultimate gas recovery of 8,784 MMCF per well was from three unstimulated wells, Divide Creek Unit Nos. 1, 2 and 9 which encountered open natural fractures during drilling.

The second highest ultimate gas recovery was 1,967 MMCF per well from Divide Creek Unit No. 10 which was given a small hydraulic fracture stimulation with 474 BBL of diesel containing 20,000 lb of 20/40 sand.

The third highest average ultimate gas recovery of 508 MMCF per well was from 6 wells which had major assisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments. These wells were all marine completions and were located in the following fields: Coal Basin (1 well), East Divide Creek (3 wells) and Ragged Mountain (2 wells).

The lowest ultimate gas recovery of 180 MMCF per well was from 10 wells, 8 marine and 2 paludal completions. All had major gelled water or crosslinked gelled water hydraulic fracture treatments with no entrained or dissolved gas phase in the treatment fluid. The two paludal completions, Divide Creek Unit No. 15A and No. 21, averaged 416 MMCF per well. The eight marine completions located at Baldy Creek (3 wells), Coal Basin (1 well) and Ragged Mountain (4 wells) have an average ultimate gas recovery of only 120 MMCF per well. The 388 MMCF per well of incremental gas production for the 6 marine wells utilizing nitrogen or carbon dioxide in the stimulation fluid compared to the eight marine wells that did not, reflects the assistance given to the treatment of liquids recovery by an entrained or dissolved gas phase in the stimulation fluid.

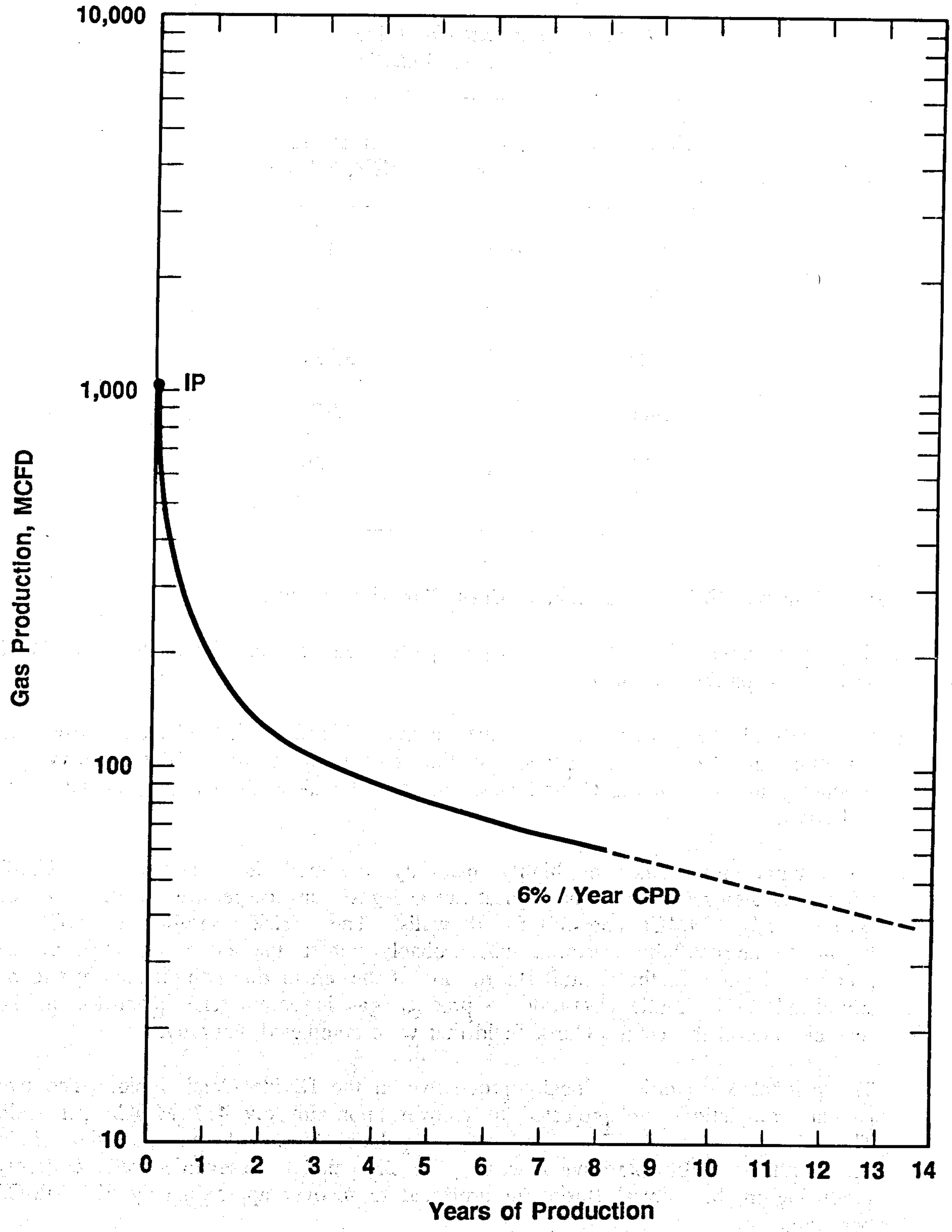



*Figure 28 Marine Interval Type Curve, Southeast Uplift Partitioned Area*

*Table 6 Southeast Uplift Area Stimulation Statistics*

| Stimulation Type | No. of Wells | Average UGR, MMCF |
|---|---|---|
| AGW | 6 | 508 |
| N2F | 0 | 0 |
| NON | 3 | 8,784 |
| Other | 1 | 1,967 |
| UGW | 10 | 180 |

### 4.2.5 Comparison with MWX and Central Basin Partitioned Area

The following comparisons of the Southeast Uplift partitioned area can be made with MWX and the Central Basin partitioned area:

- Essentially all the gas production in the Southeast Uplift partitioned area is from the Corcoran and Cozzette Sandstones of the marine Mesaverde. The primary gas producing intervals in the Central Basin are the fluvial sands and the paludal sands and coals.

- The marine reservoirs are highly naturally fractured in the Southeast Uplift partitioned area resulting in the highest average gas recovery per well in the Piceance Basin of 1,796 MMCF per well for 18 wells. The marine reservoirs at MWX are known to be naturally fractured, but probably not to the extent as those in the Southeast Uplift. In the Central Basin, nine of the ten marine completions had to be stimulated by hydraulic fracturing to produce gas in commercial quantities, unlike several wells in the Divide Creek Field that were completed naturally.

- The paludal Mesaverde is locally productive in the Divide Creek Field. The two paludal completions are projected to recover approximately 417 MMCF per well. There is, however, significant undeveloped paludal Mesaverde gas potential within the Southeast Uplift partitioned area. The 22 paludal Mesaverde wells currently producing in the Central Basin are projected to recover approximately 672 MMCF per well.

- The fluvial Mesaverde is not completed in the Southeast Uplift partitioned area and therefore has not produced any gas. This study showed that the updip fluvial Mesaverde in the Divide Creek Field is water saturated whereas the downdip portions (such as at Ragged Mountain and Baldy Creek) have some gas producing potential in the lower fluvial interval. In contrast, the fluvial Mesaverde interval is a major target in the Central Basin area. The 17 fluvial Mesaverde gas producing wells in the Central Basin are projected to recover approximately 562 MMCF per well.

- There is a broad variation in the original depth of burial in the Southeast Uplift. This is in contrast to the Central Basin area which is relatively flat in terms of depth of burial. It is postulated that the pore geometry of sands in the updip Divide Creek Field consists of more open pores as compared to the Rulison Field, whereas downdip pores in the Southeast Uplift are more similar to those at the Rulison Field. The consequence of this variation of pore geometry is that the Southeast Uplift area is postulated to have a broader range in matrix permeability, i.e., updip sands are postulated to have higher matrix permeability than Rulison sands. Aside from the probability that natural fractures are more prevalent on the Divide Creek structure this study shows that the prolific gas production of some Divide Creek Field wells is partly attributable to better matrix permeability. The lack of fluvial interval gas entrapment in the updip portions of the Southeast Uplift area may be associated with higher matrix permeability.

- There are some similarities between the areas in reservoir performance following stimulation treatments. Marine and paludal Mesaverde wells stimulated with gas assisted gelled water or cross-linked gelled water-based fluids have higher projected ultimate gas recovery than wells stimulated without gas to assist in treatment fluid recovery. This higher projected gas recovery reflects the beneficial effect to the natural fracture system of removing stimulation liquids from the natural fractures using a dissolved or entrained gas phase in the stimulation fluid.

## 4.3 SOUTHWEST FLANK PARTITIONED AREA

The Southwest Flank partitioned area encompasses T9S and T10S, R94W to R97W and includes the following fields: Shire Gulch, Brush Creek, Buzzard and Plateau. There are 137 active wells in this partitioned area of which 2 are fluvial Mesaverde completions, 3 are paludal Mesaverde completions and 132 are completed in the Corcoran, Cozzette and/or Rollins Sandstones in the marine Mesaverde. Active Mesaverde gas wells in this partitioned area are listed in Table A2-5 in Appendix 2.

### 4.3.1 Geologic Characteristics as Related to Production

The Southwest Flank partitioned area lies on the gently dipping southwestern limb of the Piceance Basin. The Mesaverde Group outcrops in the western part of the partitioned area with gentle northeastward dips from outcrop to the producing level, a distance of about 15 miles for the marine sandstones. The area lies south of a moderate east-west trending anticline near Debeque and in the partitioned area significant folds have not been mapped.

Plate 14 is a structural cross section from west (C) to east (C') across the Plateau Field which typifies the Southwest Flank area. The TITEGAS computed log results are presented through the gas interval for seven wells. The plate also contains geologic correlations, completion data, test data and production data as described previously for Plate 12.

The Southwest Flank partitioned area produces primarily from the regressive marine Corcoran and Cozzette Sandstones. While the Rollins Sandstone is sometimes completed in this area, there is no indication that the Rollins contributes to gas production. Wells completed in the Rollins have experienced water production problems.

Wells on the eastern side of the Southwest Flank partitioned area are gradational to the Central Basin area and have the potential to produce gas from the fluvial interval, although in general, sands in this interval have been swept by meteoric water. Sands of the paludal interval are not well developed.

### 4.3.2 Ultimate Gas Recovery

Table A2-5 in Appendix 2 presents a summary of the 137 active Mesaverde gas wells in the Southwest Flank partitioned area including the first 12 months' cumulative gas production, projected ultimate gas recovery to an economic limit of 30 MCFD, completion interval and type of stimulation treatment.

Of the three partitioned areas in the Piceance Basin, the Southwest Flank partitioned area ranks third in average projected gas recovery per well, 238 MMCF/well from 137 wells. The average projected gas recovery per well for the 132 marine Mesaverde completions is 237 MMCF per well, for the 3 paludal Mesaverde completions is 372 MMCF per well, and for the 2 fluvial Mesaverde completions is 115 MMCF per well.

Projected ultimate gas production in the Southwest Flank partitioned area is shown in Figure 29. Production defines an elongate, northeast-southwest trending fairway comprising several smaller gas productive fields. This fairway is not associated with any obvious folds.

Within each field, the better production defines a west-northwest subtrend. The location and orientation of three mapped faults (from Johnson, 1983) are also shown in Figure 29. Similar orientations of the faults, the production subtrends and the MWX fractures (Hogback system) suggests some correlation, but that could not be verified in this study. Likewise, the northeast-southwest trending fairway is parallel to the dominant Piceance system fractures in the area (Plate 11) which likewise suggests some correlation. The fairway trend is also subparallel to the trend of regressive marine sandstone cycles as defined by Johnson (1987) which may influence production. A detailed field study is certainly warranted in the Southwest Flank partitioned area to determine the controls on production patterns. Is production controlled by intersecting fractures, faulting, sand body geometry, local variations in kh, or by the capability of the well to unload liquids and continue to produce gas at economic rates?

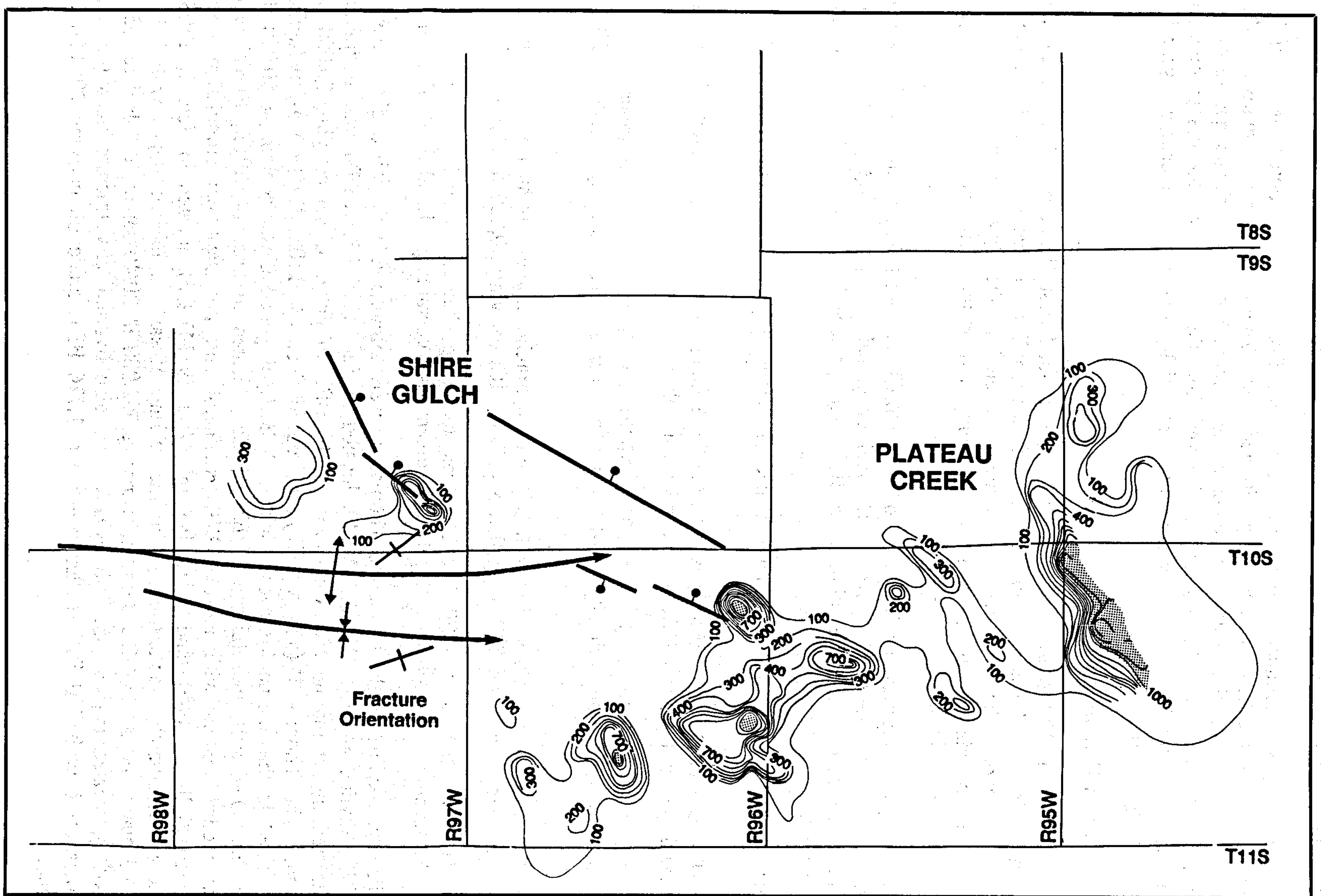



*Figure 29 Projected Ultimate Production in the Southwest Flank Partitioned Area with Ultimate Production Greater Than 1 BCF Shaded (Fault locations are from Johnson, 1983)*

### 4.3.3 Production Type Curve

Figure 30 is a composite production type curve developed from the production histories of 37 marine completions in the Southwest Flank partitioned area. This curve is representative of the decline rate for the 37 marine Mesaverde completions having projected ultimate gas recovery greater than 200 MMCF per well. As can be observed from the type curve, the gas production decline rate is severe for the first four years, but is essentially stable at 1 percent per year by the end of the eighth year.

### 4.3.4 Stimulation Evaluation

Stimulation data from 137 Mesaverde gas wells in the Southwest Flank partitioned area are presented in Table 7. The stimulations are classified according to five types as in previous sections of this report. Two of these wells are completed in the fluvial Mesaverde, 3 are completed in the paludal Mesaverde and 132 are completed in the Corcoran, Cozzette and/or Rollins Sandstones of the marine Mesaverde.

The highest projected ultimate gas recovery of 571 MMCF per well was from 9 wells which were hydraulically fractured with gelled weak acid or gelled diesel carrying proppant. The location of these nine wells, the stimulation fluid and projected ultimate gas recovery are discussed below.

Four wells were stimulated with gelled weak acid (1 percent HCl to 5 percent HCl) fluids as follows:

- The Donald 1 (413 MMCF) was hydraulic fracture treated in the paludal Mesaverde with gelled 1 percent HCl and an unknown volume of proppant.
- The H.R. Milholland Sr. 1 (1,835 MMCF) was hydraulic fracture treated in the marine Mesaverde with 1952 BBL of gelled 3 percent HCl carrying 86,000 lb 20/40 sand.
- The U.S. Moran 28-1 (136 MMCF) was hydraulic fracture treated in the marine Mesaverde with 786 BBL of gelled 5 percent HCl carrying 50,000 lb 20/40 sand.
- The B. Nichols 1 (370 MMCF) was hydraulic fracture treated in the marine Mesaverde with 738 BBL of gelled 5 percent HCl containing 44,500 lb 20/40 sand.

Two wells, the Skyline Hittle 1 and the Thomas 1, were stimulated with gelled diesel based fluids. The Skyline Hittle 1 (1,350 MMCF), located in Sec. 12, T10S, R96W was hydraulic fracture treated in the marine Mesaverde with 1,216 BBL of gelled diesel carrying 50,000 lb 20/40 sand. The Thomas 1 (520 MMCF), located in Sec. 18, T10S, R95W was hydraulic fracture treated in the marine Mesaverde with 991 BBL of gelled diesel containing 50,000 lb walnut hulls. One well, the Barnard 1 (62 MMCF), located in Sec. 14, T10S, R96W was hydraulic fracture treated with an 890 BBL methanol and propane-based stimulation fluid carrying 30,000 lb of 20/40 sand. The Federal 1-3 (169 MMCF), located in Sec. 1, T10S, R97W, was hydraulically fracture treated in the marine Mesaverde in two stages with 1,422 BBL gelled water and 3,624 BBL crude oil carrying 592,000 lb 20/40 sand. The Federal 35-1 (291 MMCF), located in Sec. 35, T9S, R97W, was also hydraulically fracture treated in the marine Mesaverde with 760 BBL gelled water and 1,726 BBL crude oil carrying 296,000 lb 20/40 sand.

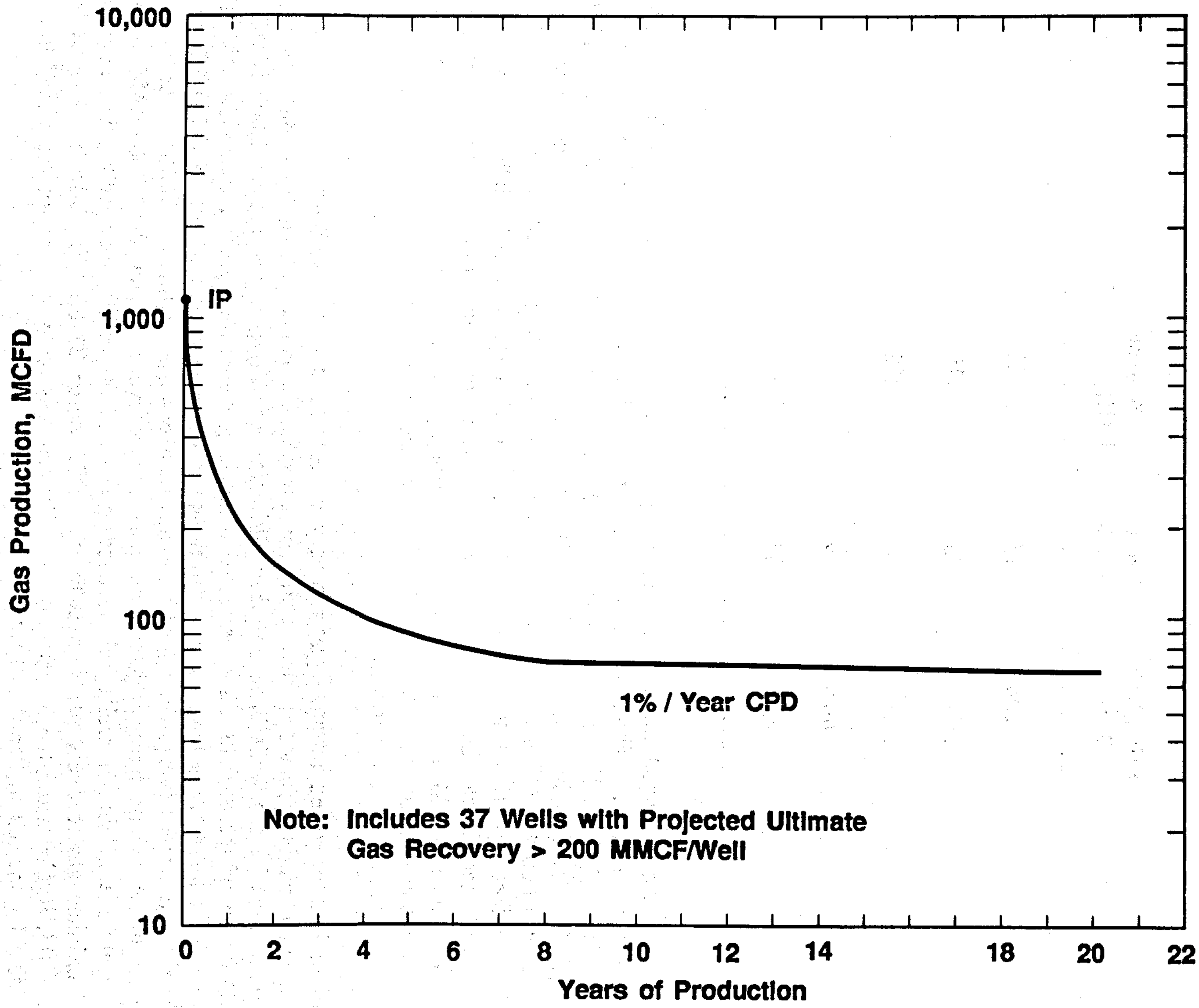



*Figure 30 Marine Interval Type Curve, Southwest Flank Partitioned Area*

*Table 7 Southwest Flank Partitioned Area Stimulation Statistics*

| Stimulation Type | No. of Wells | Average UGR, MMCF |
|---|---|---|
| AGW | 47 | 260 |
| N2F | 35 | 119 |
| NON | 8 | 412 |
| Other | 9 | 571 |
| UGW | 38 | 246 |

The second highest projected ultimate gas recovery, 412 MMCF per well, was from 8 wells that were not stimulated. Three of these wells, the Colorado Land 1 (956 MMCF) and Colorado Land 2 (1011 MMCF), both located in Sec. 17, T10S, R94W, and Colorado Land 3 (1,089 MMCF), located in Sec. 7, T10S, R94W have projected ultimate gas recoveries averaging over 1,000 MMCF per well while the five other nonstimulated wells, the Zahm 29-3 (4 MMCF), Walker 4-4 (18 MMCF), Big Creek Land and Cattle 16-1 (70 MMCF), Federal 26-2 (25 MMCF) and Hittle Ducray 1 (99 MMCF) have projected ultimate gas recoveries averaging less than 50 MMCF per well. It is strongly inferred that the higher projected ultimate gas recoveries for the Colorado Land 1, 2 and 3 are the result of penetrating an interconnected natural fracture network.

The third highest projected ultimate gas recovery of 260 MMCF per well was from 47 wells stimulated with major assisted gelled water or crosslinked gelled water hydraulic fracture treatments. Two of these wells have projected ultimate gas recovery greater than 1,000 MMCF per well. Three of these wells have projected ultimate gas recovery greater than 800 MMCF per well. Six of these wells have projected ultimate gas recovery greater than 600 MMCF per well, while seven wells have projected ultimate gas recovery greater than 400 MMCF per well. Fourteen of the 47 wells have projected ultimate gas recovery greater than 200 MMCF per well. Twenty-one of the 47 wells will recover less than 100 MMCF per well. The highest projected ultimate gas recovery per well is for the U.S. Moran 27-1 (1,307 MMCF), located in Sec. 27, T10S, R96W while the lowest projected ultimate gas recovery was for the U.S. Moran 26-1 (7 MMCF), located in Sec. 26, T10S, R96W.

The fourth highest projected ultimate gas recovery, 246 MMCF per well, was from 38 wells stimulated with major unassisted gelled water or crosslinked gelled water hydraulic fracture treatments. One of these wells has a projected ultimate gas recovery greater than 800 MMCF. Four of these wells have projected ultimate gas recoveries greater than 600 MMCF per well, while eight wells have projected gas recoveries greater than 400 MMCF per well. Sixteen of the 38 wells have projected ultimate gas recovery greater than 200 MMCF per well. Thirteen of the 38 wells will recover less than 100 MMCF per well. The highest projected ultimate gas recovery per well was for the Clydie Hall 1 (812 MMCF), located in Sec. 17, T10S, R95W while the lowest projected ultimate gas recovery was for the Federal 2-33 (4 MMCF), located in Sec. 33, T10S, R96W.

The lowest projected ultimate gas recovery, 119 MMCF per well, was for 35 wells given nitrogen-based foam hydraulic fracture stimulation treatments. Six of the 35 wells have a projected ultimate gas recovery greater than 300 MMCF per well. Eight of the 35 wells have a projected ultimate gas recovery greater than 200 MMCF per well. Twenty-one of the 35 wells have a projected ultimate gas recovery less than 100 MMCF per well. The highest projected ultimate gas recovery per well is for the Law 28-2 (372 MMCF), located in Sec. 28, T10S, R96W while the lowest projected ultimate gas recovery of 1 MMCF per well is shared by the Livingston 11-2 located in Sec. 11, T10S, R96W, the Dolley 1, located in Sec. 36, T9S, R96W, and the Federal 9-1 located in Sec. 9, T10S, R97W.

### 4.3.5 Comparison of the Southwest Flank with MWX and the Central Basin

The following comparisons of the Southwest Flank partitioned area can be made with MWX, the Rulison Field and the Central Basin partitioned area.

- Essentially all the gas production in the Southwest Flank partitioned area is from the marine sandstones of the Mesaverde while the marine, paludal and fluvial each contribute significant gas production in the Central Basin area.

- The projected average ultimate gas recovery for a marine completion in the Southwest Flank is 237 MMCF per well for 132 wells. The marine completions in the Central Basin partitioned area average 755 MMCF per well for 10 wells. Production from one well, the T.C. Currier No. 1, has a large influence upon the Central Basin marine production statistics. If this well is excluded, the statistics change to an average projected ultimate gas recovery of 128 MMCF/well for 9 wells.

- The original depth of burial on the Southwest Flank is about 4,000 to 5,000 ft less than at Rulison. These differences are reflected in a higher average reservoir porosity on the Southwest Flank and a higher matrix permeability.

- Reservoir pressure is much less on the Southwest Flank owing to a shallower depth to reservoir and a lower pore pressure gradient.

- Some areas of the Southwest Flank partitioned area, e.g., Sections 6, 7 and 17 of T10S, R94W, have wells that average the relatively high projected ultimate gas recoveries of approximately 1,000 MMCF per well. The higher production agrees with the kh map of this study (Plate 10); however, the map is based upon limited data. While there is some indication that natural fractures are a less important gas production mechanism on the Southwest Flank than at Rulison, there is insufficient evidence to unequivocally make this conclusion.

- The paludal Mesaverde is locally gas productive in three wells on the northeast side of the Southwest Flank partitioned area in Sections 14, 18, and 19 of T9S, R94W. The three paludal Mesaverde completions have a projected average ultimate gas recovery of 372 MMCF per well. In the Central Basin, the 22 paludal Mesaverde completions have a projected ultimate gas recovery of 672 MMCF per well.

- The fluvial Mesaverde is locally gas productive in only two wells, also on the northeast side of the Southwest Flank partitioned area, in Sections 24 and 29 of T9S, R94W. The two fluvial Mesaverde completions have a projected average ultimate gas recovery of 115 MMCF per well. In the Central Basin area, the 17 fluvial Mesaverde completions have a projected ultimate gas recovery of 562 MMCF per well.

- The fluvial Mesaverde on the Southwest Flank is water saturated on the updip western portion of the area. Downdip to the east, the area contains gas in the lower fluvial interval while the upper fluvial interval is water saturated. The majority of the Central Basin fluvial interval is gas saturated with only the upper fluvial being water saturated.

- In the Southwest Flank partitioned area, 38 wells completed in the marine Mesaverde with unassisted gelled water or cross-linked gelled water hydraulic fracture stimulation treatments have a projected average ultimate gas recovery of 246 MMCF per well. Forty-seven wells completed in the marine Mesaverde with major gas assisted gelled water or crosslinked gelled water hydraulic fracture stimulation treatments have a projected average ultimate gas recovery of 260 MMCF per well. The fact that the average projected ultimate gas recovery is not significantly enhanced by the addition of an entrained or dissolved gas phase in the stimulation fluid liquid phase infers that natural fractures do not play a critical role, except locally, in gas production from the marine sands in the Southwest Flank partitioned area. By contrast, in the Central Basin partitioned area, the presence of the natural fracture system is critical to commercial gas production in the marine Mesaverde as well as in the paludal and fluvial Mesaverde.

## 4.4 UNDEFINED AREAS IN THE PICEANCE BASIN

Eighty-five percent of the active Mesaverde gas wells in the Piceance Basin are located in the three partitioned areas discussed in Sections 4.1, 4.2 and 4.3. The area outside of the three partitioned areas was judged to have insufficient data to define geologic and production characteristics. Entire townships are left undrilled in the "undefined" area outside of the partitioned areas, and where control exists, gas production is sporadic.

The undefined area in the Piceance Basin includes 37 active Mesaverde gas wells. Gas production in the undefined area is localized in seven fields, as depicted by Figures 1 and 23. The fields include (1) Coon Hollow-Debeque, (2) Logan Wash, (3) Hunters Canyon, (4) Calf Canyon, (5) Baxter Pass, (6) White River Dome and (7) Sulphur Creek.

The gas production from these fields is atypical of the basin as a whole. Fields 1 through 6 above are areas peripheral to the down-dip basin gas accumulation and trap gas conventionally in combination structural-stratigraphic traps. These fields have experienced relatively shallow depth of burial, and gas reservoirs in these fields are not necessarily tight. However, due to ineffective trapping and/or regional sweeping of surface water, these fields generally have poor gas production and experience water production problems. Only a few wells in these areas have produced significant volumes of gas from the Mesaverde.

The Sulphur Creek Field is in contrast to the aforementioned six fields. It is part of the contiguous basin-centered gas resource. However, it has not been possible to produce gas economically from the Mesaverde in this field due to extremely tight reservoirs. Mesaverde sandstones in this area are similar to those in the Uinta Basin which carry high volumes of secondary carbonate minerals. The combination of clay diagenesis and carbonate cement explains the extremely low permeability.

The following discussion gives a general description of each field in the undefined area.

*Coon Hollow-Debeque*

The Coon Hollow-Debeque Mesaverde gas producing area in Secs. 29 and 30, T8S, R97W and Secs. 25, 26 and 35, T8S, R98W includes five fluvial Mesaverde completions with an average ultimate gas recovery of 207 MMCF per well and one marine Cozzette completion having a projected ultimate gas recovery of 116 MMCF.

*Logan Wash*

The Mesaverde gas producing area in Logan Wash is located in Secs. 5, 6, 7 and 31, T8S, R97W and in Secs. 1 and 12, T8S, R98W. The Logan Wash Field includes six marine Cozzette completions having an average projected ultimate gas recovery of 65 MMCF per well and one fluvial Mesaverde completion, the Cowperthwaite 2-6LW, located in Sec. 6, T8S, R97W, with a projected ultimate gas recovery of 1,433 MMCF. The six marine completions each received major assisted or unassisted gelled water-based hydraulic fracture treatments. The fluvial Mesaverde interval perforated in the Cowperthwaite 2-6LW was broken down with 500 gal acid. No fracture treatment was undertaken.

*Hunters Canyon*

The Mesaverde gas producing area in the Hunters Canyon Field is located in Secs. 24 and 25, T8S, R101W and in Sec. 30, T8S, R100W. The three marine Cozzette completions have a projected ultimate gas recovery that ranges from 168 MMCF for the Pure 1, located in Sec. 24, T8S, R101W to 4,368 MMCF for the Federal 7, located in Sec. 30, T8S, R100W. The average is 1,798 MMCF per well. None of the three wells has been hydraulic fracture treated. Following perforation, each well was given a small matrix acid treatment.

*Calf Canyon*

The Calf Canyon Field is a Dakota and Morrison gas producing area with minor Mesaverde gas producing potential above 1,500 ft. The Mesaverde gas producing area in the Calf Canyon

Field is located in Secs. 11 and 24, T6S, R102W. The two paludal Mesaverde completions in this field have an average projected ultimate gas recovery of 89 MMCF per well, varying from 2 MMCF for the Federal 11-4A, located in Sec. 11, T6S, R102W, to 176 MMCF for the Federal 24-1, located in Sec. 24, T6S, R102W. Neither well was hydraulic fracture treated. Following perforation, each well was given a small matrix acid treatment.

*Baxter Pass*

The Mesaverde gas producing area in the Baxter Pass Field occurs at a depth less than 700 ft. The Baxter Pass Field includes one paludal Mesaverde well, the Gentry 7X-29-4-103, located in Sec. 29, T4S, R103W, with a projected ultimate gas recovery of 4 MMCF and one fluvial Mesaverde well, the Federal 8-31-4-103, located in Sec. 31, T4S, R103W, with a projected ultimate gas recovery of 108 MMCF. The Gentry 7X-29-4-103 was fracture treated with 1,262 BBL of nitrogen-based foam carrying 139,000 lb sand while the Federal 8-31-4-103 was completed unstimulated.

*White River Dome*

The White River Dome Field is primarily a Wasatch gas producing area with Mesaverde gas production being secondary in importance. The Mesaverde gas producing area in the White River Dome Field is located in Secs. 28, 29, 30, 31 and 32, T2N, R96W and in Sec. 26 T2N R97W in Rio Blanco County. The seven Mesaverde gas producing wells consist of two marine Trout Creek wells with a projected average ultimate gas recovery of 344 MMCF per well, two paludal Mesaverde wells with an average projected ultimate gas recovery of 902 MMCF per well, and three fluvial Mesaverde wells having a projected ultimate gas recovery of 103 MMCF per well.

One of the two marine Trout Creek completions, the Federal Unit 3M, located in Sec. 29, T2N, R96W, was completed without stimulation and is projected to have an ultimate gas recovery of 679 MMCF. The Federal Unit 2M, located in Sec. 32, T2N, R96W, was fracture treated in the Trout Creek with 563 BBL of gelled water containing 49,000 lb sand and is projected to recover only 8 MMCF gas.

The two paludal Mesaverde completions, Federal A5 (1,025 MMCF), located in Sec. 26, T2N, R97W, and Federal Unit 3 (778 MMCF), located in Sec. 30, T2N, R96W, were completed without stimulation.

Two of the three fluvial Mesaverde completions Federal 1 (202 MMCF), located in Sec. 31, T2N, R96W, and Potter 1 (76 MMCF), located in Sec. 30, T2N, R96W, were completed without stimulation. Federal Unit 1 (30 MMCF), located in Sec. 28, T2N, R96W, was fracture treated in the fluvial Mesaverde with 1,190 BBL of gelled water containing 30,000 lb sand.

*Sulphur Creek*

The Sulphur Creek Field is primarily a Wasatch gas producing area with the Mesaverde gas production being secondary in importance. The Mesaverde gas producing area in the Sulphur Creek Field is scattered over portions of T2S to T4S, R97W and R98W in Rio Blanco County. The nine Mesaverde gas producing wells consist of one marine Trout Creek well with a projected ultimate gas recovery of 81 MMCF, two paludal Mesaverde wells with an average projected ultimate gas recovery of 36 MMCF per well, and six fluvial Mesaverde wells with an average projected ultimate gas recovery of 132 MMCF per well. One fluvial Mesaverde well, the Federal 398-17-4, located in Sec. 17, T3S, R98W, has a projected ultimate gas recovery of 629 MMCF. If this well is excluded from the fluvial statistics for Sulphur Creek, the average projected ultimate gas recovery for the remaining five fluvial completions is 33 MMCF per well.

## 4.5 RELATIONSHIP OF PRODUCTION TO STRUCTURAL FLEXURE

Because ultimate gas production at the Divide Creek Field appears to be spatially related to the anticline, it might be inferred that production in other parts of the basin is related to structural flexure (and therefore increased extensional fracturing as a result of folding strain). In the Rulison Field, production could possibly be related to location on the Rulison anticline (Peterson, 1984) (Figure 24). In other fields such as Plateau or Grand Valley, a relationship of production with either anticline or synclines is not obvious.

If local or secondary folds are appropriately oriented, their associated cross fracturing might be inferred to provide enhanced fracture permeability and higher production. In Coal Canyon near Debeque, Lorenz and Smock (1985) found subordinate cross fractures that were oblique to the dominant fractures and parallel the trend of a local anticline. Lorenz and others (1986) have demonstrated through well tests the poor connectivity of the unidirectional dominant subsurface fractures. The Coal Canyon outcrop suggests that local flexing along younger subsidiary folds or faults in the basin should enhance fracture intersections, particularly if the fold trends across the dominant fracture direction.

To better visualize the extent and locations of structural flexure throughout the Piceance Basin, a flexure map was produced. Plate 15 is a computer-generated contour map of the second derivative of layering dip. The map essentially shows the rate of change of dip magnitude and dip direction. The flexure map was generated from a digital structure map of the top of the Rollins Sandstone Member. In general, high rates (closely spaced contours) indicate areas of flexure or folds. It should be cautioned that this map be used only in a very general way as a flexure representation. It is necessarily based on structure data that includes broad areas of the basin with very sparse well control. The presence of faults (not represented in the digital structure map or flexure map) would tend to lessen local flexure; however, faults may be reflected by trends of higher flexure. Structural flexure is produced at both anticlinal and synclinal hinges.

A basin-wide comparison of flexure at well locations with ultimate gas recovery is shown in Figure 31. Except for the Divide Creek Field (three wells with highest flexure and highest ultimate production), there is no relationship of production to flexure. There are areas of very low flexure with good production, as well as areas of high flexure with low production. It can be inferred, therefore, that production is not related to increased fracturing which is genetically related to the more subtle folds. The following hypothesis may explain why there may not be increased fracturing or production directly associated with the more subtle folds.

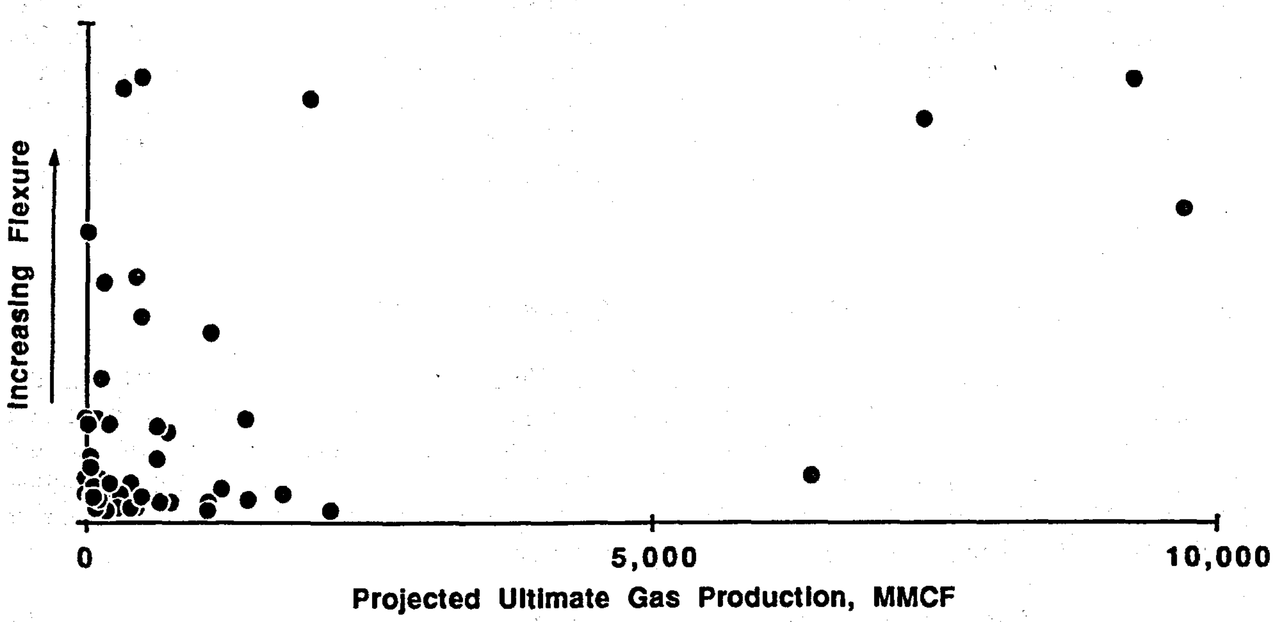



*Figure 31 Comparison of Projected Ultimate Gas Production of 64 Piceance Basin Wells with Structural Flexure at the Well Locations (Flexure is taken from Plate 15)*

Waechter and Johnson (1985) have interpreted a seismic section trending from the Debeque Field eastward through the Rulison Field to a point east of Silt, Colorado. It is their interpretation that there are several faults in pre-Cretaceous rocks that had reactivated movement during deposition of the Mancos Shale and Mesaverde Group. They suggest the Rulison anticline overlies a horst in Precambrian basement rocks which resulted in some Paleozoic rocks being eroded away during Permian time. Their interpretation shows:

- thicker Mancos Shale and Mesaverde Group in the deeper parts of the structural basin;
- differential Mancos Shale thickness across at least one fault;
- folding of the Mesaverde Group is spatially related to faults in older rocks and basement; and
- most faults are normal, grabben bounding faults.

It can be concluded from Waechter and Johnson's interpretation that subsidiary folds in the Mesaverde Group, such as the Rulison anticline, are old folds which are the products of differential subsidence along several faults during Piceance Basin subsidence and deposition.

The MWX wells are located on the flank of the Rulison anticline. Dominant fracture orientations in core from those wells are N75°W to N80°W, oblique to the anticline trend; however, the trend is not well constrained because of few marine penetrations. This orientation suggests, however, that the fractures are not fold-hinge-parallel (a-c type) extension fractures.

If, as has been previously described in this report, the MWX fractures parallel the basin axis and are related to uplift of deeply buried rocks near the basin axis (the Hogback system), then fractures at Rulison may have been superimposed across a pre-existing Rulison anticline and should also be present in the synclines. In this scenario, fractures (and production) would not be directly related to local flexure because fracturing is younger than flexure.

The Divide Creek Field is anomalous compared to other, more subtle folds such as the Rulison and Debeque anticlines. Its flexure is more intense, but its relative age is also important. In the Divide Creek anticline, the sequence of structural events was fortuitous to enhance fracture permeability. Its folding and thrusting took place after deposition; therefore, it is probably younger than the Rulison fold. If uplift of the Divide Creek anticline is similar in age to that of the White River Uplift (Lorenz, 1985), then the Mesaverde Group sediments could have already been fractured by the Hogback system fractures (or Piceance system) before uplift as they were along the Grand Hogback. Structural complexities of folding strain from thrusting and translation over ramps would have greatly increased the likelihood of having numerous cross fractures to the older regional system. Other folds that would have had a similar fracture history are those adjoining the Divide Creek anticline - Coal Basin and Wolf Creek, as well as the Ragged Mountain area because of its proximity to those structures.

Similarly, farther north, in the Piceance Creek Field, the Mesaverde Group is reported to be extremely fractured and the Piceance Creek anticline is compared with other thrust related structures, such as the Divide Creek anticline in structural style with faulting that extends to the present surface (Pittman and Sprunt, 1986). While adequate production has not been established in the Mesaverde Group in the Piceance Creek Field, a similar fracture style and history is implied for the Mesaverde and younger rocks.

The history of these structures indicates that the best production may be associated with the late Laramide thrusting and resultant folding which has been superimposed on the older, basin-wide Hogback system fractures. These features are found predominately along the eastern side of the Piceance Basin.

# 5.0 Conclusions

The extrapolation of detailed geological and engineering data from the Multiwell Experiment into the surrounding Piceance Basin has produced the following conclusions:

- Large areas of marine and paludal source rocks are presently hotter than 190°F, and gas is currently being generated in these areas. Source rocks at gas-generating temperatures are shallower in the southern part of the basin.

- Log data norms determined for MWX can be used to normalize data in the Central Basin area; however, these norms cannot be extrapolated basin wide.

- The TITEGAS log analysis model developed at MWX is able to characterize reservoir parameters basin wide by adjusting some of the constants input to the program.

- The geologic variability of the lenticular sands combined with the sparse well control prevented maps of reservoir characteristics to be prepared with a high degree of certainty.

- Cross sections of water resistivity and gas-water distribution support the basin model proposed by Masters (1979) of gas occurring down dip of water in the Piceance Basin.

- In the subsurface, two distinct, unidirectional, regional fracture systems occur within the Mesaverde Group in different parts of the basin.

- The best wells were completed with minimal or no stimulation.

- Log analysis of natural fractures indicated that the Southeast Uplift partitioned area has the greatest density of natural fractures followed by the Central Basin and Southwest Flank partitioned areas, respectively.

- The higher rates of gas production are in areas of known fractures and are believed to be the result of enhanced permeability along fractures. The highest production rates are probably the result of cross fractures of multiple sets developed during late Laramide uplift.

- The southern Piceance Basin is divided into three partitioned areas of different geological and production characteristics.

- Gas assisted gelled water or cross-linked gelled water hydraulic fracture stimulation treatments are superior to conventional gelled water stimulation treatments in naturally fractured reservoirs. This is due to the dissolved gas phase assisting with stimulation liquids recovery by dewatering the natural fracture system.

- Gas assisted gelled water or cross-linked gelled water hydraulic fracture stimulation treatments do not appear to result in greater ultimate gas recovery than conventional gelled water stimulation treatments in reservoirs that are not naturally fractured.

- Continuous removal of wellbore liquids with plunger lift equipment promotes fracture system dewatering and results in enhanced gas producing capabilities.

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# Plates

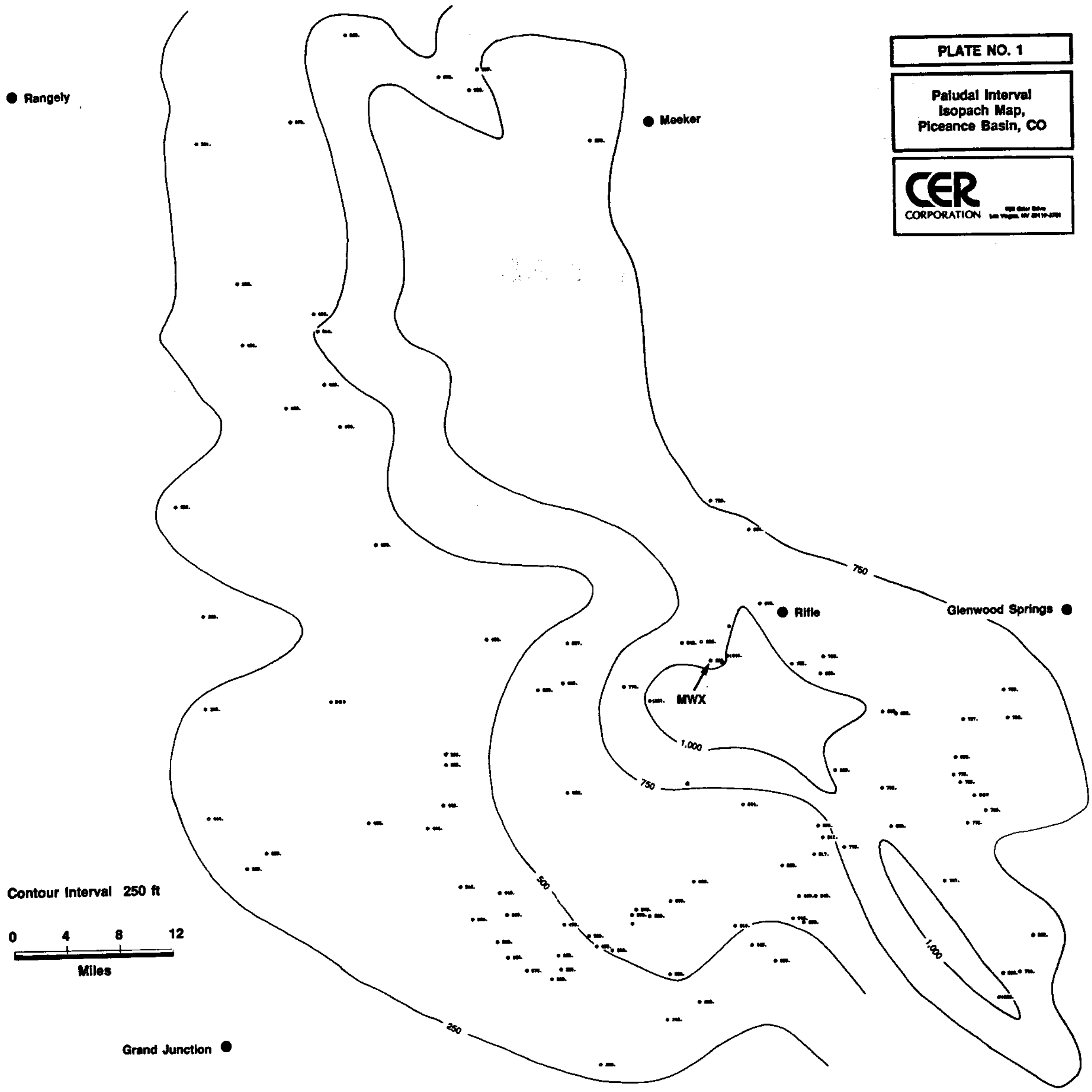


PLATE NO. 1
Paludal Interval
Isopach Map,
Piceance Basin, CO
CER
CORPORATION
Rangely
Meeker
Rifle
Glenwood Springs
MWX
Grand Junction
750
1,000
750
500
250
1,000
Contour Interval 250 ft
0
4
8
12
Miles

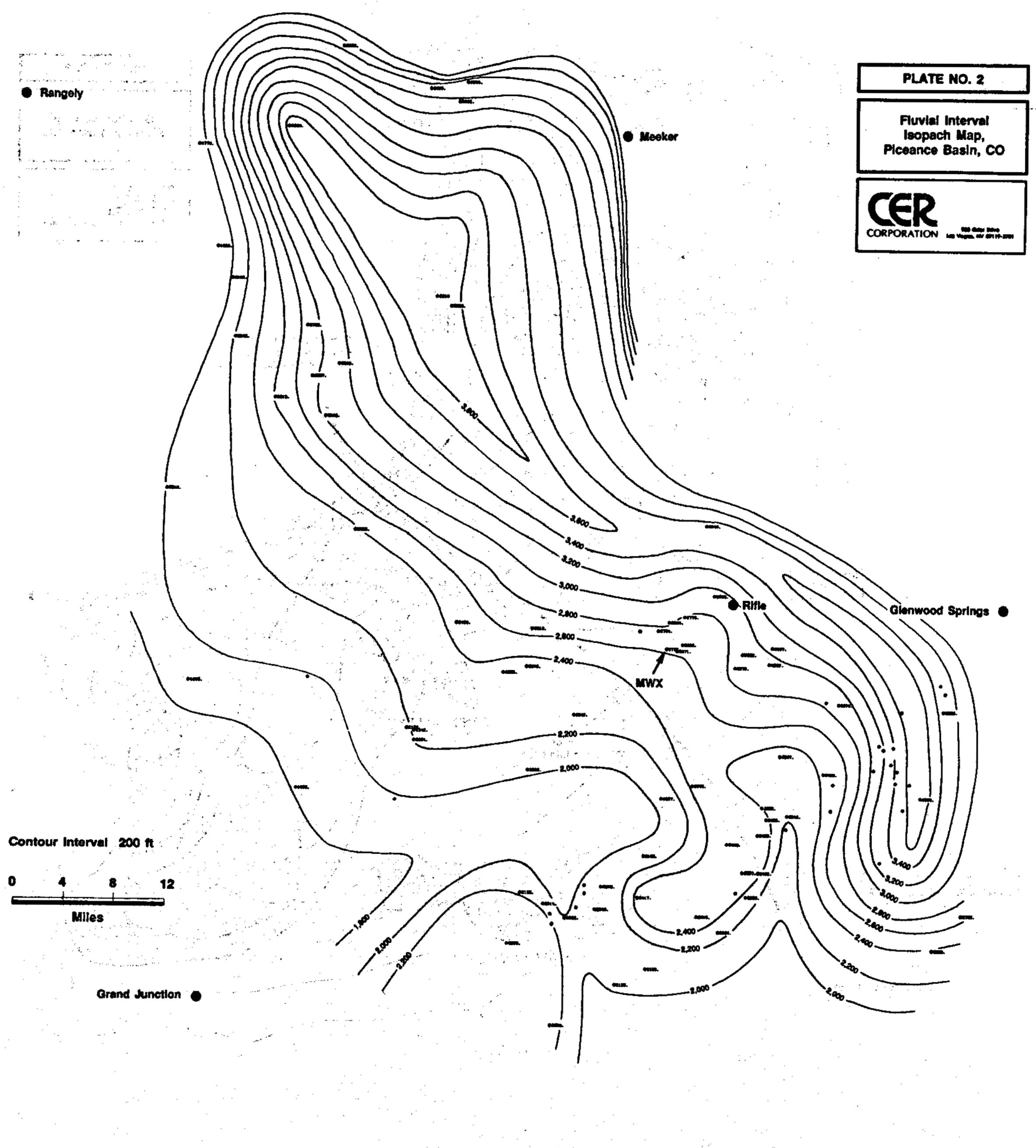


PLATE NO. 2
Fluvial Interval
Isopach Map,
Piceance Basin, CO
CER
CORPORATION
Rangely
Meeker
Rifle
Glenwood Springs
Grand Junction
MWX
3,800
3,600
3,400
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
Contour Interval 200 ft
0
4
8
12
Miles

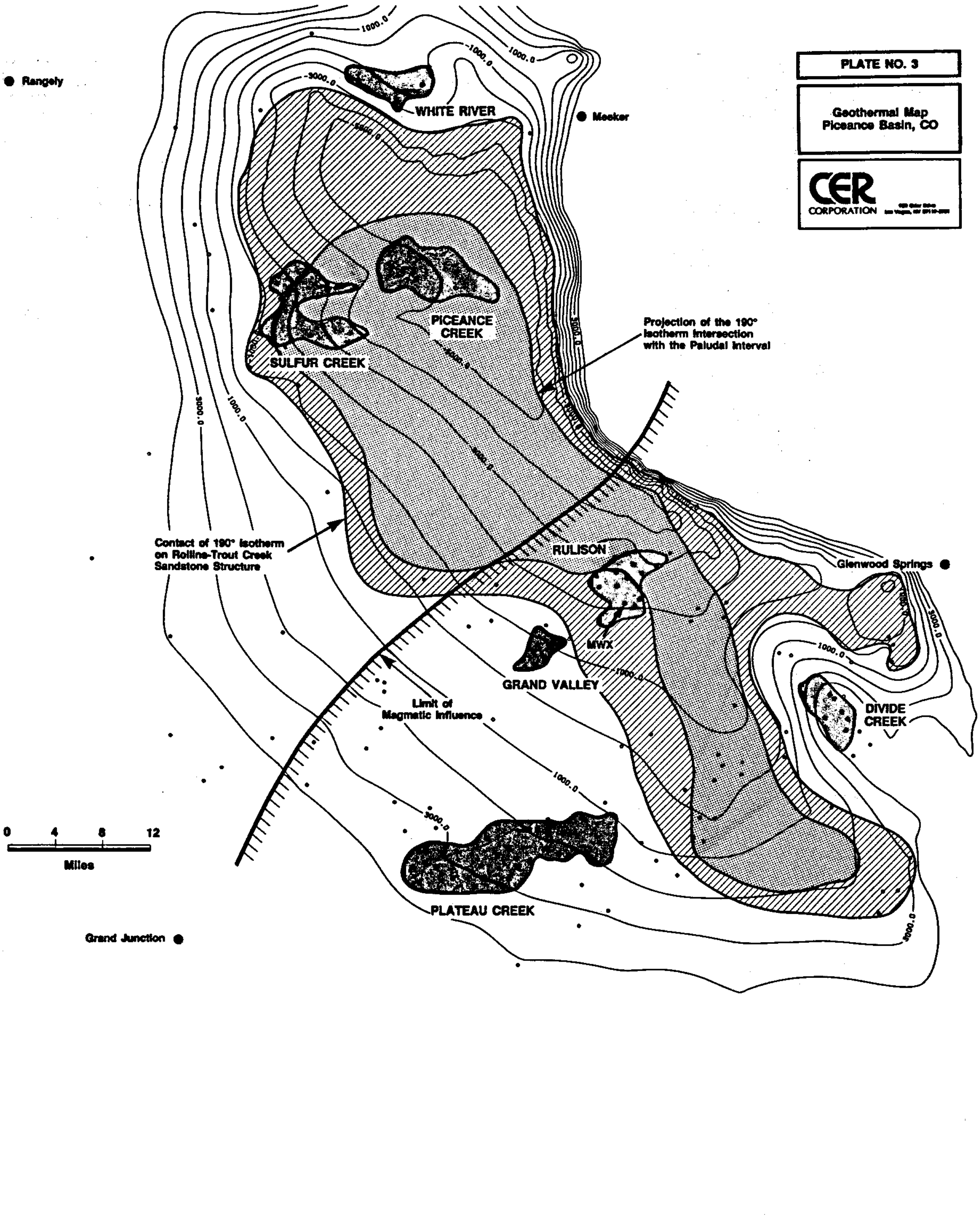


PLATE NO. 3
Geothermal Map
Piceance Basin, CO
CER
CORPORATION
Rangely
Meeker
WHITE RIVER
PICEANCE
CREEK
SULFUR CREEK
Projection of the 190° isotherm intersection with the Paludal interval
Contact of 190° isotherm on Rollins-Trout Creek Sandstone Structure
RULISON
Glenwood Springs
MWX
GRAND VALLEY
DIVIDE
CREEK
Limit of
Magmatic Influence
PLATEAU CREEK
Grand Junction
0
4
8
12
Miles

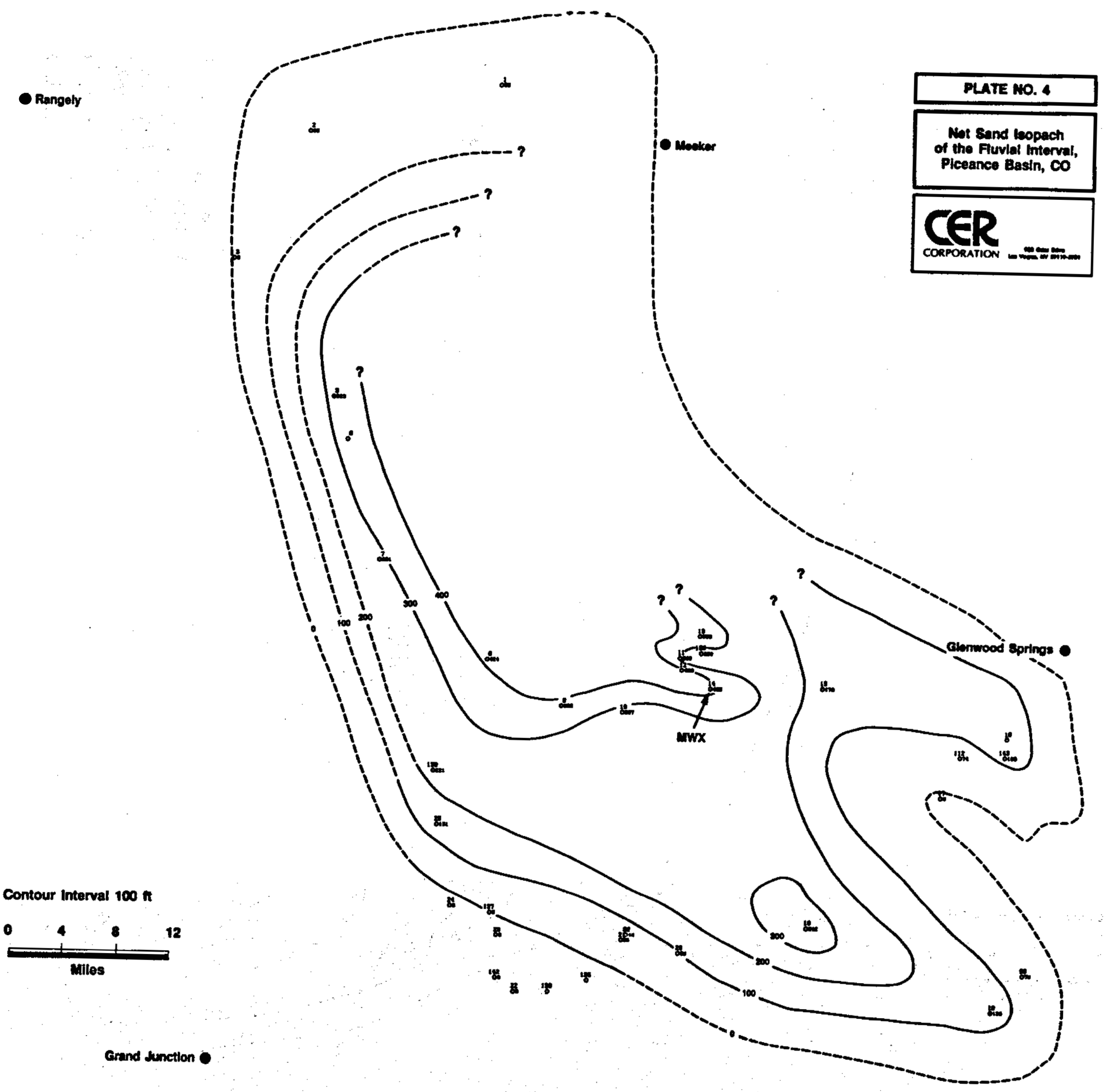


PLATE NO. 4
Net Sand Isopach of the Fluvial Interval, Piceance Basin, CO
CER
CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
0
100
200
300
400
Contour Interval 100 ft
0 4 8 12
Miles

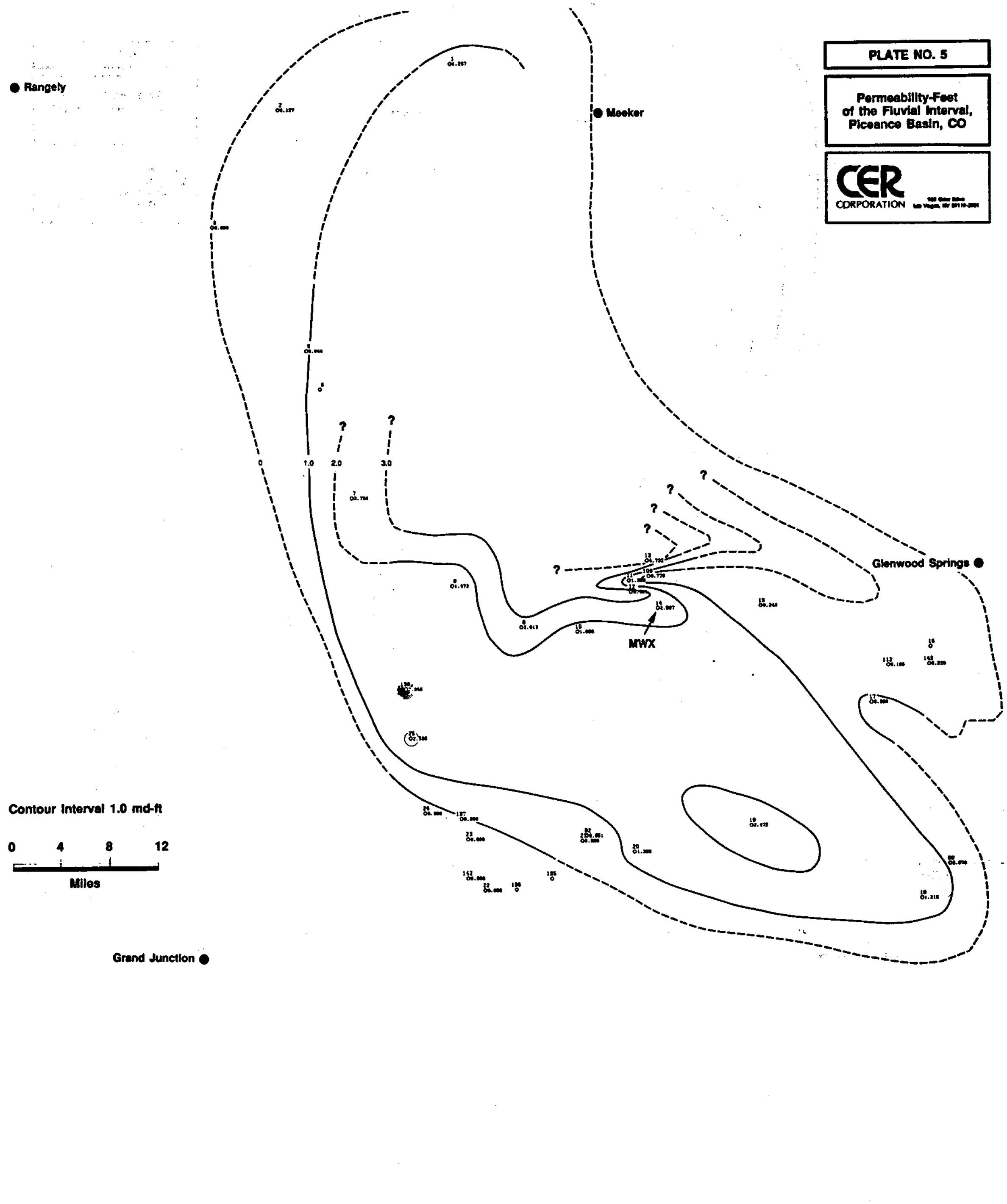


PLATE NO. 5
Permeability-Feet of the Fluvial Interval, Piceance Basin, CO
CER CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
Contour Interval 1.0 md-ft
0 4 8 12
Miles
0
1.0
2.0
3.0

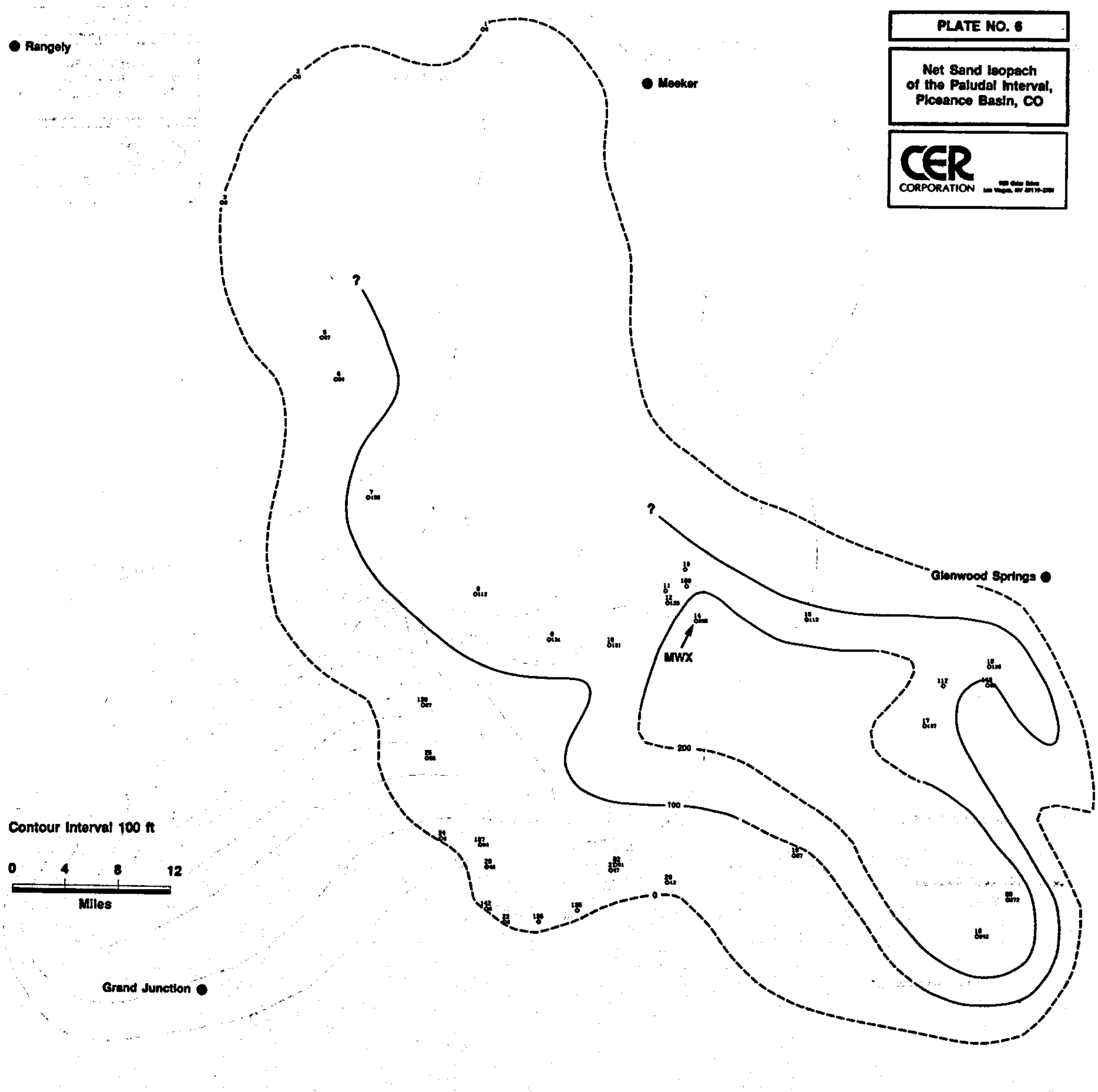


PLATE NO. 6
Net Sand Isopach
of the Paludal Interval,
Piceance Basin, CO
CER
CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
Contour Interval 100 ft
0
4
8
12
Miles
0
100
200

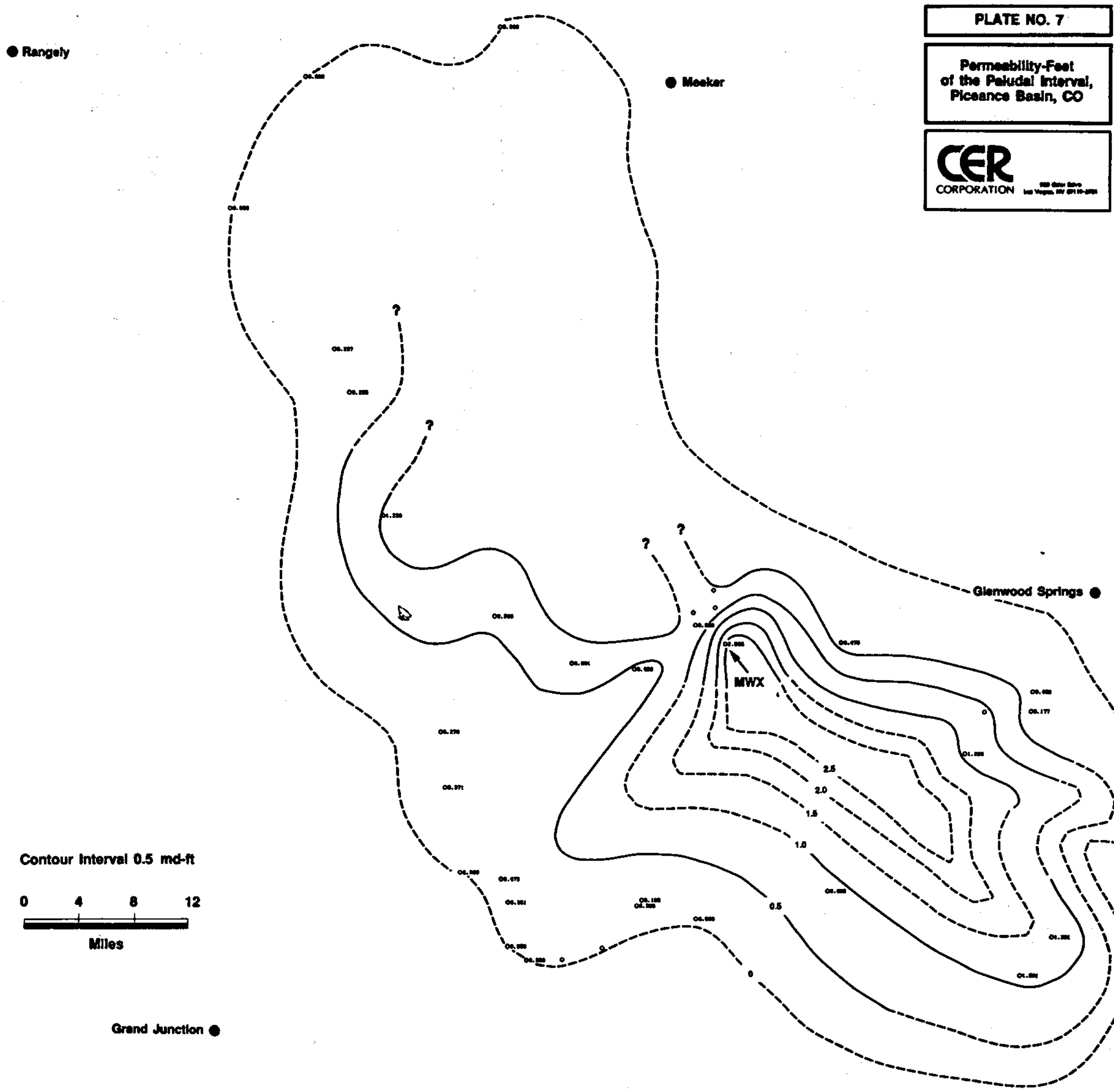


PLATE NO. 7
Permeability-Feet of the Paludal Interval, Piceance Basin, CO
CER CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
Contour Interval 0.5 md-ft
0 4 8 12
Miles
2.5
2.0
1.5
1.0
0.5

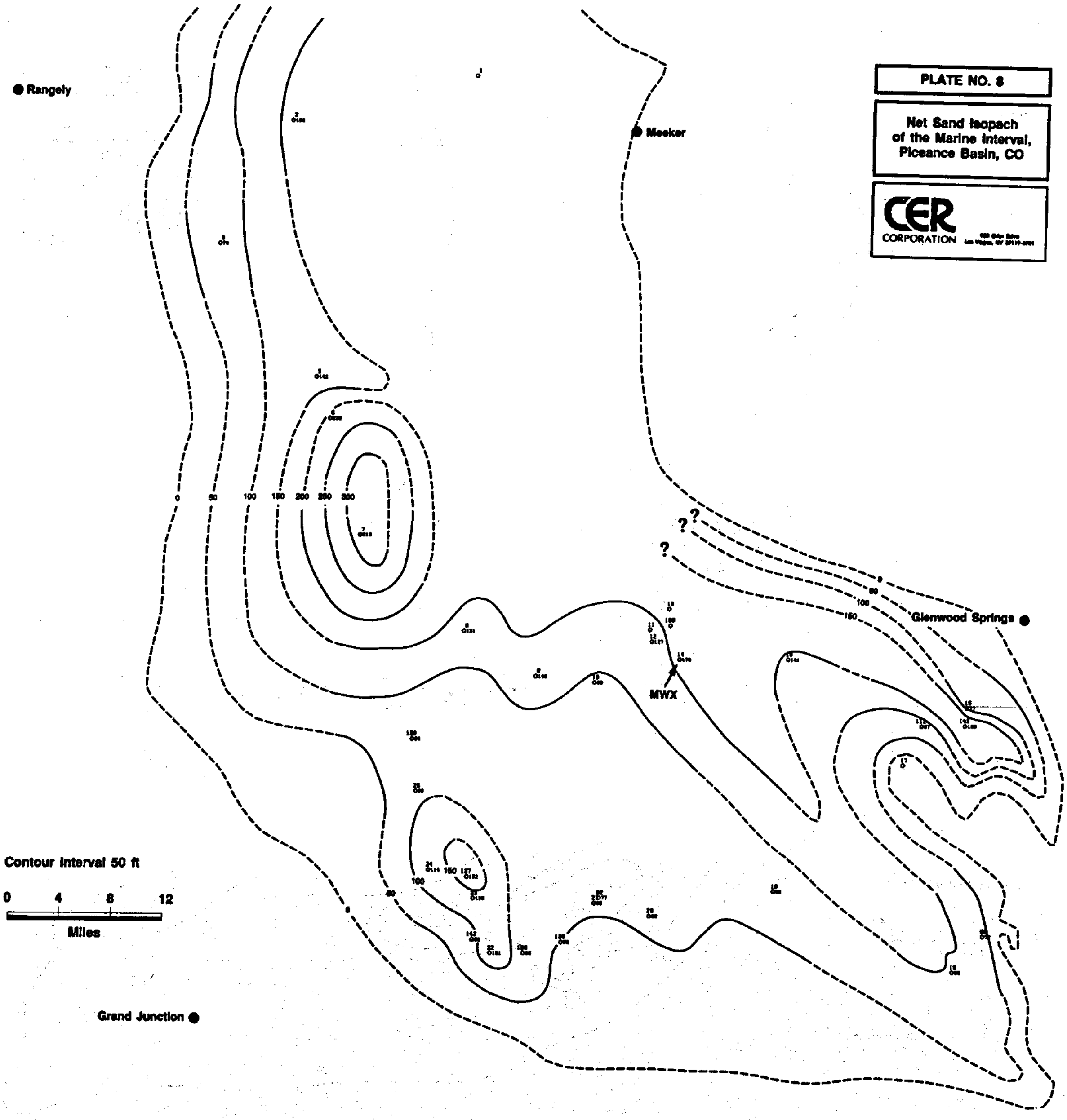


PLATE NO. 8
Net Sand Isopach of the Marine Interval, Piceance Basin, CO
CER CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
Contour Interval 50 ft
0 4 8 12
Miles
0
50
100
150
200
250
300
?

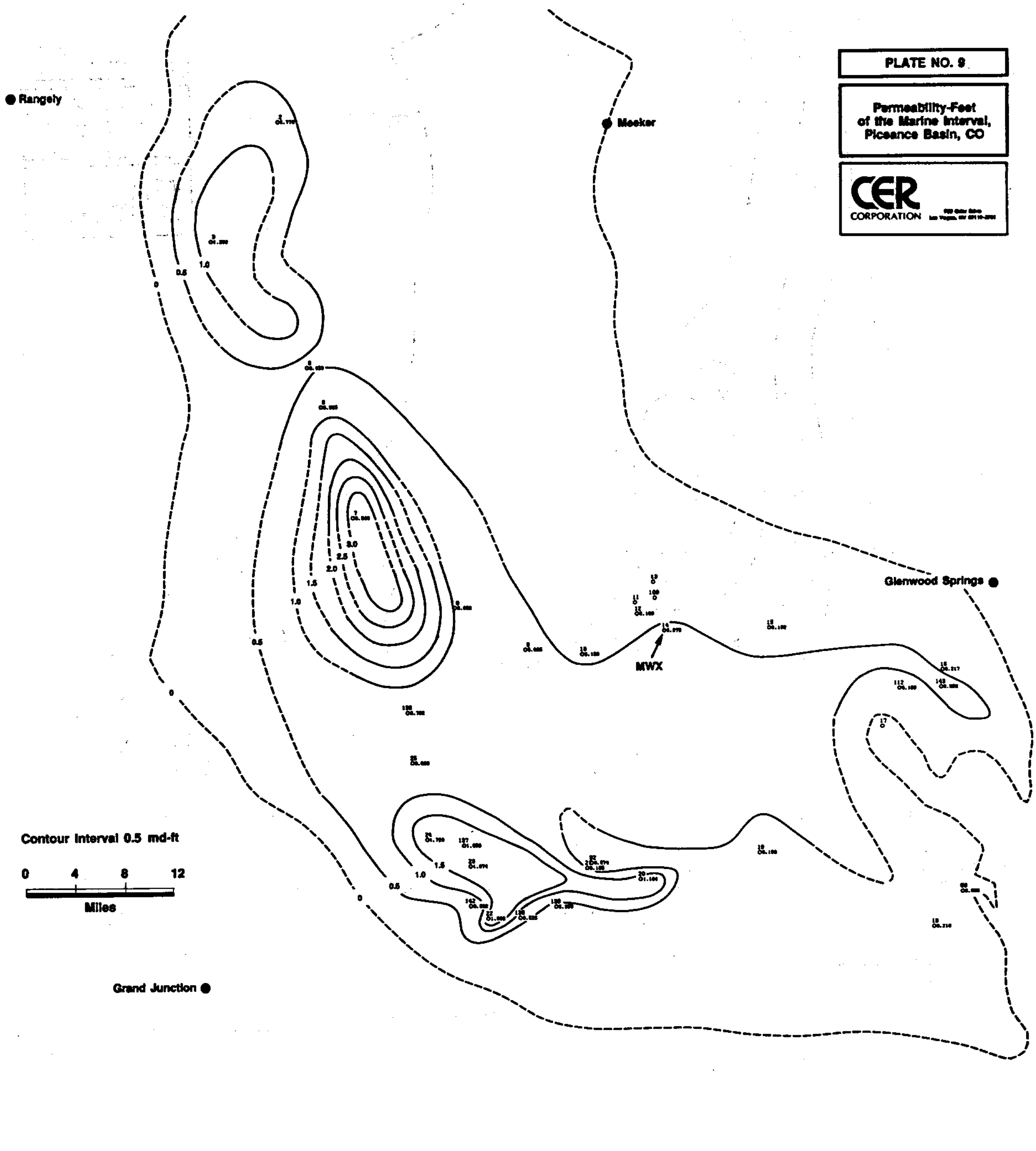
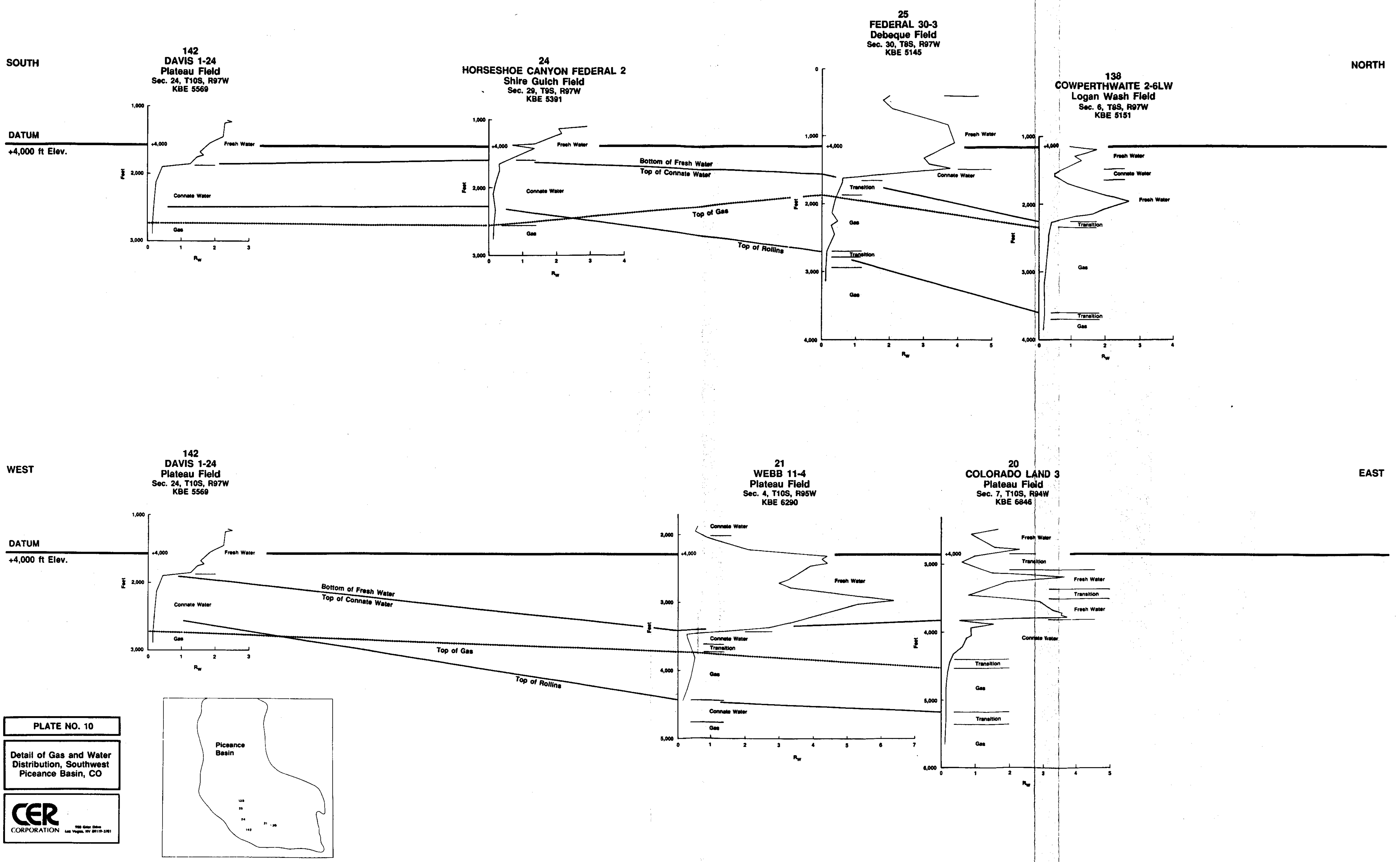


PLATE NO. 9
Permeability-Feet of the Marine Interval, Piceance Basin, CO
CER CORPORATION
Rangely
Meeker
Glenwood Springs
Grand Junction
MWX
Contour Interval 0.5 md-ft
0 4 8 12
Miles



SOUTH
NORTH
142
DAVIS 1-24
Plateau Field
Sec. 24, T10S, R97W
KBE 5569
24
HORSESHOE CANYON FEDERAL 2
Shire Gulch Field
Sec. 29, T9S, R97W
KBE 5391
25
FEDERAL 30-3
Debeque Field
Sec. 30, T8S, R97W
KBE 5145
138
COWPERTHWAITE 2-6LW
Logan Wash Field
Sec. 6, T8S, R97W
KBE 5151
DATUM
+4,000 ft Elev.
Fresh Water
Connate Water
Transition
Gas
Bottom of Fresh Water
Top of Connate Water
Top of Gas
Top of Rollins
Feet
Rw
WEST
EAST
21
WEBB 11-4
Plateau Field
Sec. 4, T10S, R95W
KBE 6290
20
COLORADO LAND 3
Plateau Field
Sec. 7, T10S, R94W
KBE 6846
Piceance Basin
PLATE NO. 10
Detail of Gas and Water Distribution, Southwest Piceance Basin, CO
CER CORPORATION

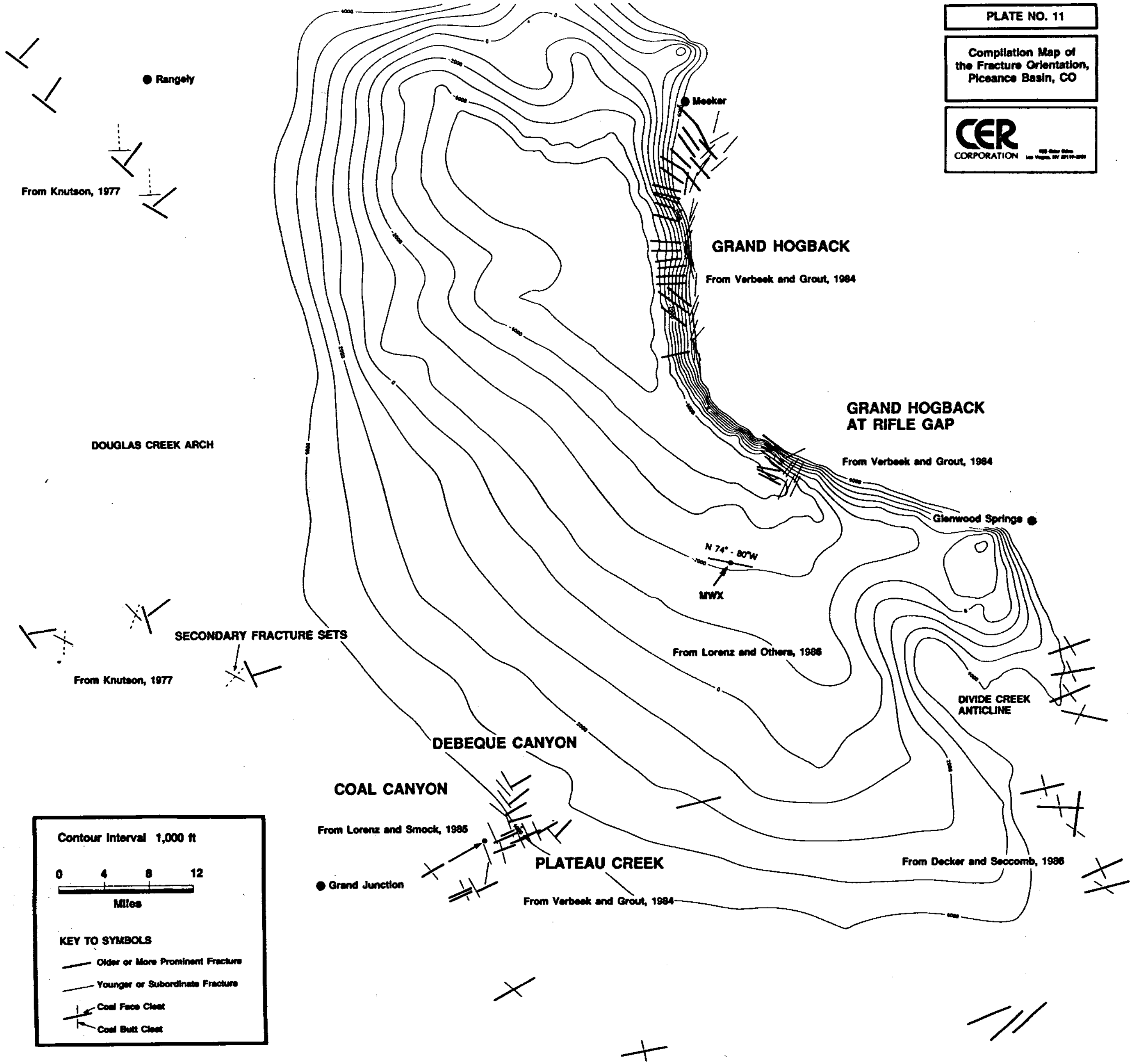
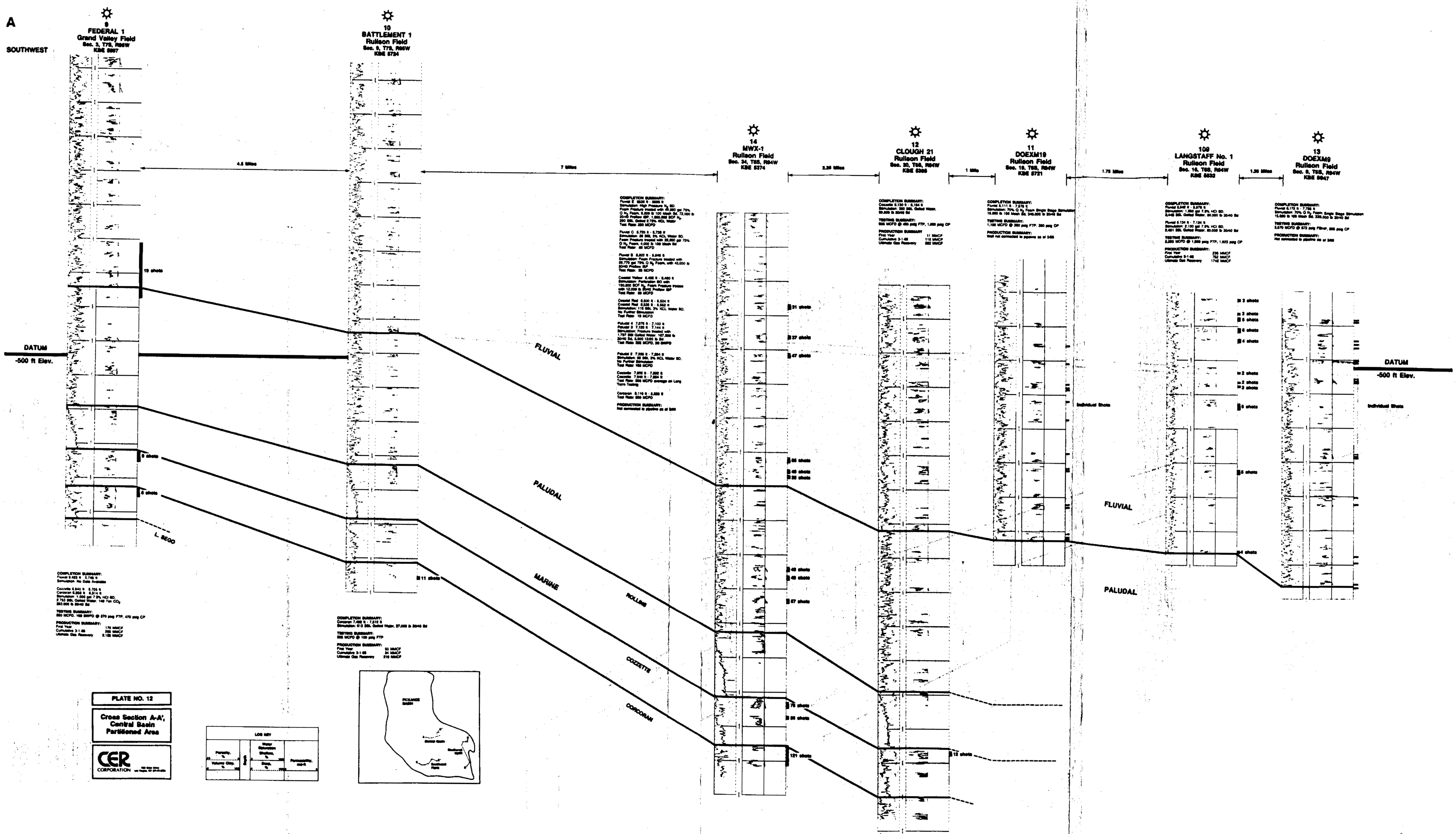
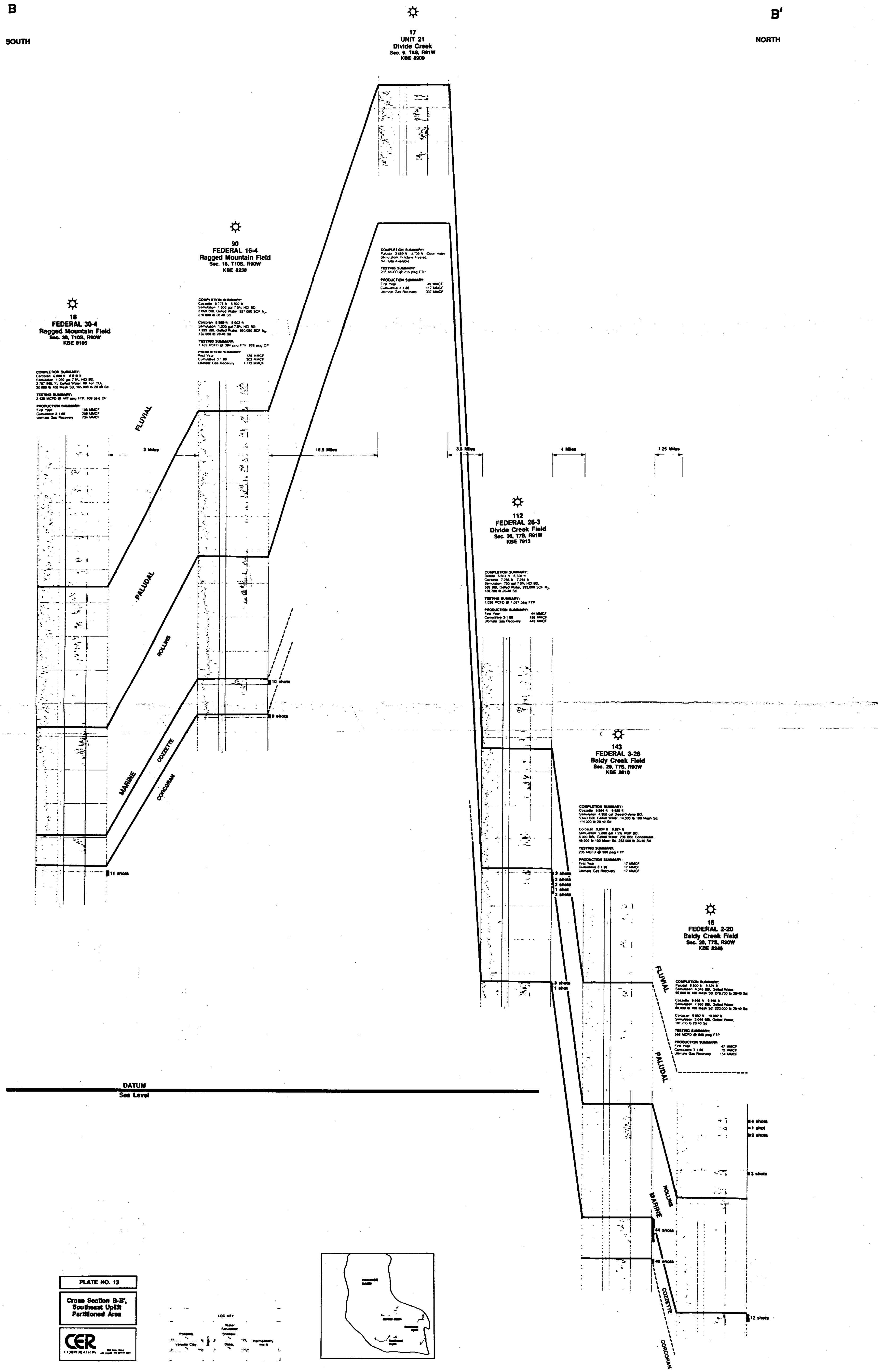
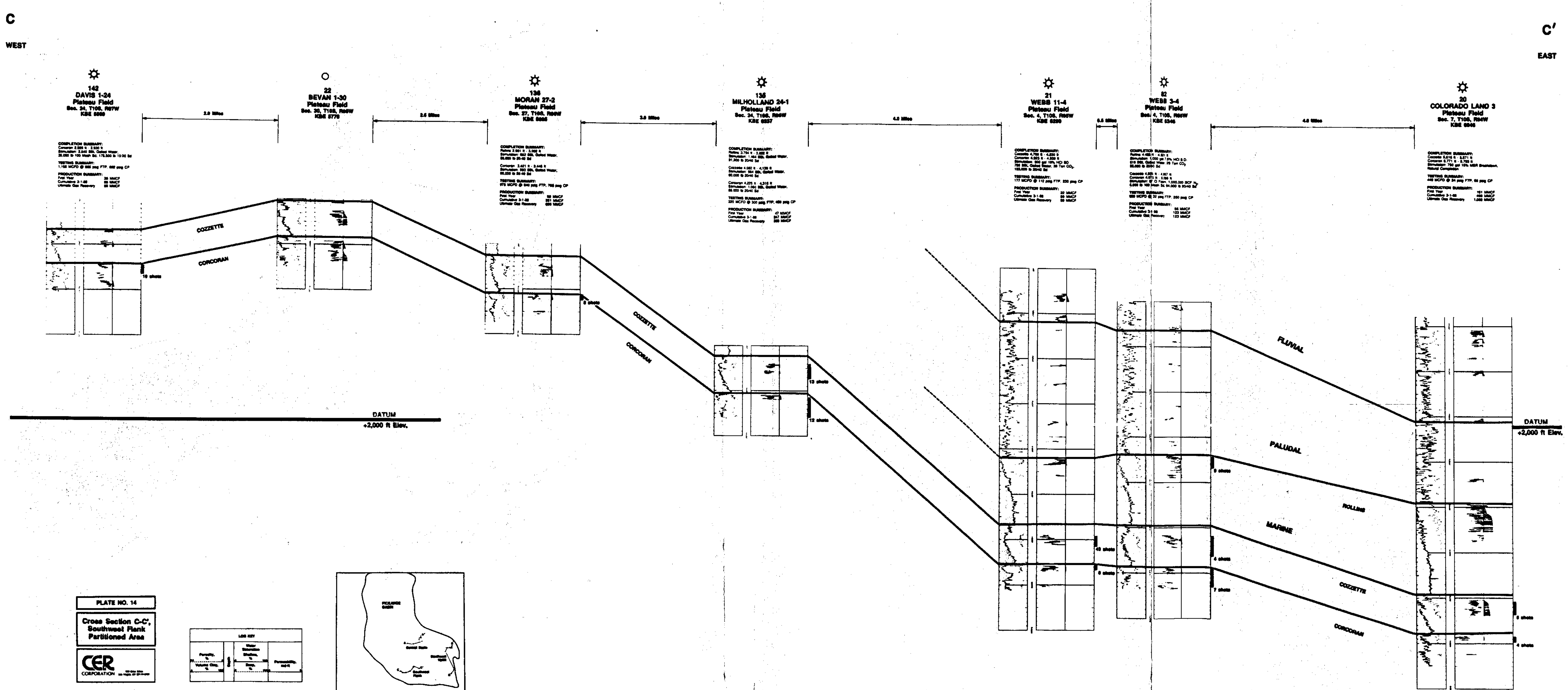


PLATE NO. 11
Compilation Map of the Fracture Orientation, Piceance Basin, CO
CER CORPORATION
Rangely
From Knutson, 1977
Meeker
GRAND HOGBACK
From Verbeek and Grout, 1984
GRAND HOGBACK AT RIFLE GAP
From Verbeek and Grout, 1984
DOUGLAS CREEK ARCH
Glenwood Springs
N 74° - 80°W
MWX
SECONDARY FRACTURE SETS
From Knutson, 1977
From Lorenz and Others, 1986
DIVIDE CREEK ANTICLINE
DEBEQUE CANYON
COAL CANYON
From Lorenz and Smock, 1985
PLATEAU CREEK
From Verbeek and Grout, 1984
Grand Junction
From Decker and Seccomb, 1986
Contour Interval 1,000 ft
0 4 8 12
Miles
KEY TO SYMBOLS
Older or More Prominent Fracture
Younger or Subordinate Fracture
Coal Face Cleat
Coal Butt Cleat


A
SOUTHWEST
9
FEDERAL 1
Grand Valley Field
10
BATTLEMENT 1
Rulison Field
7 Miles
14
MWX-1
Rulison Field
Sec. 34, T6S, R94W
KBE 5374
2.25 Miles
12
CLOUGH 21
Rulison Field
1 Mile
11
DOEXM19
Rulison Field
1.75 Miles
109
LANGSTAFF No. 1
Rulison Field
1.25 Miles
13
DOEXM9
Rulison Field
DATUM
-500 ft Elev.
FLUVIAL
PALUDAL
MARINE
ROLLINS
COZZETTE
CORCORAN
L. SEGO
Individual Shots
PLATE NO. 12
Cross Section A-A', Central Basin Partitioned Area
CER CORPORATION
LOG KEY


B
SOUTH
B'
NORTH
17
UNIT 21
Divide Creek
Sec. 9, T8S, R91W
KBE 8909
90
FEDERAL 16-4
Ragged Mountain Field
Sec. 16, T10S, R90W
KBE 8238
18
FEDERAL 30-4
Ragged Mountain Field
Sec. 30, T10S, R90W
KBE 8105
112
FEDERAL 26-3
Divide Creek Field
Sec. 26, T7S, R91W
KBE 7913
143
FEDERAL 3-28
Baldy Creek Field
Sec. 28, T7S, R90W
KBE 8610
16
FEDERAL 2-20
Baldy Creek Field
Sec. 20, T7S, R90W
KBE 8246
FLUVIAL
PALUDAL
ROLLINS
MARINE
COZZETTE
CORCORAN
3 Miles
15.5 Miles
3.5 Miles
4 Miles
1.25 Miles
10 shots
9 shots
11 shots
3 shots
2 shots
1 shot
44 shots
46 shots
12 shots
DATUM
Sea Level
PLATE NO. 13
Cross Section B-B',
Southeast Uplift
Partitioned Area
CER
CORPORATION
LOG KEY
Water Saturation
Porosity, %
Shallow, %
Volume Clay, %
Depth
Deep, %
Permeability, md-ft


C
WEST
C′
EAST
142
DAVIS 1-24
Plateau Field
Sec. 24, T10S, R97W
22
BEVAN 1-30
Plateau Field
136
MORAN 27-2
Plateau Field
Sec. 27, T10S, R96W
135
MILHOLLAND 24-1
Plateau Field
Sec. 24, T10S, R96W
21
WEBB 11-4
Plateau Field
Sec. 4, T10S, R95W
82
WEBB 3-4
Plateau Field
Sec. 4, T10S, R95W
20
COLORADO LAND 3
Plateau Field
Sec. 7, T10S, R94W
COZZETTE
CORCORAN
FLUVIAL
PALUDAL
ROLLINS
MARINE
DATUM
+2,000 ft Elev.
PLATE NO. 14
Cross Section C-C′, Southwest Flank Partitioned Area
CER CORPORATION
LOG KEY

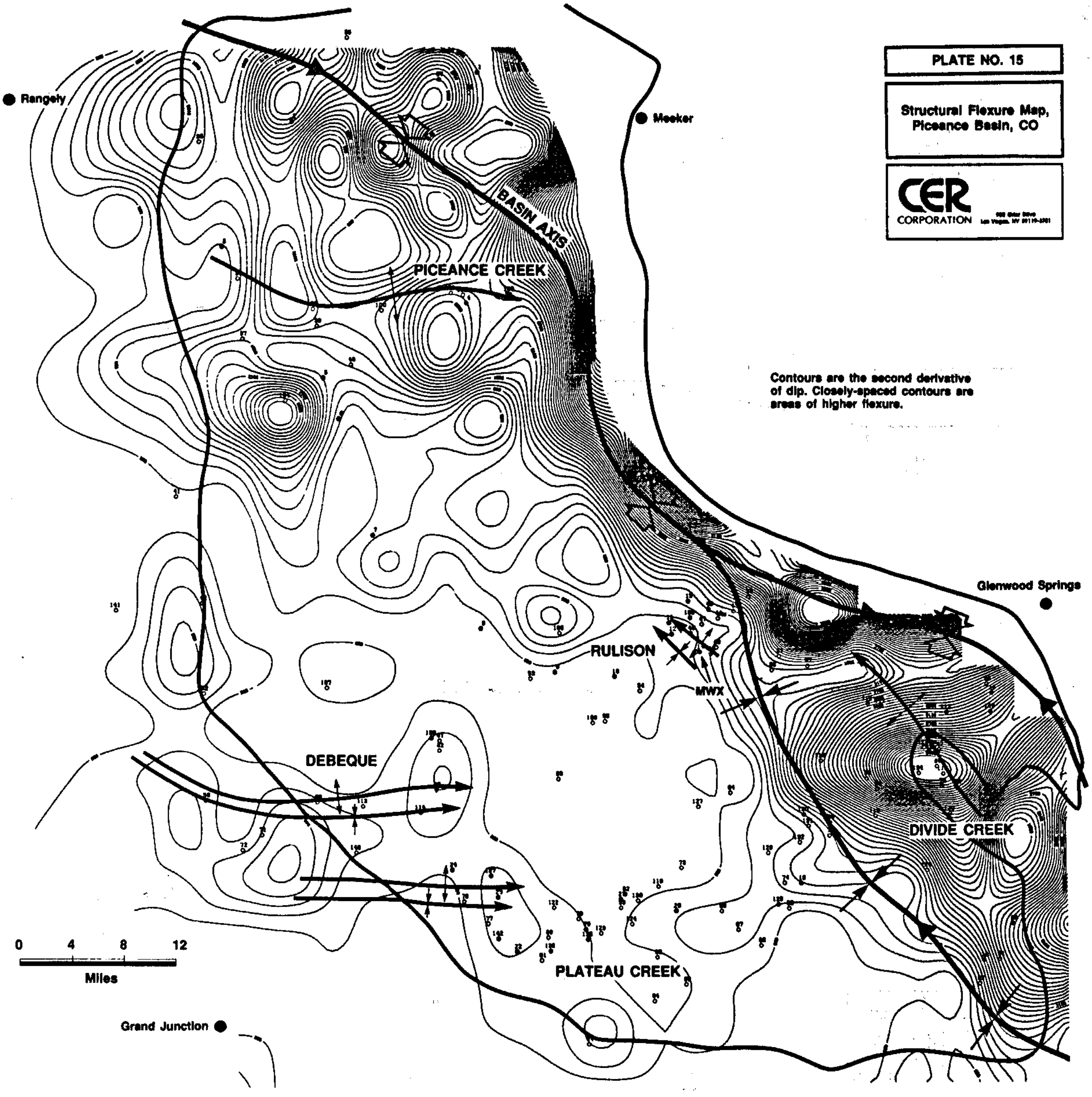


PLATE NO. 15
Structural Flexure Map, Piceance Basin, CO
CER CORPORATION
Contours are the second derivative of dip. Closely-spaced contours are areas of higher flexure.
Rangely
Meeker
BASIN AXIS
PICEANCE CREEK
Glenwood Springs
RULISON
MWX
DEBEQUE
DIVIDE CREEK
PLATEAU CREEK
Grand Junction
0 4 8 12
Miles

# Appendix 1

## DATA FOR DETERMINATION OF BOTTOMHOLE TEMPERATURE CORRECTIONS IN THE PICEANCE BASIN

## *Appendix 1 Data for Determination of Bottomhole Temperature Corrections in the Piceance Basin*

| Well Name (Location) | Depth (Feet) | Assumed Circulation Time (Hours) | Time Since Circulation Ceased (Hours) $t_e$ | BHT (°F) | Percent Correction | Equilibrium Temperatures (°F) | Correction $T_c$=(A-B ln $t_e$) BHT A=1.108 B=0.02056 (°F) | Middleton (°F) | USGS Correction (°F) | Horner Temperature (°F) |
|---|---|---|---|---|---|---|---|---|---|---|
| Cities Fed. A-5<br>26 2N 97W | 2,636 | 1 | 8 | 95 | 2.10 | | 101 | | 122 | 97 |
| RBN Govt. 398-10-1<br>10 3S 98W | 2,750 | 1 | 6.5 | 104 | 3.85 | | 111 | | 129 | 108 |
| Martin Fed. 1-3<br>1 10S 97W | 3,364 | 2 | 6.5 | 114 | 13.15 | | 122 | | 139 | 129 |
| Sun Divide Crk<br>Unit No. 21<br>9 8S 91W | 3,727 | 2 | 14 | 103 | 5.83 | | 109 | | 128 | 109 |
| N. West Battlement No. 1<br>9 7S 95W | 4,062 | 2 | 6 | 120 | 9.17 | | 129 | | 145 | 131 |
| Chevron 18-1 Fed.<br>18 7S 100W | 4,174 | 2 | 4 | 130 | 6.92 | | 140 | | 155 | 139 |
| Marathon DeBeque<br>Unit No. 2<br>34 8S 99W | 4,214 | 2 | 6 | 124 | 3.23 | | 133 | | 149 | 128 |
| CER RB-MHF-3<br>11 3S 98W | 5,503 | 3 | 30 | 172 | 0.58 | | 179 | | 212 | 173 |
| Tipperary USA 33-D-1<br>33 4S 100W | 5,722 | 3 | 7 | 131 | 6.11 | | 140 | | 156 | 139 |
| Exxon Old Man Mt. 2<br>36 10S 95W | 6,106 | 3 | 16 | 177 | 2.82 | | 186 | 194 | 217 | 182 |
| Piute Ragged Mt. Fed. 16-4<br>16 10S 90W | 6,263 | | | | | 172 | | | | |
| Coors USA 1-15-LG<br>15 9S 100W | 6,450 | 3 | 7.75 | 158 | 18.99 | | 168 | | 198 | 188 |
| CER MWX-3<br>34 6S 94W | 6,640 | 3 | 11.25 | 182 | 7.14 | 192 | 193 | | 222 | 195 |
| CER MWX-1<br>34 6S 94W | 6,836 | 3 | 14 | 170 | 7.65 | 185 | 179 | | 210 | 183 |

| Well Name (Location) | Depth (Feet) | Assumed Circulation Time (Hours) | Time Since Circulation Ceased (Hours) $t_e$ | BHT (°F) | Percent Correction | Equilibrium Temperatures (°F) | Correction $T_c$=(A-B ln $t_e$) BHT A=1.108 B=0.02056 (°F) | Middleton (°F) | USGS Correction (°F) | Horner Temperature (°F) |
|---|---|---|---|---|---|---|---|---|---|---|
| N. West Langstaff No. 1<br>16 6S 94W | 7,164 | 3 | 7.5 | 170 | 10.59 | | 181 | | 210 | 188 |
| Piute Ragged Mt. Fed. 30-4<br>30 10S 90W | 7,252 | | | | | 210 | | | | |
| Barrett Grandvalley-1<br>3 7S 96W | 7,276 | 3 | 10.5 | 176 | 2.84 | | 187 | | 216 | 181 |
| CER MWX-3<br>34 6S 94W | 7,474 | 3 | 71 | 210 | 2.38 | 217 | 214 | 228 | 260 | 215 |
| Fuelco Unit No. 2M<br>32 2N 96W | 7,483 | 3 | 5 | 149 | 4.03 | | 160 | | 174 | 155 |
| Barrett MV 10-23<br>23 6S 96W | 7,605 | 3 | 13 | 205 | 2.44 | | 216 | | 255 | 210 |
| N. West McNary No. 6<br>15 6S 94W | 7,755 | 3 | 11 | 188 | 5.86 | | 199 | | 228 | 194 |
| N. West Clough 7<br>16 6S 94W | 7,975 | 3 | 8 | 187 | 16.04 | | 199 | | 227 | 217 |
| CER MWX-1<br>34 6S 94W | 8,344 | 3 | 43 | 220 | 1.37 | 248 | 226 | 223 | 270 | 223 |
| Exxon Vega No. 1<br>9 10S 93W | 8,426 | 3 | 13.5 | 215 | 6.51 | | 227 | | 265 | 229 |
| Exxon Vega No. 3<br>10 10S 93W | 8,570 | 4 | 48 | 250 | 4.0 | | 257 | 266 | 290 | 260 |
| RBN Govt. 397-191-1<br>19 3S 97W | 8,615 | 4 | 7.5 | 192 | 2.08 | | 205 | | 232 | 196 |
| Arco Arco-Exxon 1-36<br>36 6S 93W | 8,649 | 4 | 8 | 200 | 1500 | | 213 | | 250 | 230 |
| Cleron Porter Mt. Fed 1-35<br>35 9S 92W | 8,796 | 4 | 26 | 209 | 0.96 | | 218 | 216 | 259 | 211 |

| Well Name (Location) | Depth (Feet) | Assumed Circulation Time (Hours) | Time Since Circulation Ceased (Hours) $t_e$ | BHT (°F) | Percent Correction | Equilibrium Temperatures (°F) | Correction $T_c=(A\text{-}B \ln t_e)$ BHT A=1.108 B=0.02056 (°F) | Middleton (°F) | USGS Correction (°F) | Horner Temperature (°F) |
|---|---|---|---|---|---|---|---|---|---|---|
| Exxon Vega No. 4<br>35 3S 93W | 8,989 | 4 | 13.5 | 234 | 13.68 | | 247 | | 284 | 266 |
| CGS 397-8-4<br>8 3S 97W | 9,884 | 4 | 9 | 192 | 3.13 | | 204 | | 232 | 198 |
| CSG 398-33-4<br>33 3S 98W | 9,924 | 4 | 9 | 222 | 2.25 | | 236 | | 272 | 227 |
| Exxon R.H. Ranch No. 1<br>34 6S 93W | 10,053 | 4 | 19 | 240 | 0.42 | | 251 | | 290 | 241 |
| Chorney E. Rangley 1-14<br>14 1N 100W | 10,300 | 4 | 23 | 211 | 9.00 | | 220 | 239 | 261 | 230 |
| Pacific Fed. 22-12<br>12 1N 99W | 12,200 | 5 | 39 | 218 | 2.29 | | 225 | 257 | 268 | 223 |
| Asmera Raven Ridge 1<br>29 2N 103W | 13,705 | 5 | 43 | 242 | 1.65 | | 249 | 255 | 292 | 246 |
| Mobil Unit T-52-19G<br>19 2S 96W | 19,705 | 6 | 31 | 376 | 1.33 | | 390 | 398 | 441 | 381 |

# Appendix 2

## MESAVERDE GAS WELL ACTIVITY IN THE PICEANCE BASIN

*Table A2-1 Active Mesaverde Gas Wells in the Piceance Basin*

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Baldy Creek | Federal 1-17 | 17 | 7S | 90W | Dome Petroleum | 192 | 348 | 489 | Marine | UGW |
| | Federal 2-20 | 20 | 7S | 90W | Dome Petroleum | 47 | 72 | 154 | Marine | UGW |
| | Federal 3-28 | 28 | 7S | 90W | Dome Petroleum | 17 | 17 | 17 | Marine | UGW |
| Baxter Pass | Gentry 7X-29-4-103 | 29 | 4S | 103W | Coseka Resources | 4 | 4 | 4 | Paludal | N2F |
| | Federal 8-31-4-103 | 31 | 4S | 103W | Coseka Resources | 43 | 108 | 108 | Fluvial | NON |
| Brush Creek | McDaniel 11-10 | 11 | 9S | 94W | Roundup Resources | 57 | 136 | 304 | Marine | N2F |
| | Griffith 14-2 | 14 | 9S | 94W | Roundup Resources | 53 | 133 | 264 | Paludal | N2F |
| Buzzard | Hill 29-2 | 29 | 9S | 94W | Norris Oil | 17 | 60 | 60 | Marine | N2F |
| | Hill 29-3 | 29 | 9S | 94W | Norris Oil | 17 | 41 | 41 | Fluvial | N2F |
| | Clyde 1 | 29 | 9S | 94W | Gasco | 0 | 387 | 387 | Marine | UGW |
| | Donner 1 | 24 | 9S | 95W | Fred Pool | 0 | 189 | 189 | Fluvial | UGW |
| | Donald 1 | 18 | 9S | 94W | Gasco | 0 | 379 | 413 | Paludal | OTH |
| | Hudson 1 | 19 | 9S | 94W | Gasco | 0 | 351 | 439 | Paludal | UGW |
| | Aitken 23-11 | 23 | 9S | 95W | Roundup Resources | 14 | 38 | 42 | Marine | N2F |
| | Aitken 26-4 | 26 | 9S | 95W | Roundup Resources | 7 | 18 | 18 | Marine | N2F |
| Buzzard Creek | T. C. Currier No. 1 | 12 | 9S | 93W | Union Oil | 0 | 4915 | 6404 | Marine | NON |
| | Buzzard Creek Unit 2 | 14 | 9S | 93W | Union Oil | 0 | 199 | 199 | Marine | OTH |
| | Carleton Currier 23-4 | 23 | 9S | 93W | Bow Valley | 40 | 66 | 66 | Marine | UGW |
| Calf Canyon | Federal 11-4A | 11 | 6S | 102W | American Resources | 2 | 2 | 2 | Paludal | NON |
| | Federal 24-1 | 24 | 6S | 102W | American Resources | 108 | 176 | 176 | Paludal | NON |
| Cathedral | Coors 3-10 | 10 | 3S | 100W | Twin Arrow | 1 | 2 | 2 | Paludal | NON |
| Coal Basin | Petro Lewis 11-90-7SE | 7 | 11S | 90W | Riviera Drilling | 31 | 55 | 55 | Marine | UGW |
| | Federal 10-8-11-90 | 8 | 11S | 90W | Piute Energy | 51 | 118 | 358 | Marine | AGW |
| Coon Hollow | Federal 25-3 | 25 | 8S | 98W | Piute Energy | 10 | 179 | 419 | Fluvial | NON |
| | Federal 25-4 | 25 | 8S | 98W | Piute Energy | 76 | 116 | 116 | Marine | AGW |
| | Coon Hollow 1 | 26 | 8S | 98W | Piute Energy | 10 | 41 | 41 | Fluvial | OTH |
| | Federal 35-2 | 35 | 8S | 98W | Piute Energy | 124 | 137 | 137 | Fluvial | NON |
| Debeque | Federal 29-2 | 29 | 8S | 97W | Piute Energy | 68 | 149 | 149 | Fluvial | AGW |
| | Federal 30-3 | 30 | 8S | 97W | Piute Energy | 52 | 164 | 290 | Fluvial | NON |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Divide Creek | Divide Creek Unit 2 | 26 | 8S | 91W | Sun Expl. & Prod. | 0 | 6570 | 7401 | Marine | NON |
| | Divide Creek Unit 9 | 22 | 8S | 91W | Sun Expl. & Prod. | 0 | 7352 | 9252 | Marine | NON |
| | Divide Creek Unit 10 | 27 | 8S | 91W | Sun Expl. & Prod. | 0 | 1514 | 1967 | Marine | OTH |
| | Divide Creek Unit A-15 | 20 | 8S | 91W | Sun Expl. & Prod. | 0 | 335 | 497 | Paludal | UGW |
| | Divide Creek Unit 21 | 9 | 8S | 91W | Sun Expl. & Prod. | 0 | 117 | 337 | Paludal | UGW |
| | Divide Creek Unit 1 | 36 | 8S | 91W | Sun Expl. & Prod. | 0 | 6456 | 9700 | Marine | NON |
| East Divide Creek | Rifle Boulton 1 | 23 | 7S | 91W | Piute Energy | 25 | 134 | 193 | Marine | AGW |
| | Federal 26-3 | 26 | 7S | 91W | Piute Energy | 44 | 158 | 445 | Marine | AGW |
| | Rifle Walton 25-2 | 25 | 7S | 91W | Piute Energy | 18 | 87 | 207 | Marine | AGW |
| Grand Valley | Federal MV-5-10 | 10 | 7S | 96W | Barrett Energy | 0 | 24 | 24 | Paludal | UGW |
| | Federal MV-9-32 | 32 | 6S | 94W | Barrett Energy | 67 | 112 | 1128 | Paludal | AGW |
| | Federal MV-12-3 | 3 | 7S | 96W | Barrett Energy | 30 | 116 | 2821 | Paludal | AGW |
| | Federal 1 | 3 | 7S | 96W | Barrett Energy | 170 | 255 | 2156 | Paludal | AGW |
| | Federal MV-11-11 | 11 | 7S | 96W | Barrett Energy | 32 | 56 | 690 | Paludal | AGW |
| | Arco Deep 1-27 | 27 | 6S | 97W | Barrett Energy | 0 | 15 | 102 | Paludal | AGW |
| | Federal MV-16-9 | 9 | 7S | 96W | Barrett Energy | 0 | 163 | 620 | Paludal | UGW |
| | Chevron MV-6-14 | 14 | 6S | 97W | Barrett Energy | 0 | 19 | 700 | Paludal | AGW |
| | Crystal Creek 3-30, No. 1A | 30 | 6S | 96W | Barrett Energy | 0 | 6 | 6 | Paludal | AGW |
| | Mobil MV-29-27 | 27 | 6S | 96W | Barrett Energy | 0 | 105 | 841 | Paludal | UGW |
| | Crystal Creek 1-23, No. 2A | 23 | 6S | 97W | Barrett Energy | 0 | 29 | 135 | Paludal | AGW |
| | Cathedral Creek 2-11, No. 2 | 11 | 7S | 97W | Barrett Energy | 0 | 37 | 445 | Paludal | UGW |
| | Mobil MV-23-27 | 27 | 6S | 97W | Barrett Energy | 0 | 77 | 523 | Paludal | UGW |
| | Arco MV-31-28 | 28 | 6S | 96W | Barrett Energy | 0 | 69 | 636 | Paludal | UGW |
| Hunters Canyon | Federal 25-1-81 | 25 | 8S | 101W | Walter S. Fees Jr. | 31 | 90 | 857 | Marine | NON |
| | Federal 7 | 30 | 8S | 100W | Walter S. Fees Jr. | 0 | 3346 | 4368 | Marine | NON |
| | Pure 1 | 24 | 8S | 101W | Walter S. Fees Jr. | 0 | 168 | 168 | Marine | NON |
| Logan Wash | Getty 1-7LW | 7 | 8S | 97W | Coors Energy | 1 | 2 | 2 | Marine | AGW |
| | Federal 1-12LW | 12 | 8S | 98W | Coors Energy | 27 | 76 | 81 | Marine | AGW |
| | Federal 1-5LW | 5 | 8S | 97W | Coors Energy | 10 | 22 | 22 | Marine | AGW |
| | Federal 1-6LW | 6 | 8S | 97W | Coors Energy | 19 | 49 | 49 | Marine | AGW |
| | Cowperthwaite 2-6LW | 6 | 8S | 97W | Coors Energy | 257 | 841 | 1433 | Fluvial | AGW |
| | Federal 1-1LW | 1 | 8S | 98W | Coors Energy | 19 | 54 | 54 | Marine | UGW |
| | Federal 1-31LW | 31 | 7S | 97W | Coors Energy | 27 | 76 | 184 | Marine | AGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Mamm Creek | R. H. Ranch 1 | 34 | 6S | 93W | Exxon | 67 | 85 | 1413 | Fluvial | N2F |
| | Federal 1-36 | 36 | 6S | 93W | Arco Oil & Gas | 41 | 90 | 90 | Fluvial | OTH |
| | Jake Schaeffer 1 | 12 | 7S | 93W | Hondo Oil & Gas | 0 | 622 | 622 | Fluvial | UGW |
| Plateau | Shear 30-12 | 30 | 9S | 95W | Roundup Resources | 20 | 53 | 53 | Marine | N2F |
| | Shear 30-4 | 30 | 9S | 95W | Roundup Resources | 11 | 29 | 29 | Marine | N2F |
| | Davis Dolly 36-1 | 36 | 9S | 95W | TXP | 109 | 203 | 380 | Marine | UGW |
| | Dolly 36-3 | 36 | 9S | 95W | TXP | 40 | 86 | 86 | Marine | AGW |
| | Sparks 36-4 | 36 | 9S | 95W | TXP | 78 | 167 | 261 | Marine | AGW |
| | Dolly 6-2 | 6 | 10S | 94W | TXP | 139 | 376 | 1107 | Marine | AGW |
| | Dolley 1 | 36 | 9S | 96W | Alta Energy | 1 | 1 | 1 | Marine | N2F |
| | Anderson 1 | 7 | 10S | 94W | Fuel Resources | 89 | 158 | 158 | Marine | N2F |
| | Colorado Land 3 | 7 | 10S | 94W | Fuel Resources | 161 | 498 | 1089 | Marine | NON |
| | Anderson Ranches 7-3 | 7 | 10S | 94W | TXP | 17 | 48 | 48 | Marine | UGW |
| | Ziegel 7-1 | 7 | 10S | 94W | TXP | 136 | 351 | 865 | Marine | AGW |
| | Colorado Land 1 | 17 | 10S | 94W | Fuel Resources | 124 | 354 | 956 | Marine | NON |
| | Colorado Land 2 | 17 | 10S | 94W | Fuel Resources | 116 | 341 | 1011 | Marine | NON |
| | Coury 18-2 | 18 | 10S | 94W | TXP | 80 | 195 | 435 | Marine | UGW |
| | Williams 18-3 | 18 | 10S | 94W | TXP | 77 | 151 | 151 | Marine | AGW |
| | Stites 12-3 | 3 | 10S | 95W | Chandler | 30 | 89 | 89 | Marine | AGW |
| | Gibson 4-3 | 3 | 10S | 95W | Coors Energy | 7 | 9 | 9 | Marine | N2F |
| | Hill 3X-3 | 3 | 10S | 95W | Coors Energy | 44 | 125 | 125 | Marine | AGW |
| | Long 1-3 | 3 | 10S | 95W | Coors Energy | 93 | 280 | 280 | Marine | AGW |
| | Nichols 1-32 | 32 | 10S | 95W | Coors Energy | 5 | 6 | 6 | Marine | N2F |
| | Walker 4-4 | 4 | 10S | 95W | Coors Energy | 12 | 18 | 18 | Marine | NON |
| | Webb 3-4 | 4 | 10S | 95W | Coors Energy | 55 | 123 | 123 | Marine | N2F |
| | Webb 11-4 | 4 | 10S | 95W | Coors Energy | 22 | 59 | 59 | Marine | AGW |
| | Walck 1-5 | 5 | 10S | 95W | Coors Energy | 20 | 56 | 56 | Marine | AGW |
| | Rogers Federal 1 | 6 | 10S | 95W | Exxon USA | 2 | 3 | 3 | Marine | N2F |
| | Big Creek Land & Cattle 2-7 | 7 | 10S | 95W | Coors Energy | 33 | 70 | 70 | Marine | AGW |
| | Boren 1-7 | 7 | 10S | 95W | Coors Energy | 9 | 31 | 31 | Marine | AGW |
| | Nichols 3-7 | 7 | 10S | 95W | Coors Energy | 56 | 129 | 129 | Marine | AGW |
| | Webb 2-9 | 9 | 10S | 95W | Coors Energy | 78 | 152 | 152 | Marine | AGW |
| | Big Creek Land & Cattle 1-9 | 9 | 10S | 95W | Gasco | 25 | 106 | 106 | Marine | UGW |
| | Carpenter 1-10 | 10 | 10S | 95W | Coors Energy | 57 | 81 | 81 | Marine | AGW |
| | Mooney 2-10 | 10 | 10S | 95W | Coors Energy | 34 | 80 | 80 | Marine | N2F |
| | Lyons 14-1 | 14 | 10S | 95W | Piute Energy | 62 | 135 | 206 | Marine | AGW |
| | Lyons 14-2 | 14 | 10S | 95W | Piute Energy | 31 | 52 | 52 | Marine | UGW |
| | Walck 14-3 | 14 | 10S | 95W | Piute Energy | 9 | 46 | 46 | Marine | UGW |
| | Carpenter 15-1 | 15 | 10S | 95W | Piute Energy | 47 | 112 | 170 | Marine | UGW |
| | Colorado Water 15-2 | 15 | 10S | 95W | Piute Energy | 20 | 51 | 51 | Marine | UGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Plateau (cont'd) | Kathlyn Young 1-15 | 15 | 10S | 95W | Piute Energy | 28 | 85 | 85 | Marine | UGW |
| | Kathlyn Young 4-15 | 15 | 10S | 95W | Piute Energy | 33 | 106 | 248 | Marine | UGW |
| | Big Creek Land & Cattle 16-1 | 16 | 10S | 95W | Piute Energy | 29 | 70 | 70 | Marine | NON |
| | Clydie Hall 1 | 17 | 10S | 95W | Gasco | 0 | 483 | 812 | Marine | UGW |
| | Wissel 17-1 | 17 | 10S | 95W | Bow Valley | 61 | 301 | 668 | Marine | UGW |
| | Wissel 17-2 | 17 | 10S | 95W | Bow Valley | 35 | 117 | 117 | Marine | UGW |
| | Thomas 1 | 18 | 10S | 95W | Apache | 0 | 487 | 520 | Marine | OTH |
| | Thomas 18-1 | 18 | 10S | 95W | Bow Valley | 50 | 230 | 348 | Marine | UGW |
| | Wallace Currier 19-1 | 19 | 10S | 95W | Bow Valley | 46 | 176 | 176 | Marine | UGW |
| | Wallace Currier 19-2 | 19 | 10S | 95W | Bow Valley | 54 | 279 | 350 | Marine | UGW |
| | Wallace Currier 19-3 | 19 | 10S | 95W | Bow Valley | 39 | 126 | 126 | Marine | UGW |
| | Reed 20-3 | 20 | 10S | 95W | Bow Valley | 20 | 46 | 46 | Marine | UGW |
| | Walck 23-2 | 23 | 10S | 95W | Piute Energy | 20 | 113 | 371 | Marine | AGW |
| | Nichols 1-29 | 29 | 10S | 95W | Coors Energy | 17 | 42 | 42 | Marine | AGW |
| | Wallace Currier 30-1 | 30 | 10S | 95W | Bow Valley | 135 | 490 | 490 | Marine | UGW |
| | Wallace Currier 30-2 | 30 | 10S | 95W | Bow Valley | 31 | 117 | 188 | Marine | UGW |
| | Milholland 30-3 | 30 | 10S | 95W | Bow Valley | 42 | 151 | 199 | Marine | UGW |
| | Nichols 1-31 | 31 | 10S | 95W | Coors Energy | 32 | 94 | 94 | Marine | UGW |
| | Currier 31-2 | 31 | 10S | 95W | Norris Oil | 21 | 65 | 65 | Marine | N2F |
| | Hittle-Ducray 1 | 1 | 10S | 96W | Texas Eastern Skyline | 49 | 99 | 99 | Marine | NON |
| | Livingston 11-2 | 11 | 10S | 96W | Norris Oil | 1 | 1 | 1 | Marine | N2F |
| | Skyline-Hittle 1 | 12 | 10S | 96W | El Paso Natural Gas | 0 | 1350 | 1350 | Marine | OTH |
| | B. Nichols 1 | 13 | 10S | 96W | Bow Valley | 0 | 345 | 370 | Marine | OTH |
| | Nichols 13-1 | 13 | 10S | 96W | Bow Valley | 50 | 253 | 441 | Marine | UGW |
| | Nichols 13-2 | 13 | 10S | 96W | Bow Valley | 54 | 203 | 274 | Marine | UGW |
| | Finch 13-3 | 13 | 10S | 96W | Norris Oil | 70 | 209 | 236 | Marine | UGW |
| | Pallaoro 14-2 | 14 | 10S | 96W | Bow Valley | 42 | 132 | 132 | Marine | UGW |
| | Barnard 1 | 14 | 10S | 96W | Norris Oil | 17 | 62 | 62 | Marine | OTH |
| | Currier 14-2 | 14 | 10S | 96W | Norris Oil | 51 | 298 | 437 | Marine | AGW |
| | Pallaoro 15-1 | 15 | 10S | 96W | Bow Valley | 15 | 36 | 36 | Marine | UGW |
| | Cooper 15-3 | 15 | 10S | 96W | Norris Oil | 9 | 21 | 21 | Marine | N2F |
| | Pallaoro 15-2 | 15 | 10S | 96W | Norris Oil | 6 | 15 | 15 | Marine | N2F |
| | Currier 14-16 | 16 | 10S | 96W | Coors Energy | 10 | 27 | 27 | Marine | AGW |
| | Ute 4-17 | 17 | 10S | 96W | Coors Energy | 20 | 52 | 52 | Marine | AGW |
| | Fetters 1-18 | 18 | 10S | 96W | Coors Energy | 20 | 41 | 41 | Marine | AGW |
| | Nystrom 2-18 | 18 | 10S | 96W | Coors Energy | 14 | 36 | 36 | Marine | AGW |
| | Fetters 1-19 | 19 | 10S | 96W | Coors Energy | 53 | 80 | 80 | Marine | AGW |
| | Fetters 2-19 | 19 | 10S | 96W | Coors Energy | 34 | 119 | 119 | Marine | AGW |
| | Fetters 3-19 | 19 | 10S | 96W | Coors Energy | 35 | 76 | 76 | Marine | AGW |
| | Shepard 3-20 | 20 | 10S | 96W | Coors Energy | 30 | 64 | 64 | Marine | AGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Plateau (cont'd) | Trahern 1-20 | 20 | 10S | 96W | Coors Energy | 18 | 48 | 48 | Marine | AGW |
| | Ute 1-20 | 20 | 10S | 96W | Coors Energy | 12 | 21 | 21 | Marine | AGW |
| | Currier 4-21 | 21 | 10S | 96W | Coors Energy | 21 | 47 | 47 | Marine | AGW |
| | Federal 21-2 | 21 | 10S | 96W | Norris Oil | 75 | 379 | 743 | Marine | UGW |
| | Nichols 21-3 | 21 | 10S | 96W | Norris Oil | 23 | 125 | 173 | Marine | AGW |
| | Johnson Etal 23-2 | 23 | 10S | 96W | Norris Oil | 53 | 419 | 754 | Marine | AGW |
| | Milholland 24-1 | 24 | 10S | 96W | Bow Valley | 47 | 247 | 389 | Marine | UGW |
| | Milholland 3 | 24 | 10S | 96W | Bow Valley | 47 | 339 | 445 | Marine | AGW |
| | H. R. Milholland Sr. 1 | 24 | 10S | 96W | Bow Valley | 0 | 1437 | 1835 | Marine | OTH |
| | Milholland 25-1 | 25 | 10S | 96W | Bow Valley | 31 | 98 | 98 | Marine | UGW |
| | Milholland 25-3 | 25 | 10S | 96W | Norris Oil | 39 | 343 | 737 | Marine | AGW |
| | U. S. Moran 26-1 | 26 | 10S | 96W | Norris Oil | 2 | 7 | 7 | Marine | AGW |
| | Hawkins 26-2 | 26 | 10S | 96W | Norris Oil | 19 | 56 | 56 | Marine | N2F |
| | Moran 27-2 | 27 | 10S | 96W | Bow Valley | 80 | 281 | 656 | Marine | UGW |
| | U. S. Moran 27-1 | 27 | 10S | 96W | Bow Valley | 0 | 1096 | 1307 | Marine | AGW |
| | Law 28-2 | 28 | 10S | 96W | Norris Oil | 49 | 161 | 372 | Marine | N2F |
| | U. S. Moran 28-1 | 28 | 10S | 96W | Norris Oil | 0 | 136 | 136 | Marine | OTH |
| | Bevan 1-29 | 29 | 10S | 96W | Coors Energy | 76 | 206 | 206 | Marine | AGW |
| | Wilson 2-29 | 29 | 10S | 96W | Coors Energy | 134 | 334 | 334 | Marine | AGW |
| | Zahm 29-3 | 29 | 10S | 96W | Norris Oil | 11 | 29 | 29 | Marine | NON |
| | Wood 1-32 | 32 | 10S | 96W | Coors Energy | 46 | 160 | 160 | Marine | AGW |
| | Wood 2-32 | 32 | 10S | 96W | Coors Energy | 45 | 106 | 106 | Marine | AGW |
| | Wood 3-32 | 32 | 10S | 96W | Coors Energy | 75 | 158 | 158 | Marine | AGW |
| | Federal 2-33 | 33 | 10S | 96W | Bow Valley | 3 | 4 | 4 | Marine | UGW |
| | Bull Basin Federal 1-35 | 35 | 10S | 96W | Mountain Fuel Supply | 8 | 14 | 14 | Marine | UGW |
| | Davis 1-24 | 24 | 10S | 97W | Coors Energy | 38 | 59 | 59 | Marine | UGW |
| | Meadors 1-24 | 24 | 10S | 97W | Coors Energy | 6 | 9 | 9 | Marine | UGW |
| Ragged Mountain | Federal 16-4 | 16 | 10S | 90W | Piute Energy | 128 | 303 | 1113 | Marine | AGW |
| | Federal 30-4 | 30 | 10S | 90W | Piute Energy | 105 | 209 | 734 | Marine | AGW |
| | Riviera Federal 10-90-31 SE | 31 | 10S | 90W | Piute Energy | 85 | 133 | 133 | Marine | UGW |
| | Riviera Federal 10-90-33 SE | 33 | 10S | 90W | Piute Energy | 46 | 49 | 49 | Marine | UGW |
| | Federal 10-90-34 SW | 34 | 10S | 90W | Riviera Drilling | 27 | 32 | 32 | Marine | UGW |
| | Riviera Federal 10-90-32 SE | 32 | 10S | 90W | Piute Energy | 32 | 38 | 38 | Marine | UGW |
| Rulison | Federal 3-94 | 3 | 7S | 94W | Mobil Oil | 0 | 341 | 341 | Fluvial | UGW |
| | Juhan Federal 1 | 35 | 6S | 94W | Mobil Oil | 0 | 750 | 1594 | Paludal | UGW |
| | Gross-Hahnewald 1 | 8 | 7S | 94W | Mobil Oil | 0 | 599 | 614 | Fluvial | NON |
| | Battlement 1 | 9 | 7S | 95W | Fina Oil & Chemical | 50 | 84 | 210 | Marine | UGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Rulison (cont'd) | Federal 14-95 | 14 | 7S | 95W | Mobil Oil | 0 | 75 | 75 | Marine | UGW |
| | Juhan 1 | 26 | 6S | 94W | Mobil Oil | 0 | 939 | 1197 | Fluvial | OTH |
| | Federal 28-95 | 28 | 7S | 95W | Mobil Oil | 0 | 372 | 372 | Fluvial | OTH |
| | Federal 29-95 | 29 | 7S | 95W | Mobil Oil | 0 | 905 | 1070 | Fluvial | NON |
| | Federal 30-95 | 30 | 7S | 95W | Mobil Oil | 0 | 92 | 92 | Fluvial | UGW |
| | Clough 14-24A | 14 | 6S | 94W | Mobil Oil | 55 | 94 | 397 | Paludal | N2F |
| | Clough 9 | 7 | 6S | 93W | Fina Oil & Chemical | 1 | 6 | 6 | Marine | UGW |
| | Clough 18 | 11 | 6S | 94W | Fina Oil & Chemical | 19 | 50 | 50 | Paludal | AGW |
| | Federal 8 | 12 | 6S | 94W | Fina Oil & Chemical | 21 | 66 | 66 | Fluvial | AGW |
| | Clough 13 | 13 | 6S | 94W | Fina Oil & Chemical | 7 | 47 | 47 | Fluvial | AGW |
| | Golding 4 | 14 | 6S | 94W | Fina Oil & Chemical | 57 | 180 | 251 | Fluvial | UGW |
| | Clough 20 | 15 | 6S | 94W | Fina Oil & Chemical | 68 | 194 | 288 | Paludal | UGW |
| | McNary 6 | 15 | 6S | 94W | Fina Oil & Chemical | 37 | 120 | 120 | Fluvial | AGW |
| | Clough 7 | 16 | 6S | 94W | Fina Oil & Chemical | 110 | 412 | 1070 | Paludal | AGW |
| | Langstaff 1 | 16 | 6S | 94W | Fina Oil & Chemical | 236 | 752 | 1742 | Fluvial | UGW |
| | Clough 19 | 20 | 6S | 94W | Fina Oil & Chemical | 134 | 331 | 473 | Paludal | UGW |
| | Clough 21 | 20 | 6S | 94W | Fina Oil & Chemical | 11 | 118 | 282 | Marine | UGW |
| | Clough 2 | 21 | 6S | 94W | Fina Oil & Chemical | 29 | 157 | 211 | Fluvial | UGW |
| | Clough 3 | 21 | 6S | 94W | Fina Oil & Chemical | 181 | 503 | 1000 | Fluvial | UGW |
| | Clough 26 | 22 | 6S | 94W | Fina Oil & Chemical | 33 | 134 | 301 | Fluvial | UGW |
| | NOSR Well No. 1XM19 | 19 | 6S | 94W | U.S. Department of Energy | 0 | 0 | 0 | Fluvial | N2F |
| | MWX-1 | 34 | 6S | 94W | Mobil Oil | 20 | 20 | 120 | Fluvial | N2F |
| Sheep Creek | Federal 1-17SC | 17 | 9S | 92W | Coors Energy | 63 | 113 | 113 | Marine | AGW |
| | Federal 1-16SC | 16 | 9S | 92W | Coors Energy | 44 | 82 | 82 | Marine | AGW |
| Shire Gulch | Federal 1-3 | 1 | 10S | 97W | Martin Exploration | 19 | 75 | 169 | Marine | OTH |
| | Federal 2-1 | 2 | 10S | 97W | Martin Exploration | 4 | 12 | 12 | Marine | AGW |
| | Federal 35-1 | 35 | 9S | 97W | Martin Exploration | 41 | 149 | 291 | Marine | OTH |
| | Federal 3-1 | 3 | 10S | 97W | Norris Oil | 5 | 15 | 15 | Marine | AGW |
| | Federal 9-1 | 9 | 10S | 97W | Norris Oil | 1 | 1 | 1 | Marine | N2F |
| | Federal 36-1 | 36 | 9S | 97W | Norris Oil | 69 | 439 | 717 | Marine | AGW |
| | Federal 36-3 | 36 | 9S | 97W | Norris Oil | 17 | 110 | 110 | Marine | N2F |
| | Federal 36-2 | 36 | 9S | 97W | Norris Oil | 12 | 41 | 41 | Marine | AGW |
| | Federal 36-4 | 36 | 9S | 97W | Norris Oil | 54 | 168 | 204 | Marine | N2F |
| | Federal 26-1 | 26 | 9S | 97W | Norris Oil | 49 | 190 | 482 | Marine | N2F |
| | Federal 26-2 | 26 | 9S | 97W | Norris Oil | 11 | 25 | 25 | Marine | NON |
| | Federal 25-1 | 25 | 9S | 97W | Norris Oil | 38 | 175 | 269 | Marine | AGW |
| | Federal 32-5 | 32 | 9S | 97W | Alta Energy | 7 | 21 | 21 | Marine | AGW |
| | Horseshoe Canyon Federal 4-21 | 21 | 9S | 97W | Koch Exploration | 1 | 119 | 119 | Marine | N2F |
| | Horseshoe Canyon Federal 3 | 28 | 9S | 97W | Koch Exploration | 80 | 330 | 330 | Marine | N2F |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Shire Gulch (cont'd) | Horseshoe Canyon Federal 2-27 | 27 | 9S | 97W | Koch Exploration | 21 | 66 | 66 | Marine | N2F |
| | Horseshoe Canyon Federal 4 | 33 | 9S | 97W | Koch Exploration | 25 | 65 | 65 | Marine | N2F |
| | Horseshoe Canyon Federal 2-31 | 31 | 9S | 97W | Koch Exploration | 28 | 35 | 35 | Marine | N2F |
| | Horseshoe Canyon Federal 1-28 | 28 | 9S | 97W | Koch Exploration | 24 | 70 | 70 | Marine | N2F |
| | Horseshoe Canyon Federal 2-28 | 28 | 9S | 97W | Koch Exploration | 115 | 383 | 383 | Marine | N2F |
| | Horseshoe Canyon Federal 2 | 29 | 9S | 97W | Koch Exploration | 95 | 357 | 357 | Marine | N2F |
| | Horseshoe Canyon Federal 1-33 | 33 | 9S | 97W | Koch Exploration | 58 | 103 | 103 | Marine | N2F |
| | Horseshoe Canyon Federal 5 | 34 | 9S | 97W | Koch Exploration | 42 | 127 | 127 | Marine | N2F |
| Sulphur Creek | Federal 5 | 19 | 2S | 97W | Equity Oil | 9 | 15 | 15 | Fluvial | OTH |
| | Federal 298-13-1 | 13 | 2S | 98W | Equity Oil | 2 | 2 | 2 | Fluvial | UGW |
| | Federal 7 | 19 | 2S | 98W | Equity Oil | 9 | 9 | 9 | Fluvial | UGW |
| | Federal 397-3-1 | 3 | 3S | 97W | Gordon Engineering | 23 | 47 | 47 | Paludal | UGW |
| | Federal 397-8-4 | 8 | 3S | 97W | CSG Exploration | 21 | 24 | 24 | Paludal | UGW |
| | Federal 398-17-4 | 17 | 3S | 98W | CSG Exploration | 81 | 198 | 629 | Fluvial | UGW |
| | Federal 398-10-1 | 10 | 3S | 98W | Rio Blanco Natural Gas | 24 | 54 | 54 | Fluvial | AGW |
| | Federal 398-33-4 | 33 | 3S | 98W | Rio Blanco Natural Gas | 38 | 81 | 81 | Marine | UGW |
| | Federal 498-4-1 | 4 | 4S | 98W | Rio Blanco Natural Gas | 40 | 84 | 84 | Fluvial | UGW |
| Vega | Vega Unit 1 | 9 | 10S | 93W | Exxon | 45 | 118 | 118 | Marine | UGW |
| | Vega Unit 2 | 34 | 9S | 93W | Exxon | 38 | 76 | 76 | Paludal | UGW |
| | Vegas Unit 4 | 35 | 9S | 93W | Exxon | 5 | 5 | 5 | Paludal | UGW |
| White River Dome | Federal Unit 1 | 28 | 2N | 96W | Fuel Resources | 18 | 30 | 30 | Fluvial | UGW |
| | Federal Unit 3M | 29 | 2N | 96W | Fuel Resources | 32 | 331 | 679 | Marine | NON |
| | Federal Unit 3 | 30 | 2N | 96W | Fuel Resources | 76 | 473 | 778 | Paludal | NON |
| | Federal 1 | 31 | 2N | 96W | Fuel Resources | 20 | 154 | 202 | Fluvial | NON |
| | Federal Unit 2M | 32 | 2N | 96W | Fuel Resources | 2 | 8 | 8 | Marine | UGW |
| | Federal A5 | 26 | 2N | 97W | Fuel Resources | 46 | 170 | 1025 | Paludal | NON |
| | Potter 1 | 30 | 2N | 96W | Fuel Resources | 9 | 76 | 76 | Fluvial | NON |

*Table A2-2 Permanently Abandoned Mesaverde Gas Wells in the Piceance Basin*

| Operator | Well Name | Location Sec. | Twp. | RNG | Field | Date PXA'd | Remarks |
|---|---|---|---|---|---|---|---|
| Austral Oil Co. | Hayward 25-95 | 25 | 7S | 95W | Rulison | 10/12/76 | |
| California Co. | Wolf Creek Unit 1 | 17 | 7S | 90W | Baldy Creek | 8/17/62 | |
| Gasco, Inc. | Hell's Gulch SESE | 22 | 8S | 92W | Hell's Gulch | 1/14/81 | |
| TXP, Inc. | Getty 28-1 2 | 8 | 8S | 97W | Debeque | 1985 | |
| TXP, Inc. | Getty 28-2 | 28 | 8S | 97W | Debeque | 1985 | |
| Piute Energy Co. | Calahan 29-1 | 29 | 8S | 97W | Debeque | 1985 | |
| Teton Energy Co. | Federal 26-3 | 26 | 8S | 98W | Coon Hollow | 8/30/84 | |
| Teton Energy Co. | Federal 26-4 | 26 | 8S | 98W | Coon Hollow | 8/30/84 | |
| Piute Energy Co. | Federal 1-34 | 34 | 8S | 98W | Coon Hollow | 10/25/84 | |
| Pacific Nat'l Gas | Rushmore USC | 5 | 9S | 92W | Sheep Creek | 10/03/64 | |
| Nat'l Fuels Corp. | USA-19-1-800 | 19 | 8S | 100W | Hunters Canyon | ? | |
| Unocal | Gunderson NENE | 20 | 9S | 93W | Buzzard Creek | 9/22/78 | |
| Gasco, Inc. | Lowther RP | 17 | 9S | 94W | Buzzard | 12/12/75 | |
| North America Gas Ltd. | Moss R | 20 | 9S | 94W | Buzzard | 8/23/68 | |
| Gasco, Inc. | Hawkins 1 | 33 | 9S | 94W | Buzzard | 7/01/79 | |
| Wacker Oil Inc. | Hawkins | 33 | 9S | 94W | Buzzard | 1966 | |
| North American Gas LTd. | McCurry 1 | 13 | 9S | 95W | Buzzard | 3/17/68 | |
| Wacker Oil Inc. | Garner, SENW | 36 | 9S | 95W | Buzzard | 4/15/66 | |
| Gasco, Inc. | Robbins | 11 | 10S | 94W | Buzzard | 8/01/79 | |
| TXP, Inc. | Gasco-Garner 1 | 36 | 9S | 95W | Buzzard | Standing | Junked Hole, to be PXA'd |
| Chandler Assoc. | N. Plateau CK 11-32 | 32 | 9S | 96W | Shire Gulch | 1986 | |
| Norris Oil Co. | Federal 4-1 | 4 | 10S | 97W | Shire Gulch | 11/13/79 | |
| Chandler Assoc. | States 15-33 | 33 | 9S | 95W | Plateau | 2/12/83 | |
| Gasco, Inc. | George B. Currier 1 | 19 | 10S | 95W | Plateau | 9/08/82 | |
| Gasco, Inc. | Alice E.Reed 1 | 30 | 10S | 95W | Plateau | 9/07/82 | |
| Gasco, Inc. | Johnson 23-1 | 23 | 10S | 96W | Plateau | 8/25/82 | |
| Chandler Assoc. | Barnard 6-22 | 22 | 10S | 96W | Plateau | 10/24/86 | |
| Chandler Assoc. | Kuehn 15-17 | 17 | 10S | 96W | Plateau | * | *Sold to landowner |
| Gasco, Inc. | Walker 1 | 11 | 10S | 96W | Plateau | 8/14/79 | |
| Chandler Assoc. | Woodring 8-16 | 16 | 10S | 96W | Plateau | 1985 | |
| Chandler Assoc. | Woodring 15-16 | 16 | 10S | 96W | Plateau | 1985 | |
| Chandler Assoc. | Bruton 5-17 | 17 | 10S | 96W | Plateau | * | *Sold to landowner |
| Gasco, Inc. | US Pickens 33-1 | 33 | 10S | 96W | Plateau | 8/25/80 | |
| Great Western | Mickelson Gov't 1 | 15 | 11S | 94W | Grand Mesa | 8/14/73 | |

## Table A2-3 Central Basin Partitioned Area Active Mesaverde Gas Wells

| FIELD | WELL NAME | LOCATION Sec | LOCATION TWP | LOCATION RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | GAS PRODUCTION MMCF Cum 3/88 | GAS PRODUCTION MMCF ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Buzzard Creek | T. C. Currier No. 1 | 12 | 9S | 93W | Union Oil | 0 | 4915 | 6404 | Marine | NON |
| | Buzzard Creek Unit 2 | 14 | 9S | 93W | Union Oil | 0 | 199 | 199 | Marine | OTH |
| | Carleton Currier 23-4 | 23 | 9S | 93W | Bow Valley | 40 | 66 | 66 | Marine | UGW |
| Grand Valley | Federal MV-5-10 | 10 | 7S | 96W | Barrett Energy | 0 | 24 | 24 | Paludal | UGW |
| | Federal MV-9-32 | 32 | 6S | 94W | Barrett Energy | 67 | 112 | 1128 | Paludal | AGW |
| | Federal MV-12-3 | 3 | 7S | 96W | Barrett Energy | 30 | 116 | 2821 | Paludal | AGW |
| | Federal 1 | 3 | 7S | 96W | Barrett Energy | 170 | 255 | 2156 | Paludal | AGW |
| | Federal MV-11-11 | 11 | 7S | 96W | Barrett Energy | 32 | 56 | 690 | Paludal | AGW |
| | Arco Deep 1-27 | 27 | 6S | 97W | Barrett Energy | 0 | 15 | 102 | Paludal | AGW |
| | Federal MV-16-9 | 9 | 7S | 96W | Barrett Energy | 0 | 163 | 620 | Paludal | UGW |
| | Chevron MV-6-14 | 14 | 6S | 97W | Barrett Energy | 0 | 19 | 700 | Paludal | AGW |
| | Crystal Creek 3-30, No. 1A | 30 | 6S | 96W | Barrett Energy | 0 | 6 | 6 | Paludal | AGW |
| | Mobil MV-29-27 | 27 | 6S | 96W | Barrett Energy | 0 | 105 | 841 | Paludal | UGW |
| | Crystal Creek 1-23, No. 2A | 23 | 6S | 97W | Barrett Energy | 0 | 29 | 135 | Paludal | AGW |
| | Cathedral Creek 2-11, No. 2 | 11 | 7S | 97W | Barrett Energy | 0 | 37 | 445 | Paludal | UGW |
| | Mobil MV-23-27 | 27 | 6S | 97W | Barrett Energy | 0 | 77 | 523 | Paludal | UGW |
| | Arco MV-31-28 | 28 | 6S | 96W | Barrett Energy | 0 | 69 | 636 | Paludal | UGW |
| Mamm Creek | R. H. Ranch 1 | 34 | 6S | 93W | Exxon | 67 | 85 | 1413 | Fluvial | N2F |
| | Federal 1-36 | 36 | 6S | 93W | Arco Oil & Gas | 41 | 90 | 90 | Fluvial | OTH |
| | Jake Schaeffer 1 | 12 | 7S | 93W | Hondo Oil & Gas | 0 | 622 | 622 | Fluvial | UGW |
| Rulison | Federal 3-94 | 3 | 7S | 94W | Mobil Oil | 0 | 341 | 341 | Fluvial | UGW |
| | Juhan Federal 1 | 35 | 6S | 94W | Mobil Oil | 0 | 750 | 1594 | Paludal | UGW |
| | Gross-Hahnewald 1 | 8 | 7S | 94W | Mobil Oil | 0 | 599 | 614 | Fluvial | NON |
| | Battlement 1 | 9 | 7S | 95W | Fina Oil & Chemical | 50 | 84 | 210 | Marine | UGW |
| | Federal 14-95 | 14 | 7S | 95W | Mobil Oil | 0 | 75 | 75 | Marine | UGW |
| | Juhan 1 | 26 | 6S | 94W | Mobil Oil | 0 | 939 | 1197 | Fluvial | OTH |
| | Federal 28-95 | 28 | 7S | 95W | Mobil Oil | 0 | 372 | 372 | Fluvial | OTH |
| | Federal 29-95 | 29 | 7S | 95W | Mobil Oil | 0 | 905 | 1070 | Fluvial | NON |
| | Federal 30-95 | 30 | 7S | 95W | Mobil Oil | 0 | 92 | 92 | Fluvial | UGW |
| | Clough 14-24A | 14 | 6S | 94W | Mobil Oil | 55 | 94 | 397 | Paludal | N2F |
| | MWX-1 | 34 | 6S | 94W | Mobil Oil | 20 | 20 | 120 | Fluvial | N2F |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Rulison (cont'd) | Clough 9 | 7 | 6S | 93W | Fina Oil & Chemical | 1 | 6 | 6 | Marine | UGW |
| | Clough 18 | 11 | 6S | 94W | Fina Oil & Chemical | 19 | 50 | 50 | Paludal | AGW |
| | Federal 8 | 12 | 6S | 94W | Fina Oil & Chemical | 21 | 66 | 66 | Fluvial | AGW |
| | Clough 13 | 13 | 6S | 94W | Fina Oil & Chemical | 7 | 47 | 47 | Fluvial | AGW |
| | Golding 4 | 14 | 6S | 94W | Fina Oil & Chemical | 57 | 180 | 251 | Fluvial | UGW |
| | Clough 20 | 15 | 6S | 94W | Fina Oil & Chemical | 68 | 194 | 288 | Paludal | UGW |
| | McNary 6 | 15 | 6S | 94W | Fina Oil & Chemical | 37 | 120 | 120 | Fluvial | AGW |
| | Clough 7 | 16 | 6S | 94W | Fina Oil & Chemical | 110 | 412 | 1070 | Paludal | AGW |
| | Langstaff 1 | 16 | 6S | 94W | Fina Oil & Chemical | 236 | 752 | 1742 | Fluvial | UGW |
| | Clough 19 | 20 | 6S | 94W | Fina Oil & Chemical | 134 | 331 | 473 | Paludal | UGW |
| | Clough 21 | 20 | 6S | 94W | Fina Oil & Chemical | 11 | 118 | 282 | Marine | UGW |
| | Clough 2 | 21 | 6S | 94W | Fina Oil & Chemical | 29 | 157 | 211 | Fluvial | UGW |
| | Clough 3 | 21 | 6S | 94W | Fina Oil & Chemical | 181 | 503 | 1000 | Fluvial | UGW |
| | Clough 26 | 22 | 6S | 94W | Fina Oil & Chemical | 33 | 134 | 301 | Fluvial | UGW |
| | NOSR Well No. 1XM19 | 19 | 6S | 94W | U.S. Department of Energy | 0 | 0 | 0 | Fluvial | N2F |
| Sheep Creek | Federal 1-17SC | 17 | 9S | 92W | Coors Energy | 63 | 113 | 113 | Marine | AGW |
| | Federal 1-16SC | 16 | 9S | 92W | Coors Energy | 44 | 82 | 82 | Marine | AGW |
| Vega | Vega Unit 1 | 9 | 10S | 93W | Exxon | 45 | 118 | 118 | Marine | UGW |
| | Vega Unit 2 | 34 | 9S | 93W | Exxon | 38 | 76 | 76 | Paludal | UGW |
| | Vegas Unit 4 | 35 | 9S | 93W | Exxon | 5 | 5 | 5 | Paludal | UGW |

Summary

Ultimate Gas Recovery

Average for 49 Wells 650 MMCF/Well
Average for 17 Fluvial Wells 562 MMCF/Well
Average for 22 Paludal Wells 672 MMCF/Well
Average for 10 Marine Wells 755 MMCF/Well

Note: Average for 9 Marine wells (omitting T.C. Currier #1) is 128 MMCF/well
MWX-1 not included in summary data.

*Table A2-4 Southeast Uplift Partitioned Area Active Mesaverde Gas Wells*

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF lst yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Baldy Creek | Federal 1-17 | 17 | 7S | 90W | Dome Petroleum | 192 | 348 | 489 | Marine | UGW |
| | Federal 2-20 | 20 | 7S | 90W | Dome Petroleum | 47 | 72 | 154 | Marine | UGW |
| | Federal 3-28 | 28 | 7S | 90W | Dome Petroleum | 17 | 17 | 17 | Marine | UGW |
| Coal Basin | Petro Lewis 11-90-7SE | 7 | 11S | 90W | Riviera Drilling | 31 | 55 | 55 | Marine | UGW |
| | Federal 10-8-11-90 | 8 | 11S | 90W | Piute Energy | 51 | 118 | 358 | Marine | AGW |
| Divide Creek | Divide Creek Unit 2 | 26 | 8S | 91W | Sun Expl. & Prod. | 0 | 6570 | 7401 | Marine | NON |
| | Divide Creek Unit 9 | 22 | 8S | 91W | Sun Expl. & Prod. | 0 | 7352 | 9252 | Marine | NON |
| | Divide Creek Unit 10 | 27 | 8S | 91W | Sun Expl. & Prod. | 0 | 1514 | 1967 | Marine | OTH |
| | Divide Creek Unit A-15 | 20 | 8S | 91W | Sun Expl. & Prod. | 0 | 335 | 497 | Paludal | UGW |
| | Divide Creek Unit 21 | 9 | 8S | 91W | Sun Expl. & Prod. | 0 | 117 | 337 | Paludal | UGW |
| | Divide Creek Unit 1 | 36 | 8S | 91W | Sun Expl. & Prod. | 0 | 6456 | 9700 | Marine | NON |
| East Divide Creek | Rifle Boulton 1 | 23 | 7S | 91W | Piute Energy | 25 | 134 | 193 | Marine | AGW |
| | Federal 26-3 | 26 | 7S | 91W | Piute Energy | 44 | 158 | 445 | Marine | AGW |
| | Rifle Walton 25-2 | 25 | 7S | 91W | Piute Energy | 18 | 87 | 207 | Marine | AGW |
| Ragged Mountain | Federal 16-4 | 16 | 10S | 90W | Piute Energy | 128 | 303 | 1113 | Marine | AGW |
| | Federal 30-4 | 30 | 10S | 90W | Piute Energy | 105 | 209 | 734 | Marine | AGW |
| | Riviera Federal 10-90-31 SE | 31 | 10S | 90W | Piute Energy | 85 | 133 | 133 | Marine | UGW |
| | Riviera Federal 10-90-33 SE | 33 | 10S | 90W | Piute Energy | 46 | 49 | 49 | Marine | UGW |
| | Federal 10-90-34 SW | 34 | 10S | 90W | Riviera Drilling | 27 | 32 | 32 | Marine | UGW |
| | Riviera Federal 10-90-32 SE | 32 | 10S | 90W | Piute Energy | 32 | 38 | 38 | Marine | UGW |

Summary

Ultimate Gas Recovery

Average for 20 Wells 1658 MMCF/Well
Average for 18 Marine Wells 1796 MMCF/Well
Average for 2 Paludal Wells 417 MMCF/Well

# Table A2-5 Southwest Flank Partitioned Area Active Mesaverde Gas Wells

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Brush Creek | McDaniel 11-10 | 11 | 9S | 94W | Roundup Resources | 57 | 136 | 304 | Marine | N2F |
| | Griffith 14-2 | 14 | 9S | 94W | Roundup Resources | 53 | 133 | 264 | Paludal | N2F |
| Buzzard | Hill 29-2 | 29 | 9S | 94W | Norris Oil | 17 | 60 | 60 | Marine | N2F |
| | Hill 29-3 | 29 | 9S | 94W | Norris Oil | 17 | 41 | 41 | Fluvial | N2F |
| | Clyde 1 | 29 | 9S | 94W | Gasco | 0 | 387 | 387 | Marine | UGW |
| | Donner 1 | 24 | 9S | 95W | Fred Pool | 0 | 189 | 189 | Fluvial | UGW |
| | Donald 1 | 18 | 9S | 94W | Gasco | 0 | 379 | 413 | Paludal | OTH |
| | Hudson 1 | 19 | 9S | 94W | Gasco | 0 | 351 | 439 | Paludal | UGW |
| | Aitken 23-11 | 23 | 9S | 95W | Roundup Resources | 14 | 38 | 42 | Marine | N2F |
| | Aitken 26-4 | 26 | 9S | 95W | Roundup Resources | 7 | 18 | 18 | Marine | N2F |
| Plateau | Shear 30-12 | 30 | 9S | 95W | Roundup Resources | 20 | 53 | 53 | Marine | N2F |
| | Shear 30-4 | 30 | 9S | 95W | Roundup Resources | 11 | 29 | 29 | Marine | N2F |
| | Davis Dolly 36-1 | 36 | 9S | 95W | TXP | 109 | 203 | 380 | Marine | UGW |
| | Dolly 36-3 | 36 | 9S | 95W | TXP | 40 | 86 | 86 | Marine | AGW |
| | Sparks 36-4 | 36 | 9S | 95W | TXP | 78 | 167 | 261 | Marine | AGW |
| | Dolly 6-2 | 6 | 10S | 94W | TXP | 139 | 376 | 1107 | Marine | AGW |
| | Dolley 1 | 36 | 9S | 96W | Alta Energy | 1 | 1 | 1 | Marine | N2F |
| | Anderson 1 | 7 | 10S | 94W | Fuel Resources | 89 | 158 | 158 | Marine | N2F |
| | Colorado Land 3 | 7 | 10S | 94W | Fuel Resources | 161 | 498 | 1089 | Marine | NON |
| | Anderson Ranches 7-3 | 7 | 10S | 94W | TXP | 17 | 48 | 48 | Marine | UGW |
| | Ziegel 7-1 | 7 | 10S | 94W | TXP | 136 | 351 | 865 | Marine | AGW |
| | Colorado Land 1 | 17 | 10S | 94W | Fuel Resources | 124 | 354 | 956 | Marine | NON |
| | Colorado Land 2 | 17 | 10S | 94W | Fuel Resources | 116 | 341 | 1011 | Marine | NON |
| | Coury 18-2 | 18 | 10S | 94W | TXP | 80 | 195 | 435 | Marine | UGW |
| | Williams 18-3 | 18 | 10S | 94W | TXP | 77 | 151 | 151 | Marine | AGW |
| | Stites 12-3 | 3 | 10S | 95W | Chandler | 30 | 89 | 89 | Marine | AGW |
| | Gibson 4-3 | 3 | 10S | 95W | Coors Energy | 7 | 9 | 9 | Marine | N2F |
| | Hill 3X-3 | 3 | 10S | 95W | Coors Energy | 44 | 125 | 125 | Marine | AGW |
| | Long 1-3 | 3 | 10S | 95W | Coors Energy | 93 | 280 | 280 | Marine | AGW |
| | Nichols 1-32 | 32 | 10S | 95W | Coors Energy | 5 | 6 | 6 | Marine | N2F |

| FIELD | WELL NAME | LOCATION | | | OPERATOR | GAS PRODUCTION MMCF | | | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sec | TWP | RNG | | 1st yr | Cum 3/88 | ULT | | |
| Plateau (cont'd) | Walker 4-4 | 4 | 10S | 95W | Coors Energy | 12 | 18 | 18 | Marine | NON |
| | Webb 3-4 | 4 | 10S | 95W | Coors Energy | 55 | 123 | 123 | Marine | N2F |
| | Webb 11-4 | 4 | 10S | 95W | Coors Energy | 22 | 59 | 59 | Marine | AGW |
| | Walck 1-5 | 5 | 10S | 95W | Coors Energy | 20 | 56 | 56 | Marine | AGW |
| | Rogers Federal 1 | 6 | 10S | 95W | Exxon USA | 2 | 3 | 3 | Marine | N2F |
| | Big Creek Land & Cattle 2-7 | 7 | 10S | 95W | Coors Energy | 33 | 70 | 70 | Marine | AGW |
| | Boren 1-7 | 7 | 10S | 95W | Coors Energy | 9 | 31 | 31 | Marine | AGW |
| | Nichols 3-7 | 7 | 10S | 95W | Coors Energy | 56 | 129 | 129 | Marine | AGW |
| | Webb 2-9 | 9 | 10S | 95W | Coors Energy | 78 | 152 | 152 | Marine | AGW |
| | Big Creek Land & Cattle 1-9 | 9 | 10S | 95W | Gasco | 25 | 106 | 106 | Marine | UGW |
| | Carpenter 1-10 | 10 | 10S | 95W | Coors Energy | 57 | 81 | 81 | Marine | AGW |
| | Mooney 2-10 | 10 | 10S | 95W | Coors Energy | 34 | 80 | 80 | Marine | N2F |
| | Lyons 14-1 | 14 | 10S | 95W | Piute Energy | 62 | 135 | 206 | Marine | AGW |
| | Lyons 14-2 | 14 | 10S | 95W | Piute Energy | 31 | 52 | 52 | Marine | UGW |
| | Walck 14-3 | 14 | 10S | 95W | Piute Energy | 9 | 46 | 46 | Marine | UGW |
| | Carpenter 15-1 | 15 | 10S | 95W | Piute Energy | 47 | 112 | 170 | Marine | UGW |
| | Colorado Water 15-2 | 15 | 10S | 95W | Piute Energy | 20 | 51 | 51 | Marine | UGW |
| | Kathlyn Young 1-15 | 15 | 10S | 95W | Piute Energy | 28 | 85 | 85 | Marine | UGW |
| | Kathlyn Young 4-15 | 15 | 10S | 95W | Piute Energy | 33 | 106 | 248 | Marine | UGW |
| | Big Creek Land & Cattle 16-1 | 16 | 10S | 95W | Piute Energy | 29 | 70 | 70 | Marine | NON |
| | Clydie Hall 1 | 17 | 10S | 95W | Gasco | 0 | 483 | 812 | Marine | UGW |
| | Wissel 17-1 | 17 | 10S | 95W | Bow Valley | 61 | 301 | 668 | Marine | UGW |
| | Wissel 17-2 | 17 | 10S | 95W | Bow Valley | 35 | 117 | 117 | Marine | UGW |
| | Thomas 1 | 18 | 10S | 95W | Apache | 0 | 487 | 520 | Marine | OTH |
| | Thomas 18-1 | 18 | 10S | 95W | Bow Valley | 50 | 230 | 348 | Marine | UGW |
| | Wallace Currier 19-1 | 19 | 10S | 95W | Bow Valley | 46 | 176 | 176 | Marine | UGW |
| | Wallace Currier 19-2 | 19 | 10S | 95W | Bow Valley | 54 | 279 | 350 | Marine | UGW |
| | Wallace Currier 19-3 | 19 | 10S | 95W | Bow Valley | 39 | 126 | 126 | Marine | UGW |
| | Reed 20-3 | 20 | 10S | 95W | Bow Valley | 20 | 46 | 46 | Marine | UGW |
| | Walck 23-2 | 23 | 10S | 95W | Piute Energy | 20 | 113 | 371 | Marine | AGW |
| | Nichols 1-29 | 29 | 10S | 95W | Coors Energy | 17 | 42 | 42 | Marine | AGW |
| | Wallace Currier 30-1 | 30 | 10S | 95W | Bow Valley | 135 | 490 | 490 | Marine | UGW |
| | Wallace Currier 30-2 | 30 | 10S | 95W | Bow Valley | 31 | 117 | 188 | Marine | UGW |
| | Milholland 30-3 | 30 | 10S | 95W | Bow Valley | 42 | 151 | 199 | Marine | UGW |
| | Nichols 1-31 | 31 | 10S | 95W | Coors Energy | 32 | 94 | 94 | Marine | UGW |
| | Currier 31-2 | 31 | 10S | 95W | Norris Oil | 21 | 65 | 65 | Marine | N2F |
| | Hittle-Ducray 1 | 1 | 10S | 96W | Texas Eastern Skyline | 49 | 99 | 99 | Marine | NON |
| | Livingston 11-2 | 11 | 10S | 96W | Norris Oil | 1 | 1 | 1 | Marine | N2F |
| | Skyline-Hittle 1 | 12 | 10S | 96W | El Paso Natural Gas | 0 | 1350 | 1350 | Marine | OTH |
| | B. Nichols 1 | 13 | 10S | 96W | Bow Valley | 0 | 345 | 370 | Marine | OTH |
| | Nichols 13-1 | 13 | 10S | 96W | Bow Valley | 50 | 253 | 441 | Marine | UGW |
| | Nichols 13-2 | 13 | 10S | 96W | Bow Valley | 54 | 203 | 274 | Marine | UGW |
| | Finch 13-3 | 13 | 10S | 96W | Norris Oil | 70 | 209 | 236 | Marine | UGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Plateau (cont'd) | Pallaoro 14-2 | 14 | 10S | 96W | Bow Valley | 42 | 132 | 132 | Marine | UGW |
| | Barnard 1 | 14 | 10S | 96W | Norris Oil | 17 | 62 | 62 | Marine | OTH |
| | Currier 14-2 | 14 | 10S | 96W | Norris Oil | 51 | 298 | 437 | Marine | AGW |
| | Pallaoro 15-1 | 15 | 10S | 96W | Bow Valley | 15 | 36 | 36 | Marine | UGW |
| | Cooper 15-3 | 15 | 10S | 96W | Norris Oil | 9 | 21 | 21 | Marine | N2F |
| | Pallaoro 15-2 | 15 | 10S | 96W | Norris Oil | 6 | 15 | 15 | Marine | N2F |
| | Currier 14-16 | 16 | 10S | 96W | Coors Energy | 10 | 27 | 27 | Marine | AGW |
| | Ute 4-17 | 17 | 10S | 96W | Coors Energy | 20 | 52 | 52 | Marine | AGW |
| | Fetters 1-18 | 18 | 10S | 96W | Coors Energy | 20 | 41 | 41 | Marine | AGW |
| | Nystrom 2-18 | 18 | 10S | 96W | Coors Energy | 14 | 36 | 36 | Marine | AGW |
| | Fetters 1-19 | 19 | 10S | 96W | Coors Energy | 53 | 80 | 80 | Marine | AGW |
| | Fetters 2-19 | 19 | 10S | 96W | Coors Energy | 34 | 119 | 119 | Marine | AGW |
| | Fetters 3-19 | 19 | 10S | 96W | Coors Energy | 35 | 76 | 76 | Marine | AGW |
| | Shepard 3-20 | 20 | 10S | 96W | Coors Energy | 30 | 64 | 64 | Marine | AGW |
| | Trahern 1-20 | 20 | 10S | 96W | Coors Energy | 18 | 48 | 48 | Marine | AGW |
| | Ute 1-20 | 20 | 10S | 96W | Coors Energy | 12 | 21 | 21 | Marine | AGW |
| | Currier 4-21 | 21 | 10S | 96W | Coors Energy | 21 | 47 | 47 | Marine | AGW |
| | Federal 21-2 | 21 | 10S | 96W | Norris Oil | 75 | 379 | 743 | Marine | UGW |
| | Nichols 21-3 | 21 | 10S | 96W | Norris Oil | 23 | 125 | 173 | Marine | AGW |
| | Johnson Etal 23-2 | 23 | 10S | 96W | Norris Oil | 53 | 419 | 754 | Marine | AGW |
| | Milholland 24-1 | 24 | 10S | 96W | Bow Valley | 47 | 247 | 389 | Marine | UGW |
| | Milholland 3 | 24 | 10S | 96W | Bow Valley | 47 | 339 | 445 | Marine | AGW |
| | H. R. Milholland Sr. 1 | 24 | 10S | 96W | Bow Valley | 0 | 1437 | 1835 | Marine | OTH |
| | Milholland 25-1 | 25 | 10S | 96W | Bow Valley | 31 | 98 | 98 | Marine | UGW |
| | Milholland 25-3 | 25 | 10S | 96W | Norris Oil | 39 | 343 | 737 | Marine | AGW |
| | U. S. Moran 26-1 | 26 | 10S | 96W | Norris Oil | 2 | 7 | 7 | Marine | AGW |
| | Hawkins 26-2 | 26 | 10S | 96W | Norris Oil | 19 | 56 | 56 | Marine | N2F |
| | Moran 27-2 | 27 | 10S | 96W | Bow Valley | 80 | 281 | 656 | Marine | UGW |
| | U. S. Moran 27-1 | 27 | 10S | 96W | Bow Valley | 0 | 1096 | 1307 | Marine | AGW |
| | Law 28-2 | 28 | 10S | 96W | Norris Oil | 49 | 161 | 372 | Marine | N2F |
| | U. S. Moran 28-1 | 28 | 10S | 96W | Norris Oil | 0 | 136 | 136 | Marine | OTH |
| | Bevan 1-29 | 29 | 10S | 96W | Coors Energy | 76 | 206 | 206 | Marine | AGW |
| | Wilson 2-29 | 29 | 10S | 96W | Coors Energy | 134 | 334 | 334 | Marine | AGW |
| | Zahm 29-3 | 29 | 10S | 96W | Norris Oil | 11 | 29 | 29 | Marine | NON |
| | Wood 1-32 | 32 | 10S | 96W | Coors Energy | 46 | 160 | 160 | Marine | AGW |
| | Wood 2-32 | 32 | 10S | 96W | Coors Energy | 45 | 106 | 106 | Marine | AGW |
| | Wood 3-32 | 32 | 10S | 96W | Coors Energy | 75 | 158 | 158 | Marine | AGW |
| | Federal 2-33 | 33 | 10S | 96W | Bow Valley | 3 | 4 | 4 | Marine | UGW |
| | Bull Basin Federal 1-35 | 35 | 10S | 96W | Mountain Fuel Supply | 8 | 14 | 14 | Marine | UGW |
| | Davis 1-24 | 24 | 10S | 97W | Coors Energy | 38 | 59 | 59 | Marine | UGW |
| | Meadors 1-24 | 24 | 10S | 97W | Coors Energy | 6 | 9 | 9 | Marine | UGW |

| FIELD | WELL NAME | LOCATION Sec | TWP | RNG | OPERATOR | GAS PRODUCTION MMCF 1st yr | Cum 3/88 | ULT | FORMATION | STIM. |
|---|---|---|---|---|---|---|---|---|---|---|
| Shire Gulch | Federal 1-3 | 1 | 10S | 97W | Martin Exploration | 19 | 75 | 169 | Marine | OTH |
| | Federal 2-1 | 2 | 10S | 97W | Martin Exploration | 4 | 12 | 12 | Marine | AGW |
| | Federal 35-1 | 35 | 9S | 97W | Martin Exploration | 41 | 149 | 291 | Marine | OTH |
| | Federal 3-1 | 3 | 10S | 97W | Norris Oil | 5 | 15 | 15 | Marine | AGW |
| | Federal 9-1 | 9 | 10S | 97W | Norris Oil | 1 | 1 | 1 | Marine | N2F |
| | Federal 36-1 | 36 | 9S | 97W | Norris Oil | 69 | 439 | 717 | Marine | AGW |
| | Federal 36-3 | 36 | 9S | 97W | Norris Oil | 17 | 110 | 110 | Marine | N2F |
| | Federal 36-2 | 36 | 9S | 97W | Norris Oil | 12 | 41 | 41 | Marine | AGW |
| | Federal 36-4 | 36 | 9S | 97W | Norris Oil | 54 | 168 | 204 | Marine | N2F |
| | Federal 26-1 | 26 | 9S | 97W | Norris Oil | 49 | 190 | 482 | Marine | N2F |
| | Federal 26-2 | 26 | 9S | 97W | Norris Oil | 11 | 25 | 25 | Marine | NON |
| | Federal 25-1 | 25 | 9S | 97W | Norris Oil | 38 | 175 | 269 | Marine | AGW |
| | Federal 32-5 | 32 | 9S | 97W | Alta Energy | 7 | 21 | 21 | Marine | AGW |
| | Horseshoe Canyon Federal 4-21 | 21 | 9S | 97W | Koch Exploration | 1 | 119 | 119 | Marine | N2F |
| | Horseshoe Canyon Federal 3 | 28 | 9S | 97W | Koch Exploration | 80 | 330 | 330 | Marine | N2F |
| | Horseshoe Canyon Federal 2-27 | 27 | 9S | 97W | Koch Exploration | 21 | 66 | 66 | Marine | N2F |
| | Horseshoe Canyon Federal 4 | 33 | 9S | 97W | Koch Exploration | 25 | 65 | 65 | Marine | N2F |
| | Horseshoe Canyon Federal 2-31 | 31 | 9S | 97W | Koch Exploration | 28 | 35 | 35 | Marine | N2F |
| | Horseshoe Canyon Federal 1-28 | 28 | 9S | 97W | Koch Exploration | 24 | 70 | 70 | Marine | N2F |
| | Horseshoe Canyon Federal 2-28 | 28 | 9S | 97W | Koch Exploration | 115 | 383 | 383 | Marine | N2F |
| | Horseshoe Canyon Federal 2 | 29 | 9S | 97W | Koch Exploration | 95 | 357 | 357 | Marine | N2F |
| | Horseshoe Canyon Federal 1-33 | 33 | 9S | 97W | Koch Exploration | 58 | 103 | 103 | Marine | N2F |
| | Horseshoe Canyon Federal 5 | 34 | 9S | 97W | Koch Exploration | 42 | 127 | 127 | Marine | N2F |

Summary
Ultimate Gas Recovery

| | |
|---|---|
| Average for 137 Wells | 238 MMCF/Well |
| Average for 132 Marine Wells | 237 MMCF/Well |
| Average for 3 Paludal Wells | 372 MMCF/Well |
| Average for 2 Fluvial Wells | 115 MMCF/Well |